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Integrated Research in Agricultural Production and Natural Resource Management:

Agricultural Research and Training Support (ARTS) Project, Burkina Faso, 1990-94

Purdue University and Winrock International

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Agricultural Research and Training Support Project

Technical Report

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Purdue University
and the
Institut d'Etudes et de Recherches Agricoles (IN.E.R.A)
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Forward

This is a technical report of research in progress at the Institut d'Etudes et de Recherches Agricoles (IN.E.R.A). Although the ARTS project has ended, agricultural research in Burkina Faso is just beginning. The work done during the ARTS project will be a starting point, not an end in itself. Results will be further tested and conclusions will continue to be refined.

In this context, the usual summary of project results written by the campus staff and technical assistance team would be inappropriate. Instead this technical report is composed of "working papers" co-authored by the Burkinabé and American scientists. These are working papers in the sense that they are not final products, but rather documents written to help researchers organize their materials and communicate preliminary results to those colleagues whose comments and criticism are essential elements in refining and polishing scientific communications.

This document is by nature a partial record of the ARTS project accomplishments. Some activities remain to be completed. Others have yet to be analyzed and written up.

French and English versions of the technical report are being published to facilitate communication. The original language of a working paper is noted in the table of contents. Because of timing and logistical problems authors have not had the chance to proof read the translations of their papers. The version in the original language should be considered the definitive version, if the word "definitive" can be applied to a working paper.

As with all working papers, comments and criticism from readers is welcome. Comments should be addressed to the authors of individual working papers.

A complete summary of project objectives and activities can be found in the administrative report entitled "Integrated Research in Agricultural Production and Natural Resource Management: Agricultural Research and Training Support (ARTS) Project, Burkina Faso, 1990-1994, Administrative Report."

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* Original Document in French
** Original Document in English
*** Supplied by author(s) in English and French

SECTION I
SOIL AND WATER CONSERVATION

Principal Production Constraints and Findings of a Selection of RSP Production Research, 1990-1994

J. Dickey, E. Sankara, A. Sohoro, and S.J.B. Taonda

I. INTRODUCTION

The approach of RSP during the period of the ARTS Project was similar to RSP's continuing methodology which consists of the following general steps:

- Diagnostic study (problem definition, definition of important — demographic economic, natural, social — parameters)

- Identification of potential solutions, including preliminary discussions with farmers, as well as appropriate development and research personnel

- On-farm technology testing to provide a common base of experience with technology among farmers and researchers of various disciplines

- Field observation (observations of production, natural resource evolution, farmer opinion, farm expenditures and income), laboratory analyses (statistical, chemical, physical, etc.), and evaluation of results. Farmers, and ideally collaborators in development and research, take part in field evaluation

- Restitution of results to collaborators, especially to farmers, and refinement of results by collaborators, especially farmers.

This process is necessarily iterative, but to the extent possible, each cycle should produce something usable by farmers, development, and/or research. The formats for communication with these groups are informal and formal. Formal means include field days, meetings, reports, technical bulletins, and scholarly presentations, articles, theses, and dissertations. Informal means are visits among small groups of individuals.

The activities of the ARTS Project were limited mostly to the Central and Western Zones of RSP, which contain 8 village sites (Figure 1). These sites encompassed a wide variety of socioeconomic and biophysical production conditions, some of which are summarized in Table 1.

Sites and Intervention Zones

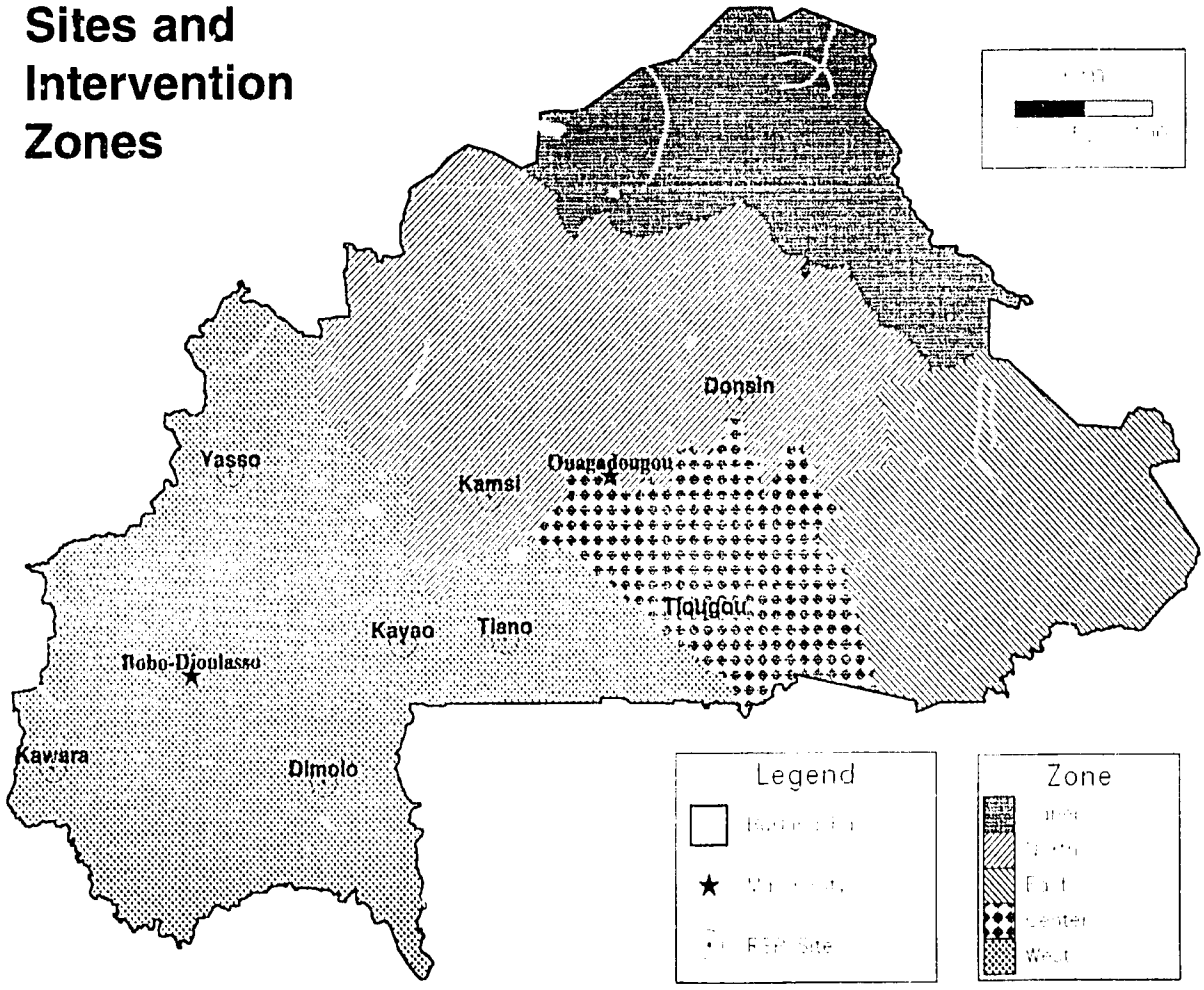

Table 1. RSP Village Sites, Central and Western Zones

Zone	*Village/ Annual Rainfall[a] (mm)*	*Animal Traction*	*Principal Crops Degradation*	*Level of NR Migratory*	*Dominant Trend*
Central	Donsin 647	Absent	Sorghum, millet	Extreme	Old and recent emigration
Central	Kamsi 741	Little	Sorghum, millet	Advanced	Recent emigration
Central 723	Thiougou	Dominant	Sorghum, millet	Moderate to advanced	Recent emigration
Western	Yasso 802	Dominant	Sorghum, maize, cotton	Moderate to advanced	Old and recent immigration
Western	Kayao 819	Dominant	Sorghum, maize, cotton	Moderate to advanced	Recent immigration
Central	Tiano 848	Dominant	Sorghum, maize	Moderate	Recent immigration
Western	Kawara 1010	Little, but increasing	Maize, sorghum, rice	Slight	Old immigration
Western	Dimolo 1015	Little, but increasing	Maize, sorghum, yam	Slight	Slight, recent immigration

[a]Post-1969. For West African sites, rainfall means including post-1969 data are considered a better indicator of current rainfall expectations than means including pre-1970 data. This is because a relatively rainy period of what appears to be a long-term climate cycle came to an end in about 1969. Post-1969 means for RSP villages are from 150 to 200 mm less than means for pre-1970 data.

A number of the papers contained in this collection are the results of work on individual research themes that made up a coordinated, evolving research program. Each work had a place in the above research process, and many were interrelated. This paper is not an exhaustive listing of all research activities. Rather, it ties a selection of activities to the principal constraints they were meant to address. The objective is to share some of the overall logic of the production research activities, and thereby to provide a general context for the various individual studies reported in other papers.

Principal Constraints:

Major constraints to sustainable, secure, and productive management of natural, other capital, and labor resources in Burkina Faso can be divided into primary (fundamental), secondary (derived from fundamental constraints), and tertiary (derived from secondary constraints) groups.

Primary constraints:

1. Shortage of uncultivated land for clearing and cultivation, pasturage, or gathering (of wood, pharmacopoeia, mulching materials, or other forest products). This is generally due to demographic pressure on the land resource.
2. Erratic rainfall, especially early- and late-season drought periods, as well as occasional and very damaging mid-season droughts.
3. Pest and disease pressure on production (e.g. Striga spp.,maize streak virus, downy mildew, numerous cowpea insect pests).
4. Insufficient access to markets (e.g. maize sold in Yasso at 2500 CFA/100 kg, January, 1994) and erratic, often low pricing (e.g. the 1993 cotton crisis).
5. Storage pests and rots, especially for their effect on seed and setts.

Traditional, low-input, rotational bush fallow farming systems require large land areas to function productively, since a large percentage of the land must be in fallow at any one time. Demographic pressure is such that this is no longer possible in many areas. Rainfall quantity and distribution are rarely ideal and often result in significant stress on plants and animals in the production system. Pests and diseases, especially when crop vigor is reduced by other stresses, can limit production and destroy planting material. These are cited as primary constraints because they exist in the presence or absence of other constraints, although they do give rise to other (secondary) constraints.

Secondary constraints:

6. Insufficient village political organization to solve resource-use problems (e.g. insecurity of usufruct landholders, chronic cultivator-pastoralist conflicts).
7. The degraded state of land (including soil and vegetation) resources. For the soil this includes erosion, crusting, reduced water holding capacity and organic matter contents, as well as chemical constraints to fertility (largely shortages of N and P) and localized acidity. Wild plant and weed communities have become less diverse, more dominated by plants selectively preserved by farmers (e.g. *Hibiscus sabdarifa* or da, *Butyrospermum paradoxum* or karité), relatively unpalatable forage and browse, and weed populations capable of surviving continuous cropping and frequent cultivation (e.g. *Digitaria horizontalis, Striga hermonthica*).

Primary constraints on land require that this resource be managed skillfully by village communities. Traditional land tenure systems provide the community with a rich assortment of tools. However, these systems are often understandably in the process of adapting to changing demographic conditions (population density, ethnic makeup, and families' economic objectives), and a deteriorating resource base. During this period of adaptation, when production systems must be transformed in profitable steps, substantial physical and biological degradation of the land base can occur. Organization for land management (constraint 6) and land degradation (constraint 7), therefore, are secondary constraints by virtue of their dependence on constraints (1) and (2).

Tertiary constraints:

8. Shortage of biomass (animal wastes and vegetative matter) with which to nourish people, crops, livestock and wildlife.
9. Scarcity of labor and animal traction in certain regions, making cultivation and materials transport (of organic fertilizer, mulch, and stones, for example) for land management very costly.
10. Ignorance of resource management possibilities and probable results.
11. Access to capital (partially resolved for cotton producers, who use cotton credit to purchase fertilizer used on a number of other, notably grain crops).
12. Poor animal health due to insufficient nutrition and veterinary care.

Degradation of the land resource and failure to address this degradation by changing village land management (secondary constraints 6 and 7) requires that farmers seeking sustained production invest labor and capital in land maintenance (fertility, soil and water conservation), pest control, and animal feeding (on distant pastures or cut forage), however, these efforts are often insufficient. These unmet needs give rise to the tertiary constraints listed above.

II. RESEARCH ACTIVITIES

Thematically, the activities can be broken down into the following categories:

Crops and cropping systems

1. Varietal evaluation, including analysis of yield stability
2. Disease and pest management
3. Evaluation of agricultural machinery and its use
4. Training in methods of seed/sett production and storage
5. Evaluation of crops or cropping systems
6. Improved feed production, livestock feeding, and animal health

Environmental monitoring, conservation, and regeneration

7. Soil fertility, including use of mineral fertilizers, fabrication and use of organic fertilizers, and definition of fertility requirements of varieties
8. Land conservation and reclamation
9. Characterization of land degradation and variability
10. Environmental monitoring

Findings: Crops and Cropping Systems. Farmers' needs and measures they are willing and able to take to resolve them vary greatly across Burkina Faso. While much of this variability is due to the nature of the individual farmer, some community characteristics help one to understand and organize thinking about farmers and their behavior. The environmental conditions and the importance of cotton in the production unit strongly influence the way people farm in Burkina. This, in turn, has a large impact on the relevance of a given

technology to farmers. The influence of these factors on farmers' use of inputs and animal traction for land preparation and weeding are described below. Clearly, cropping environments that are untilled, unfertilized and weedy will welcome different kinds of innovations than fields that are tilled, fertilized, and weeded on time. This makes it critical to understand these patterns of land management before discussing research results for specific technologies.

Prolonged and substantial public investment in cotton production (extension of information on improved practices, credit for equipment purchase and production costs, input availability, and organized marketing) has borne fruit. Farming practices in cotton production areas are in general strikingly different from practices outside these areas.

There are areas with favorable environmental conditions for crop production, which for various reasons do not currently produce much cotton. Naturally, these areas benefit much less from investments made to encourage cotton production.

Farmers in the Central Zone, generally not cotton producers, lack access to credit and run a greater risk of crop failure. This is especially so in the dryer northern areas, where rainfall is scarce and relatively erratic in distribution. Farmers therefore favor a strategy that minimizes capital inputs, thus limiting the capital put at risk. Five examples along this transect, taken in RSP villages, follow. Refer to Table 1 for additional information about these villages.

- At Kayao and Yasso a high proportion of farmers have and use animal traction, (for land preparation, weeding, and transportation), cotton is widely produced, and chemical fertilizers are habitually applied to field crops (not only to cotton, but also to cereals, especially maize). The combination these practices with higher, less variable rainfall than in much of the rest of Burkina Faso provides field conditions with relatively high yield potential and low risk of crop failure.

- At Tiano there is relatively little cotton, yet farmers have a rather entrepreneurial approach to farming, (many are recent migrants). Many farmers have animal traction, and are prepared to plow and apply chemical fertilizer to achieve good maize yields on large areas.

- At Kawara and Dimolo, little cotton is produced, and the use of animal traction, mechanization, and inputs is much less prominent than at Kayao and Yasso. Dimolo youths are frequently absent, gone to Côte d'Ivoire to find wage labor jobs. Farming of rice on hydromorphic soils is a major activity at Kawara.

- At Thiougou, many farmers have animal traction and plow, and organic fertilizer is produced (some with Burkina phosphate — rock phosphate — added) and used intensively in village fields. Practically no fertilizer of any kind is used in bush fields. Maize in large fields is considered too risky. Farmers are sometimes willing to purchase pesticide for cowpea production.

- At Donsin, animal traction is very rare, farmers recently began very labor-intensive use of manure and compost in zaï in 1993, and practically no mineral fertilizer or pesticide is

purchased. Cash is scarce and needed to pay for food during the hungry season (July, August). Farmers are clear in their priorities; many will not spend money on pesticide or fertilizer.

- Kamsi is somewhat particular due to the large amount of dependency on income from emmigrants, which changes farmer motivation.

The use of inputs by farmers in the cotton-production region means that new varieties find themselves in much the "improved" (relatively low-stress) conditions that the breeders who developed them anticipated. As a result, varietal introduction is relatively easy and effective. That is, a new variety has a reasonable chance to out-yield the local variety in a farmer's field, so if its culinary quality is satisfactory, it runs a good chance of some adoption and of making a positive impact on production. Testing is straightforward: put the variety in the field under conditions stipulated in the breeder's technical bulletin, because the breeder knows what the variety needs to perform, and the farmer frequently can approximate these conditions.

On the other end of the spectrum, the strategy of farmers at Donsin (on all fields) and at Thiougou (in the bush), however, is in direct conflict with the dominant milieu of varietal selection and with management stipulations in technical bulletins associated with improved varieties. These bulletins are conceived to allow these varieties, given adequate rainfall, to yield well, (or to realize their potential). Low to moderate doses of chemical or organic fertilizer are generally recommended, and in the case of cowpea, so is treatment with insecticide. When planning varietal tests in cultural environments that do not match the bulletins' recommendations, the question becomes who to please, the breeder or the farmer?

The research approach in the Central Zone was therefore two-tiered, with new varieties introduced under at least two fertility regimes, to get an idea of how varieties would do under farmers' and "improved farmer-managed" conditions, and therefore of their stability across the real spectrum of fertility conditions. The results for sorghum, millet, and cowpea were surprising: local varieties frequently out yielded improved varieties at both ends of the fertility spectrum, exceptions being the millet IRAT P8 (virtually identical to the local), millet IKMP-3 (which yielded slightly better than the local without fertilizer), and the cowpea local Donsin (which did not respond to fertility as well as improved varieties).

Improved peanuts yielded well and were similar to locals across the fertility spectrum, except at Thiougou, where the local was slightly superior.

Several good, disease resistant maize varieties had been produced by INERA and were in theory already passed to extension, however these varieties were relatively unknown in all RSP villages. Introduction of these maize varieties was of interest to RSP for the following reasons:

- It benefited cooperating farmers.
- It responded to a need for new alternatives in the face of difficulties in the cotton sector.
- It provided a common base of experience in food crop production for farmers and the RSP teams. (All aspects of maize production and the adoption of new technology were studied by the various disciplines, not just yield performance.)

- Productive working relationships and dialogue between cooperating farmers were developed around this and other production activities.

At Tiano, maize varieties SR22 and DMR.W each produced about 3 Mg/ha (at recommended fertilization rates), out yielding local maize by about 20%. The variety SR22 was so productive in Kayao, Yasso, and Kawara that it was rapidly adopted. The early maize varieties KPB and KPJ were tested and adopted by some, especially in Dimolo, as crops to provide some early relief from the hungry season. Tested hybrid maize did not perform well, and in retrospect probably had little place in on-farm tests.

Another promising innovation is the introduction of upland rice cultivation, based on the availability of early varieties adapted to upland conditions, (FKR-5 and FKR-33). Yields averaged over 2 Mg paddy rice/ha, and maximum yields were upwards of 5.5 Mg/ha. Yield stability of FKR-33 was superior, while given adequate rainfall, FKR-5 had higher yield potential. In general, the crop is sensitive to dry spells of over 10 days. The preceding crop is important, with preference in the order rice < upland cereals < cotton < garden crops. Hand planting and weeding consume an enormous amount of labor and are the major constraints to increased area in upland rice. Mechanized and chemical weeding were examined in 1993, each showing some promise. The INERA Water, Soil, Irrigation, and Agricultural Mechanization program (ESFIMA) worked on tools for mechanized planting at close spacing during 1993, and RSP will test these tools in 1994. RSP has done some work on hand-planting rice at wider spacing, also with some success. Burkina imports a great deal of rice. If prices stay sufficiently high, there is tremendous productive potential for rice in Burkina Faso.

Untimely weeding is a major upland cereal production constraint in the Western Zone. As for rice, herbicides are on the market and used by some farmers. Without prejudging the environmental or production advantages of chemical weed control, tests in maize (on-station and on-farm) began in 1993. Control was frequently achieved, but the economic benefit is less clear than for rice.

Sorghum, on the other hand, suffers greatly from *Striga* infestation, especially on continuously cultivated land. *Striga* is cited by farmers in Yasso and Kawara among their principal production constraints, and as a principal indicator of land degradation. Where land cannot be left fallow, rotation, resistant varieties, and chemical control are options. Six resistant lines were tested in an infested sorghum field at Yasso in 1993. All lines showed significant resistance relative to the local check. Taken together, the six lines had 13% of the Striga infestation level of the local check, and produced 242% of its grain yield. Spraying with 2,4-D was also effective, and relatively inexpensive due to the low cost of this herbicide.

Mildew attacks millet in much of Burkina Faso, with the yield reduction depending on severity. The seed treatment Apron Plus, (100 g metalaxyl, 60 g carboxine, and 340 g furathiocarbe, all per kg of powder), provides protection from mildew at about 2000 CFA/ha, equivalent to about 25 kg millet/ha. RSP has participated in widespread testing of the product in farmers' fields and developed a technical bulletin for the use of Apron Plus aa well as another bulletin to help estimate the potential economic benefit of using Apron Plus in a given field. Impact appears to depend on the region, particularly on the native level of mildew infestation.

As for use of insecticide on cowpeas, the approach up to 1994 was to treat as needed, and to experiment with cereal intercropping as a means of reducing the absolute need for insecticides. Given the response of many farmers (indicating unwillingness to purchase insecticide), a test oriented toward reducing the number of insecticide treatments is planned for 1994. The test will include some of the more resistant cowpea materials that are currently available. Among monitored farmers, few at Donsin treat their cowpeas, yet they manage to get acceptable harvests, even with improved materials, which they generally consider more susceptible to insect attack. This has not been the case at Thiougou, where insect attack is much more severe. Farmer interest in cowpea as a source of food, cash, and fodder (roughly in that order) is strong.

Production quality and quantity are very important issues for grain/forage varieties of cowpea (7/180-4-5) and sorghum (ICSV-1049). In Donsin, where grain production for human consumption is the overwhelming preoccupation, the lower yields (relative to KVX395-4-4 and local), the recommended forage harvest date (after one pod picking), and propensity for shattering limited interest in 7/180-4-5. On the other hand, Thiougou farmers, while noting that the grain production is somewhat low, appreciated the forage quality, and seemed willing to sacrifice second and third pod pickings to get quality forage. The need to nourish draft animals motivated farmers most strongly to produce forage.

The caudatum heritage of the sorghum ICSV-1049 renders it particularly sensitive to head rots, and makes the grain difficult to process into flour. It also appears to be sensitive to late-season drought. At least in the south (Thiougou), delayed planting (as recommended) can largely resolve the problem of head rot, if the end of the rains is timely. As with cowpea, the feed value of the stalk, (which is considerable — animals prefer it and will destroy fields to get it), is more appreciated in the south, where animal traction is more common and where food production is more assured.

This leaves a large hole in what RSP has to offer to farmers in the way of cereal grains. Through 1993, no sorghum or millet has competed favorably with local varieties for a substantial spot in the farming system. In 1994, the sorghum varieties Sariaso-9 and Sariaso-10 will be tested in all sites. Sariaso-9 is an improved local selected at Saria (about 710 mm/year average annual rainfall since 1970), and Sariaso-10 is another improved caudatum. Only Sariaso-9 will be put under farmers' management. In the south, planting date trials will be run jointly with the Sorghum, Millet and Maize Program (SOMIMA) to refine this aspect of management.

To further respond to severe limitations to pasturage and corresponding farmer interest in forage production (at Yasso and Kayao), several alternatives for feeding are being explored:

- Production of *Andropogon* guayanus in vegetated bands in fields
- Improvement of feed value of crop residues by grinding and mixing with urea
- Supplement with cottonseed cake, a byproduct of cotton processing
- Production of forage crops, like dolic and sudan grass (*Sorgho sudanense*)

Benefits from these feeding systems can include:

- Improvements in animal health and reductions in mortality
- Increased weight gains (recorded for milking cows and calves) and milk production
- Strengthening of draft animals before the cropping season
- Concentration of animal wastes and association with compost pits or bins

So far, farmer interest in these alternatives is running high. The economic benefits of supplementary feeding seem to be high when meat prices are high (as they have been since the CFA devaluation in January 1994), and milk prices are good (in zones like Kayao and Yasso, where milk consumers outnumber milk producers).

A general problem for all crops is production and storage of high-quality planting materials. There are two cases in which high levels of farmer and RSP interest have combined to help solve this problem. When SR22 trials were at first successful in 1991, large, seed-production fields were established during 1992, and this constituted much of the seed supply for the widespread planting of this variety in 1993. Likewise, several kg of sudan grass was successfully multiplied at Yasso in 1993 for more widespread production of seed and forage in 1994.

Seed production and post-harvest storage is also the focus of several other 1994 activities. The problem of storage, especially seed storage, is most pronounced for cowpea. It is sensitive to a number of storage pests (notably bruchids). Seed production and storage is also a hurdle when farmers wish to retain a new variety in their cropping system: a sustainable local seed stock must be established. For this reason, production and storage of quality seed is the major theme of the monitoring of farmers' use of improved varieties in 1994 and in other, specific, seed-production activities for sudan grass, cowpea, and dolic. Siting and maintenance of fields will be monitored jointly, and training in effective storage techniques will take place at harvest time. Likewise, training in and farmer-testing of sett multiplication for yam began this year at Tiano. This activity will be followed up by activities in yam production and storage.

Yams for market also suffer from storage problems. Large yams are preferred for the premium they bring in the market, but they store poorly. One of the varieties involved in the yam activities is Florido, which is smaller in size and lends itself to planting in ridges instead of the traditional mounds. It could provide a product to store and sell later in the year, when large yams are off of the market and small yams bring a good price. Also, when produced in ridges, it can produce roughly double the yield of the traditional variety in mounds. Setts multiplied for both local and Florido during 1994 will be planted in these two systems for comparison in 1995. Marketing will also be monitored.

The above work was oriented toward understanding and improvement of crops and cropping systems. RSP also devoted much of its research effort to the broader, natural-resources context of crop production. Among other things, this includes land conservation and reclamation.

III. FINDINGS: ENVIRONMENTAL MONITORING, CONSERVATION, AND REGENERATION

The RSP Geographer produced maps of natural resource distribution and use for each village, based on aerial photographs and field investigations. These maps and the associated knowledge base have been invaluable tools for orienting subsequent work in sustainable resource management and production. Many of the impressions of land use in this report are derived, at least in part, from those mapping efforts.

One of the greatest challenges facing Burkina Faso is the identification and implementation of sustainable land use in the most productive regions. These same regions also receive many immigrants. As areas of bush and old fallow are grazed, logged, or cleared and farmed, their capacity to produce fuel, feed, food, fiber, and pharmacopoeia is often degraded, sometimes irreversibly. If this land resource is lost, this largely agricultural country risks becoming one of the worlds' "basket cases". For this reason, several research activities have focused on various aspects of land degradation, conservation, and reclamation.

As with other cultural practices, soil management problems and the measures farmers are willing to take to solve them vary greatly by region. Understanding of the pattern of this variation is critical if one is to interpret farmers' reactions. Major driving forces of this variation are population density, rate and history of migration, and climate. A sample transect of these factors and of land management across Burkina, stopping in RSP villages (Table 1) would be:

- Dimolo (1015 mm rainfall/year — mean from 1970 to 1993), where bush land is available for pasture or for clearing of new fields, and the rate of immigration is relatively low. Soil-related problems are predominantly fertility, and the main action to resolve them is to fallow land. Animal traction exists but does not predominate, and is used mainly for plowing.

- Kayao and Tiano (819 and 848 mm rainfall/year, respectively), where the rate of immigration is very high, and pasture is becoming scarce with the clearing of more land for cultivation. Immigrants and natives alike are motivated to cultivate extensively because cultivation secures land for future use. Animal traction is predominant and is used for plowing and weeding. For some farmers, soil fertility problems are increasingly addressed with chemical fertilizers purchased with credit for cotton production, and compost production is increasing.

- Thiougou (723 mm rainfall/year) has some neighborhoods that border the forest. Immigrants have recently settled this land. Land management in these areas is similar to that of Tiano and Kayao, except for the absence of cotton. Otherwise, Thiougou and Yasso (802 mm/year rainfall for Yasso) received large, early (30-80 years ago) waves of migration. Migration has now slowed due to crowding. In most areas of these villages, very little bush remains to be cleared, and fallow periods on cleared land have become increasingly rare. Animal traction is widely used for plowing and weeding, and low fertility and *Striga hermonthica* (a parasitic weed symptomatic of continuous cereal cultivation) have become major production

constraints. Credit for cotton production has provided a means for chemical fertilizer purchase in Yasso, but there is increasing interest in compost production as an alternative and/or complement. Compost production is widespread in Thiougou, but does not suffice for fertilization of bush fields. Rock bunds were constructed on Thiougou village fields about 10 years ago. With the land shortage and a stabilizing population, farmers in both villages are increasingly prepared to consider land conservation measures, with strong preference for measures requiring a low capital and labor demand.

- Donsin (647 mm rainfall/year) has a relatively stable farming population and practically no land available for clearing for new settlement. Pasturage is extremely limiting, *Striga* infestation is widespread, large areas of village land have become so degraded as to be completely denuded and abandoned, and crop production and the food supply are insecure. Farmers are highly motivated to stem what they consider an environmental/economic crisis. On remaining arable land, farmers increasingly use traditional soil and water conservation measures to improve current and future production (grass mulching, leaving strips of native vegetation on clearing, laying down of branches roughly on the contour or in gullies to reduce water erosion). Two years ago, the non-governmental organization Foster Parents' Plan began to support rock bund construction, (training in contour identification, free transport of rocks from quarries to fields) and assisted natural regeneration of *Piliostygma spp.* This precipitated the sudden and widespread installation of rock bunds on much of the cultivated land. RSP initiatives in soil and water conservation have been rapidly adopted by most of the village, as will be discussed later. Animal traction is practically absent, and although fertility constrains production, cash scarcity and high risk of crop failure result in very little mineral fertilizer purchase. Composting was introduced by RSP, and some farmers have adopted it.

The character of land and weather dictates management possibilities and, to some extent, their relative costs and benefits. African landscapes encompass extreme variability in productivity and vegetation. High levels of short-range (over distances of several meters) soil variability, for example, are well-documented in West Africa, and pose special management problems. Several of RSP's research projects were aimed at land characterization. These projects included soil/landscape/vegetation mapping, soil sampling and description on short transects to answer specific questions, woody plant community inventory, and detailed evaluation of the process of land degradation under cultivation. The longer-range objective of each study was to provide basic knowledge for the development of sustainable systems of land management.

The large-scale mapping efforts will not be discussed at length. Soil or soil/landscape maps of Kamsi and Thiougou villages were prepared, largely to meet the requirements of two dissertation studies. A vegetation mapping effort was begun at Donsin by the agroforesters. At each site, the soil mapping information contributed heavily to the planning of research. In Thiougou, in particular, it permitted the researcher to control for soil type in a very exacting study of land degradation.

In the context of another dissertation on the socioeconomic role of trees in parklands, woody plant communities maintained by farmers in their croplands were characterized. This

demonstrated the variability of farmer woody-plant management strategies, the importance of variables such as the presence of animal traction in farmer decision making, the predominance of shea nut trees in cleared and uncleared land, and that the pattern of woody plant evolution with time under cultivation is not a simple rapid reduction in woody plant numbers and species richness.

Two small studies of soil variability were undertaken. Sampling across a transect heading up-slope from a rock bund resulted in a detailed description of erosion, sedimentation, and revegetation across this zone. In a second study, soil samples were taken late in the cropping season across transects of evident soil variability. Corresponding harvest observation plots permitted the correlation of soil and crop results in a village field, in a bush field under prolonged, continuous cultivation, and in a newly-cleared field. Fieldwork for these two studies was informally organized as on-the-job training in micro-profile description and in diagnostic soil sampling in farmers' fields, respectively. Each study required about 1 day of field time. This sort of activity could be used far more frequently to fill data gaps with at least some provisional information, and to create educational fieldwork opportunities with various resource people. The economists made effective use of rapid techniques to respond to specific, well-defined questions (e.g. estimation of opportunity costs of capital, estimation of partial budgets for soil conservation practices).

In the regions of immigration and little chemical fertilizer use, intensively managed village fields (plowed and receiving substantial organic fertilization) produce well year after year, even after many years of continuous cultivation. Bush fields, on the other hand, are mined of their fertility and abandoned. Reduced land availability has resulted in reduction or elimination of fallow periods in the rotation, so that fallow no longer achieves the needed regeneration of fertility in bush fields. The nature of land degradation during the years after clearing was studied in great detail. Changes in crop production as well as soil chemical and physical characteristics were monitored and described. Nitrogen immobilization and/or alelopathy limited sorghum yield in the first season after clearing. Thereafter, production decayed exponentially from a maximum during the second year after clearing. The same practices that allow sustainable production in the village (protection with rock bunds, application of 2.5 Mg manure/ha) succeeded in bringing the oldest bush field back from 13 to 74% of the productivity level of newly cleared land.

Several other activities were focused on joint evaluation of soil and water conservation (SWC) practices with farmers. In Tiano and Kayao, where farmers have little time for these practices, but nevertheless sense a need for a fertility maintenance program, composting activities have begun. In Thiougou and Yasso, where farmers will consider some intensified efforts to conserve land and water, soil conservation activities are beginning. In spite of the history of rock bunds at Thiougou in village fields, the labor and transportation constraints to their installation makes less demanding technologies (such as vegetated strips) more attractive for the more extensive bush. Land tenure can figure even more importantly in the choice of an SWC technology. In regions such as these, most farmers are on loaned land, and therefore lack the necessary land tenure security, and often the right to install in durable SWC technologies (i.e. rocks, trees). Furthermore, cultivation of land by an immigrant (usufructuary) can augment his

chance of borrowing that land the next year. For the autochthonous farmer, it helps to morally justify a future refusal to loan the land. This motivates both, therefore, to cultivate a lot of land to retain the option of future cultivation. This works against intensive investment in maintenance of a given field. This pattern is most noticeable where the rate of immigration is currently rapid and farmers are therefore scrambling for land.

Donsin has had little recent immigration and therefore land tenure is rather secure for most residents, which helps explain their rapid and enthusiastic adoption of rock bunds when Foster Parents' Plan began to support their installation. Along with the intensive traditional methods of SWC (e.g. grass mulching) that are widely used at Donsin, this suggests a very different situation from Yasso and Thiougou. Farmer opinion surveys and field observations indicated that the problems of food insecurity are substantial and also motivated investment in SWC. Difficulties during stand establishment and with mid- and late-season droughts have all plagued Donsin during RSP's time there and before. Farmers have begun to act.

Indeed, farmer response to the introduction of zaï (manure-filled planting holes), another labor-intensive SWC technology, proves this. After a field trip of RSP researchers and Donsin farmer representatives to a zone where zaï are used, zaï was tested in several farmers' fields alone and in combination with grass mulching, and compared to grass mulching and planting bare ground. In the year of introduction of zaï at Donsin, 70% of the production units experimented with them, experiencing variable, but generally very positive results. Fully 80% of production units plan to plant into zaï in 1994. The technology is adapted to farmer labor constraints, since most or all of the additional demand is during the off-season, when labor is available. The ability of zaï to reduce risk of drought stress by capturing and holding water around a healthy plant reduces farmers' risk, especially during stand establishment. Time for re-sowing is reduced, which increases labor time available for weeding. Due to more timely establishment and perhaps to reduced stress from drought, nutrient deficiency, and weed competition, crop yields are doubled, or tripled when grass mulching is included.

With the rapid adoption of this technology, the major limiting factor for many farmers, especially those with few livestock, will become organic fertilizer. While composting is being practiced by a number of households, its potential to increase organic fertilizer volume in the village has yet to be realized. The scarcity of feed and pasture complicate manure recovery schemes. To increase manure recovery, some producers are beginning to stable animals during the night and constrain daytime grazing to defined areas, from which the manure is collected. Manure is being traded and purchased at Donsin. This ensemble of considerations could motivate forage production by reclamation of rangeland or by forage field-crop production.

A significant proportion of Donsin's land area is highly degraded, producing practically no vegetation (zi-pelé). Although some of these lands were once among the most fertile at Donsin, they are generally considered by farmers to be lost for productive uses. A thematic trial by ESFIMA and field experience of farmers and NGO's in Yatenga and Bam provinces demonstrated that the combination of rock bunds with zaï with or without mulch would reclaim such land for cereal production. After reclamation, clearly other land uses (pasture, forestry) could be imagined, however cereal production remains a strong motivator of hungry, rural

families to reclaim land. These results were applied to a zi-pelé at Donsin, where mulch, zaï, and zaï with mulch treatments produced 430, 1060, and 2290 kg of sorghum grain/ha, respectively. Average grain yields in farmers' fields this year was in the neighborhood of 400 kg/ha. As with zaï in farmers' fields, these methods of land reclamation are experiencing some adoption on other zi-pelé. The progress of several farmers who have reclaimed substantial areas for cereal production will be monitored in 1994.

Cereal production, or something with a similar payoff, may be needed to pay for the labor-intensive practices of zaï, rock bunds, and grass mulching. However, more productive pasture may be sufficient to motivate investment in less expensive reclamation technologies, like small earth bunds in the form of half-moons. One farmer has planned to collaborate with RSP in the evaluation of half-moons for pasture reclamation. The idea is that the bunds slow runoff and favor greater infiltration on eroded, slowly-permeable, shrink-swell clay soils. The wetted soil swells, then dries and shrinks, leaving a somewhat roughened, cracked land surface. Infiltration from the next storm is greatly increased. The greater volume of water stored in the soil supports more vegetation, and the pasture begins to improve.

IV. CONCLUSION

By any measure, Donsin has demonstrated extraordinary dynamism in the rapid evolution of natural resources management in the village. Likewise, the rapid and widespread adoption of SR22 in maize-production zones signals that an important production constraint was identified and addressed by RSP in the south and west. The enthusiasm for forage (dolic and sudan grass) production and upland rice are producing very successful results. If RSP were a development agency working in these few village sites, this would be enough to claim success.

However, RSP's job is to support development institutions so that they may increase their impact in a much greater number of villages. Therefore, RSP must now describe what has happened in each of these instances in such a way that development institutions can identify similar situations and replicate these successes on a larger scale.

Survey: Farmer Evaluation of Zaï in Donsin, 1993

E. Robins and M.C. Sorgho

I. Introduction

"Zaï" is a technology indigenous to Burkina and used in Yatenga on the Central Plateau to reclaim exhausted soils for cultivation. It involves digging a hole 20 cm wide and 15 cm deep. This is then filled with manure and seeds are planted in it. This "zaï" creates a moist environment for the plants, which favors germination, growth and crop yield.

In the Namentenga (also in the Central Plateau), where soil degradation resembles what used to be the case in Yatenga, "zaï" has been recently introduced.

The Farming Systems Research Program (RSP) values the experience acquired by the Yatenga farmers, and sees its pertinence for Namentenga. Therefore, to facilitate teaching Namentenga farmers how to fight soil degradation, a "farmer to farmer" visit was organized by the RSP in May, 1993. A group of farmers from Donsin, which is one of the RSP research sites in Namentenga, traveled to Ouahigouya, in Yatenga, to observe water and soil conservation techniques.

Zaï was one of the technologies observed during this visit. Donsin farmers were already aware of the existence of this technology. One farmer from the neighboring village of Bonam had tried it the previous year. The latter's highly positive experience encouraged the Donsin farmers to follow his example and try it for themselves. After their visit to Yatenga, these farmers therefore undertook the extension of zaï technology to their own village. The number of farmers volunteering to try zaï was phenomenal - more than 70% of villagers tried it in 1993.

The RSP, together with its collaborating program, ESFIMA, were part of this effort.. They collected data from 6 farmers testing zaï. Researchers also demonstrated zaï on "zi-pélé" (i.e. exhausted, infertile land which no longer produces anything). The results of this are reported elsewhere (the agronomic report by the RSP center team, 1993).

In order to assess the results of the zaï trial in the village, the RSP chose a random sample among the farmers surveyed. This report presents the results of this study, which aimed to improve our knowledge of the agricultural impact of zaï methods, based on field trials and evaluations made by the farmers themselves.

II. METHODOLOGY

A stratified and random sub-sample was taken from a sample group of farms, itself chosen randomly for another research purpose (i.e. the socio-economic profiles of village farms). This enabled us to see whether the variation in the farmers' experiences could be attributed, among

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other things, to their socio-economic status. The sub-sample comprised 37 farmers, who were divided into 4 categories. Another 5 farmers, none of whom had been in the original sample, and who were therefore unclassified, also tested zaï methods, following protocol previously established by RSP. These 5 are also included in the sample for this study. The distribution of the sample group is described in Table 1. The 42 (out of 186) farmers studied represented 23% of the village farms.

Table 1. Farmers surveyed on the performance of Zaï

Producers	1st Category	2nd Category	3rd Category	4th Category	not classified	Total
Number in Sample group	7	7	7	16	5	42
% of sample	17	17	17	38	11	100
% of the village	12	12	24	52	- -	100

A questionnaire was compiled and tested. The questions, often non directive (or "open") focused on two main themes:

1. The evaluation of zaï used in the previous trials; and
2. the intentions of the farmers concerning the reuse of zaï the following year.

The replies were coded, recorded and analyzed with the help of Quattro-Pro software.

III. RESULTS: EVALUATION OF ZAI

The Trial and the Yield. 71% of the villagers tried zaï. The majority of them reported a positive impact on crop yield. This is consistent with results from agronomic tests. Refer to Figures 1 and 2.

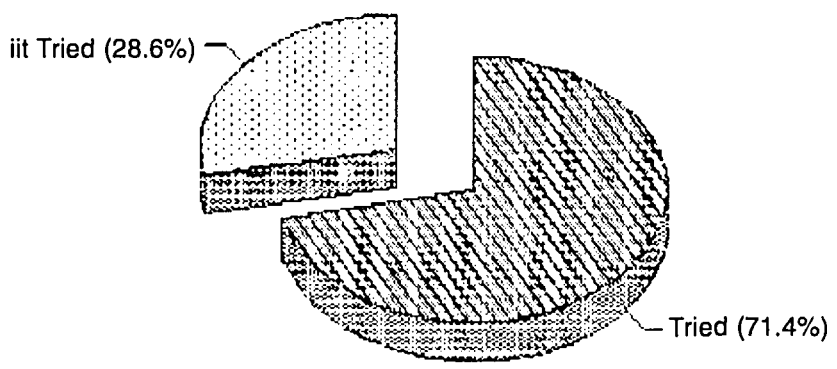

Figure 1.

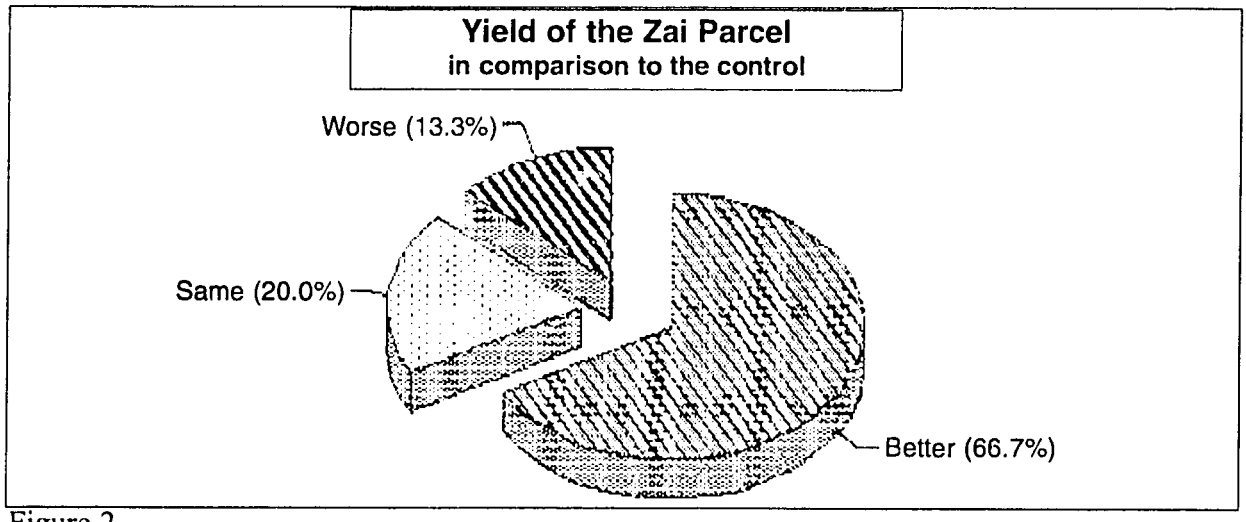

Figure 2.

The yield of zaï parcels (zaï alone) was two thirds better than that of the control area (i.e. the plot with neither zaï nor mulch) according to farmers' estimates. (For example: 10 baskets, as opposed to 6 baskets for the same surface area). Some farmers reported an increase of up to three times the yield on the zaï plot.

The majority of farmers say that the greatest differences in yield (when comparing plots with and without zaï planting) occurs on the most degraded land. One farmer, on the contrary, held the opinion that zaï had more impact on moist, fertile land. Neither the position of the zaï plot within the toposequence, nor the number of years that the parcel had been established, were considered factors determining yield.

Where the yield of a zaï parcel was not so good as, or even worse than the control parcel, the following explanations are proposed: Striga may have been present on the plot; sowing may have been late; the site was chosen badly (on a farmer house site, or in a water-logged depression). Another reason could have been failure to close over the zaï holes adequately.

The observations of farmers using zaï and mulch together are not conclusive. Some said that the mulch helped protect the young plants during a period of drought; others saw this as doubling the labor involved when doing both, and proposed instead to choose one or the other method, rather than combining the two. The choice of technique also depended on the availability of help, on manure supplies, and on the characteristics of the site. This will be discussed again later,

Twelve farmers did not try using zaï in 1993. They said that they did not have manure, or that the family's labor was taken up mulching, building rock bunds, or clearing land, or that old age prevented strenuous work. However, 9 of the 12 declared their intention to use zaï the following year (see section 4).

Germination and reseeding. Germination was more successful in the zai parcels than in others: seedlings came up at a rate of 91%, as opposed to 77% in other parcels. All parcels were

threatened by a period of drought in the last two weeks of June. During this time, producers observed that the need to resow was reduced on the zaï parcels, where plants showed greater resistance to drought.

For the whole sample, the zaï parcels were resown 1.5 times; other parcels were reseeded twice. Figure 3 shows the number of producers who had to reseed zaï or non-zaï parcels.

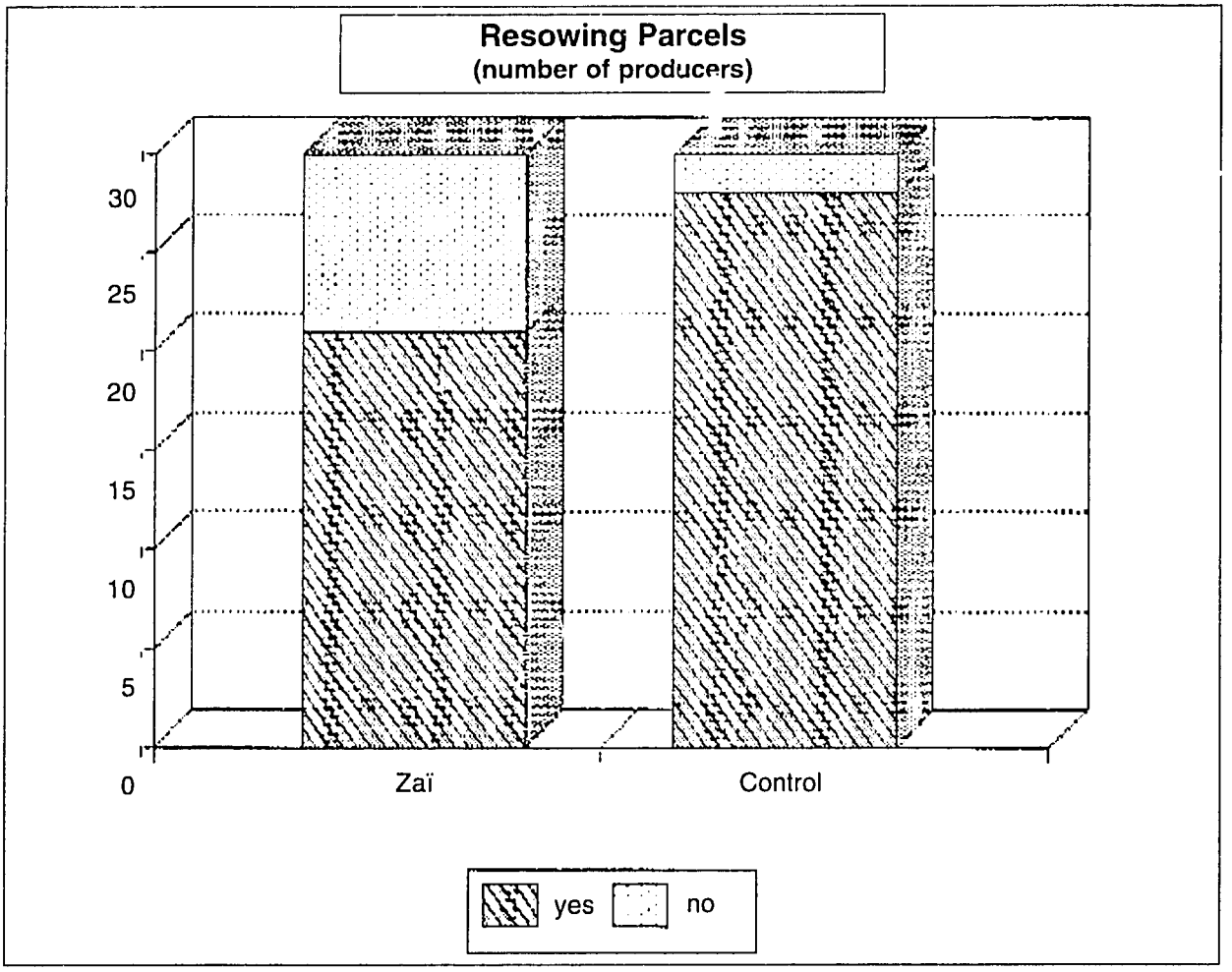

Figure 3.

Zaï parcels were resown less frequently, and by fewer producers. As has already been noted, germination was better in the zaï parcels. It could therefore be concluded that zaï parcels favor better germination. Zaï's greater resistance to drought was also brought out in comments made by farmers.

In assessing the need to reseed zai parcels, a number of factors were cited. These are summarized in Figure 4. Observations made by the farmers themselves complete this discussion.

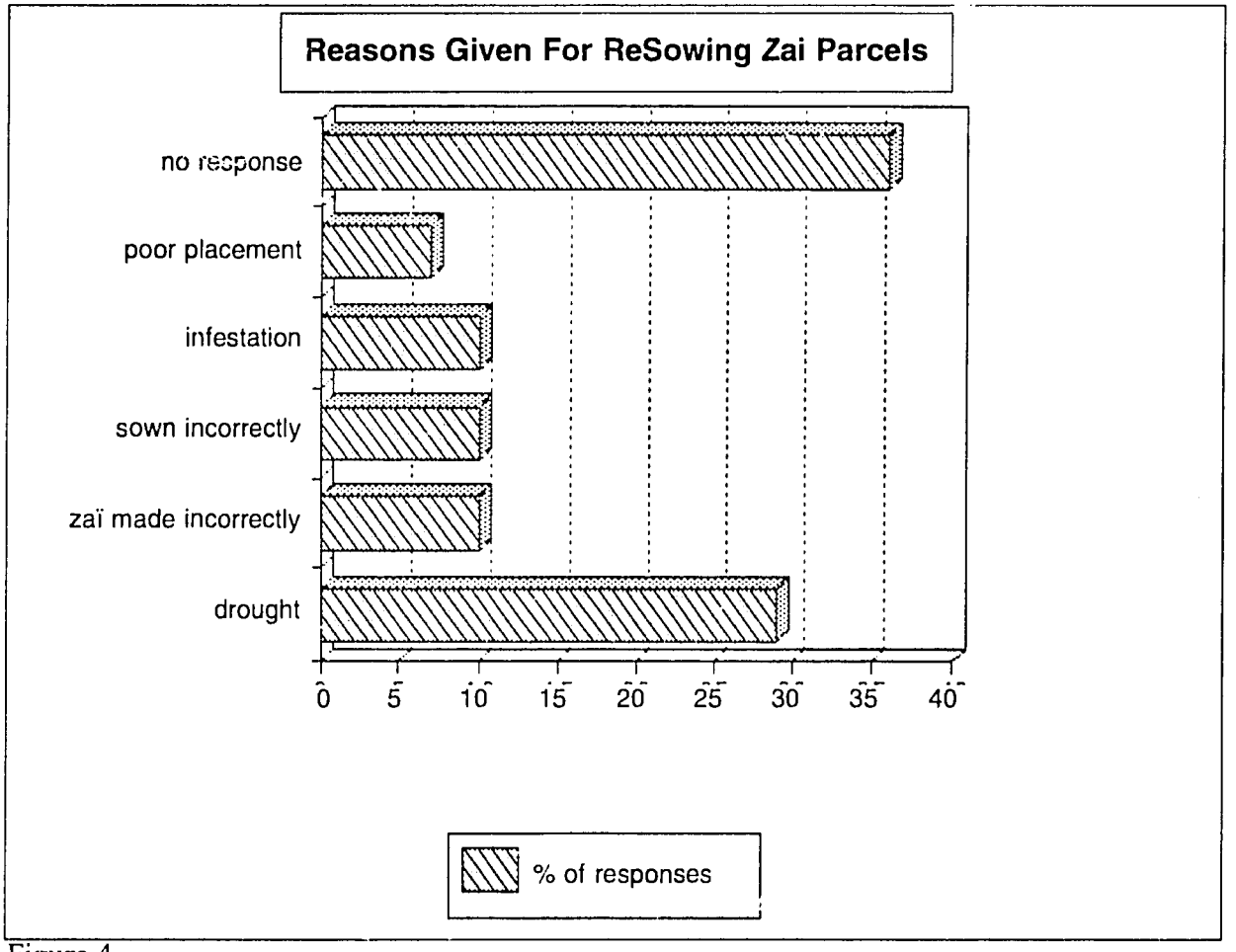

Figure 4.

The drought affected all parcels, both zaï and non-zaï. Its impact was felt more on the latter, but the difference between the two in terms of the area that had to be re-seeded was not calculated. The lack of practical knowledge concerning how to most effectively implement zaï methods presents significant problems to those considering adopting such methods. Errors were made, for example:

Digging holes incorrectly: either not deep enough (so that seeds were washed away by rain); or dug too early (so that wind formed a hard crust on top, making it necessary to dig again, more deeply, before sowing). Also, sometimes, not enough manure was used.

Sowing was done incorrectly in some cases. Instead of waiting for the first rains before sowing producers say that it is better to sow on dry soil.

Sowing directly onto manure is not advised. Instead, soil and manure must be mixed well in order to promote deep root growth (otherwise, the plant will not withstand drought).

Pests were often responsible for the failure of the first sowing. In particular, there were infestations of Striga in the parcel and worms in the manure. Shea nut leaves and debris blown by the wind blocked the holes.

Choice of site may also be a source of problems. If a parcel is located in the way of natural drainage, water washes the manure away. In low-lying areas, maintenance is too difficult. One site which was situated where there used to be a house suffered from soil that was both too dry and too acid.

Expectations from Zai parcels. Producers employing zai methods for the first time enjoyed an increase in productivity both in parcels that were already fairly productive, as well as in those parcels that had been degraded. Three quarters of those surveyed were expecting to improve production with zaï. For the others, this represented a trial: new technology that was the talk of the village, and they took part in the trial for that reason.

For whatever reason given for trying zaï at the outset, producers were clearly interested in repeating the trial next year, as can be seen in Figure 5. The comments of both those who were and were not interested in the trial are recorded in the next section.

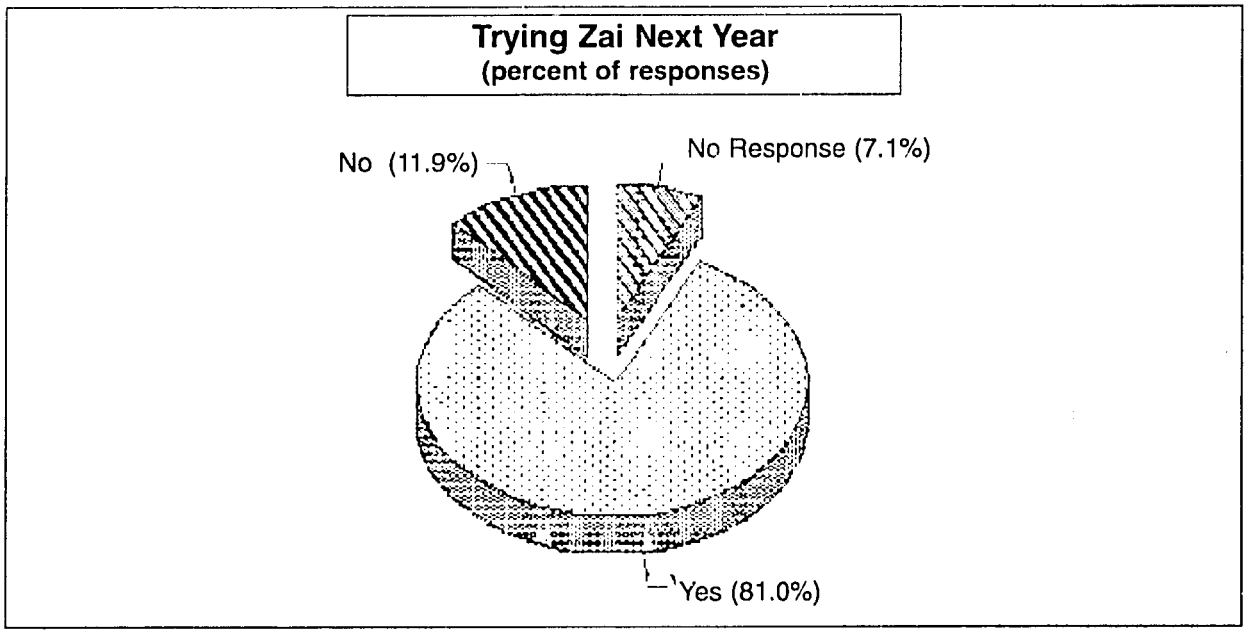

Figure 5.

IV. PERSPECTIVES: GOALS FOR NEXT YEAR

What to do next year and where. Eighty one percent of producers are planning to use zaï next year. Of the five that are not interested, three decided not to try in 1993. Why not? Reasons for not trying include a lack of manure, or of manpower, or a preference for mulching. Two others did try in 1993, but were not satisfied with the results.

For the remainder, zaï represented a breakthrough, to quote one participant: *"The RSP showed us how to reclaim exhausted soil "*. The great majority of producers plan on using zaï next year, and use it on larger areas (see Figure 6). Some producers plan on reusing last year's holes, taking advantage of the *remaining manure* left there.

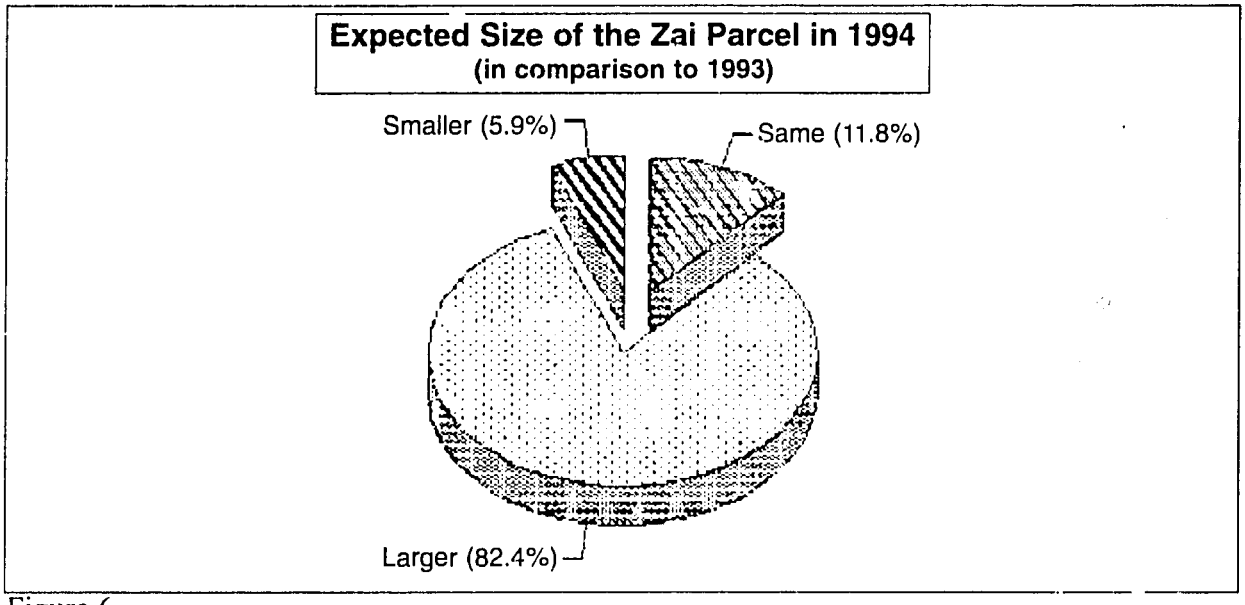

Figure 6.

Factors that influence the choice of site are many (see Figure 7). In general producers start by tackling poor, dry soils, which yield almost nothing. Some producers have targeted the *zi-pélé*, or *koun koubris*.

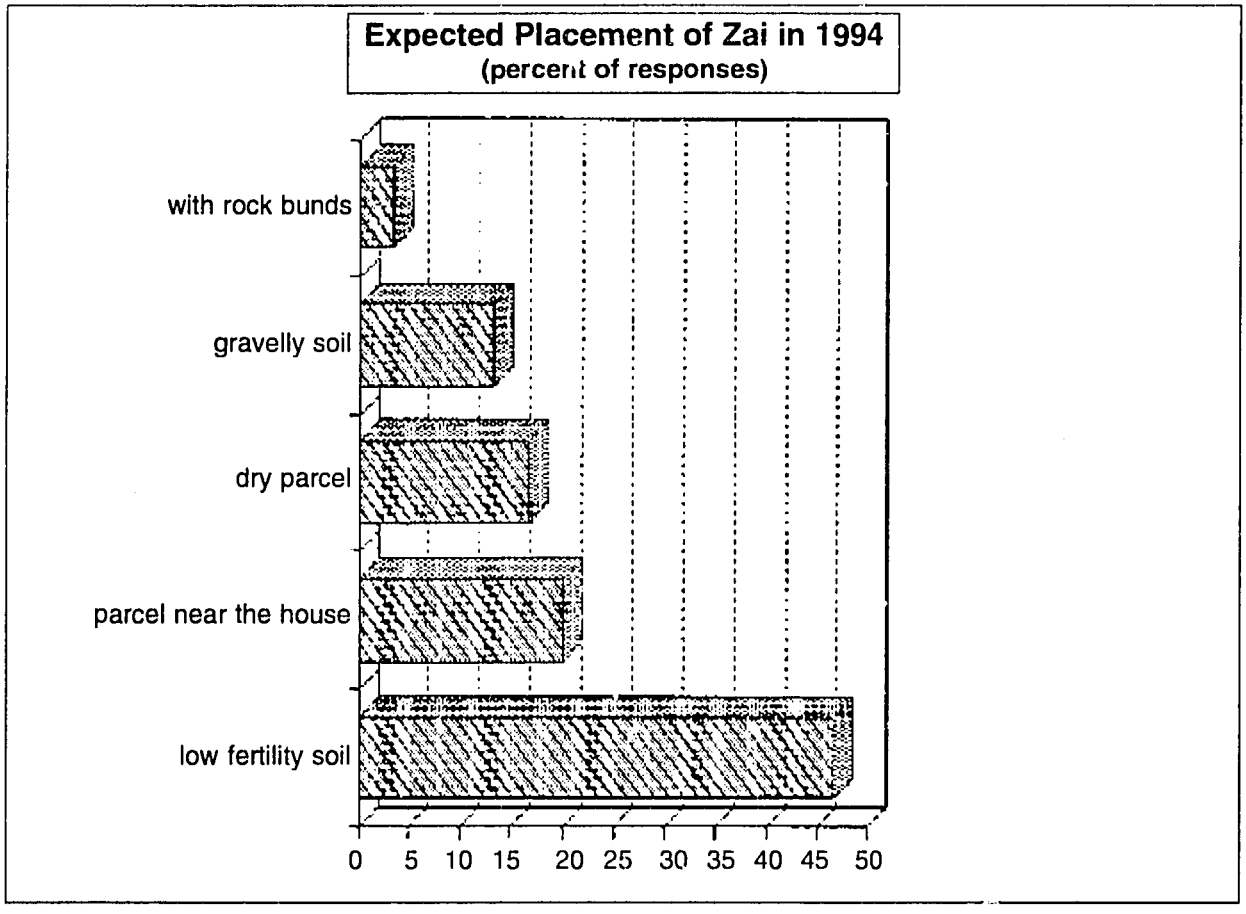

Figure 7.

Gravel-based soil *(well drained)* is also considered appropriate. Where transport (of manure) is a challenge, compound land is used for the zaï site.

The predominance of mulching in Donsin indicates its importance. In spite of their satisfaction with zaï, farmers do not intend to abandon mulching.

Certain recommend using both zaï and mulching together. For others, zaï is more appropriate for use on the most unproductive parcels, such as zi-pélé land, and mulching is used for the remainder.

Inputs: Fertilizer, Equipment, and Labor. It is clear that the availability of manure and manpower in each family are prerequisites for the use of zaï. Almost every producer expressed his intentions for next year in terms of a precise and pragmatic scenario comprising various activities which make competing demands on his time. Work (involving either mulch-collection , the construction of zaï or of bunds) starts in January and continues through until the first rains. The area involved is limited by the amount of labor available. Manure, compost and household waste are more or less available, but if it is necessary to go and collect manure from the fields that also takes time. The farmers therefore manage their limited resources according to a given strategy. Manpower becomes an issue especially when the number of able-bodied workers in the family is less than four. One result that is not without interest is noted in Figure 8, namely that farmers who come from the highest socio-economic class in the village do not experience the same constraints in this respect.

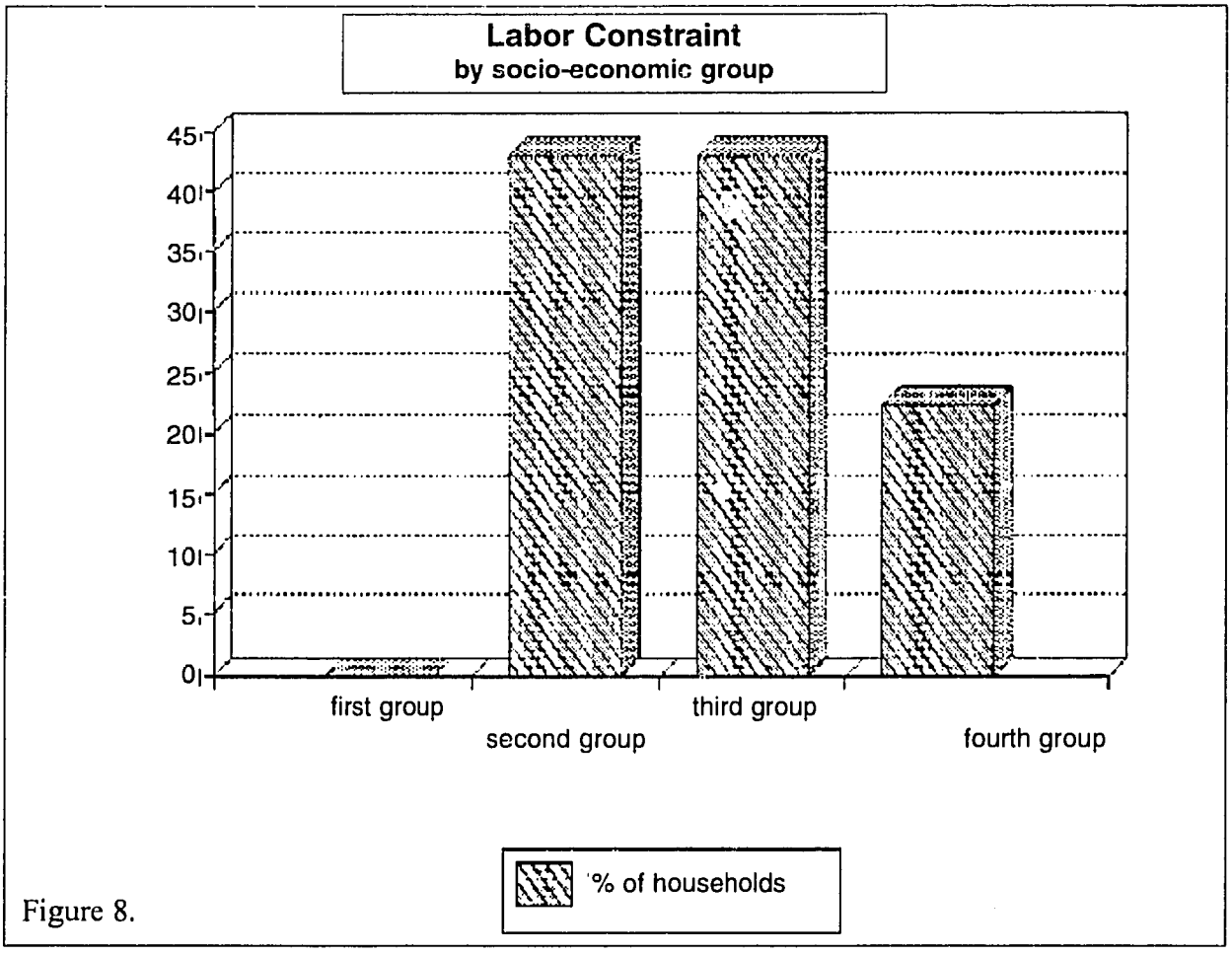

Figure 8.

The availability of manure to make zaï does not pose a problem for the majority of producers (see Figure 9). Animals, and especially small ruminants are numerous in Donsin. Even if one farmer does not have enough of his own animals, he can get manure from a neighbor, parent, or from pasture land. Some farmers have their own compost pits; others collect household waste. In any case, producers worry more about the problem of distribution than the availability of manure. This question is tackled in the discussion of the impact of zaï in the future.

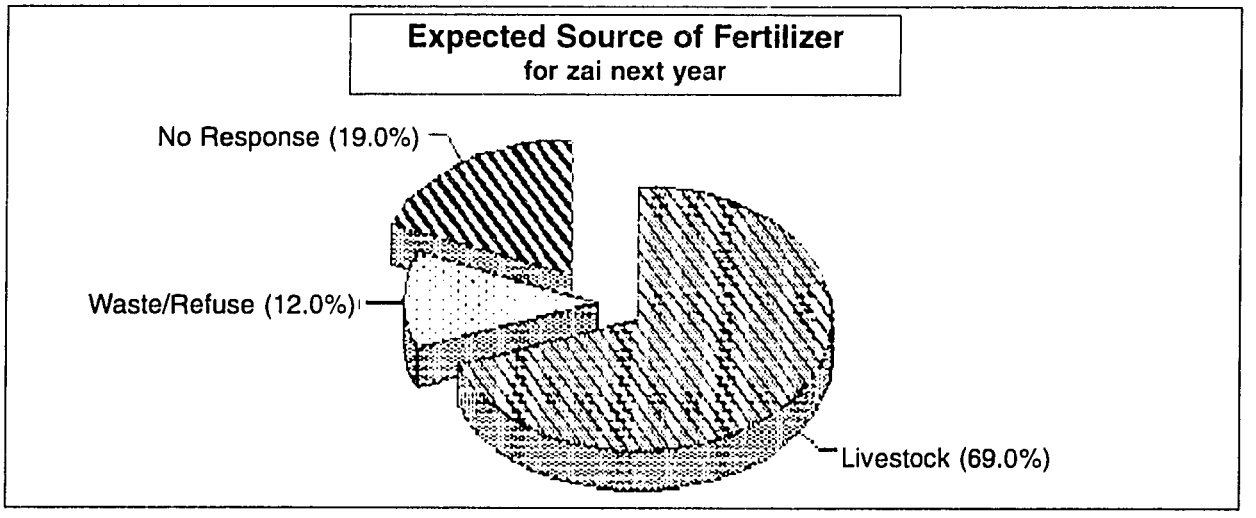

Figure 9.

Producers are interested in using the appropriate equipment for preparing zaï. Traditional hoes are not strong enough to dig the zaï pits. Instead, it is suggested that ice-picks or *Yatenga axes* be used to make the task less costly.

Techniques of choice for successful zaï. Farmers recognize the importance of mulch, rock bunds, and other measures taken to fight resource degradation such as earth bunds and scattering tree branches. Zaï is perceived as another such technique, but one which does not necessarily go with those mentioned above. Forty two percent (42%) of farmers have already used one CES technique on their land.

Farmers make their own suggestions for successful zaï cultivation. For example, they recommend leaving ample space between rows to encourage plant growth. In addition, they recommend that zaï pits should not be dug too deeply, since this tends to increase the worm population in the manure. Zaï that are dug too closely together inhibit the growth of shoots. Lastly, manure is preferred to household waste.

The Impact of Zaï on the Village. The farmers agreed almost unanimously that farming with zaï would result in a reduction in the amount of land cultivated. The sheer demands zaï makes on labor make it impossible to carry on cultivating the same surface area as at present. Moreover, the presence of rock bunds, or other CES measures will establish defined field limits. The farmers therefore foresee an end to itinerant farming. At the same time, the new methods would bring improvements to the soil.

A definite need for fertilizer is foreseen. Farmers talk of stalling their animals as one solution. However, one must admit that the local population did have a certain reticence to this method. This is most probably due to their concerns about how to feed their livestock. RSP experience has shown that the Donsin villagers are not interested in producing fodder. Sheepfolds, cited by quite a lot of villagers, are a realistic alternative for the production of organic material.

Donsin villagers consider making sturdier hoes. The RSP conducted tests on several models which had been made in Yatenga. At present, any model can be chosen and a copy made up by a blacksmith in Boulsa. The SANREM project also plans to help the Donsin villagers to develop appropriate tools.

Two further observations complete this discussion. Mutual aid group work in Donsin could resolve the labor shortage but this practice is not well developed in the village and its future development is uncertain.

Wandering animals prevent sowing at the beginning of the season. In principle, the village chief puts a stop to this when he considers it time to start sowing. If sowing is to be done before the first rain, wandering animals should be stopped earlier. The likelihood of this happening is equally uncertain.

The role of RSP. The villagers were consulted as to how the RSP and its collaborators (researchers, extensionists etc.) could best help them prepare the zaï next year.

Typically this kind of question provokes a passive response, of the "give us this, give us that" kind. This kind of reply indicates a strongly felt need for the right equipment to prepare the zaï and was quite a common response in the village. More important still are those replies which manifest the villagers' constructive interest in making the best tools themselves or in improving the making of zaï should the material and knowledge be supplied. (Diagram 10). Education figures prominently in the current role of the RSP in the village.

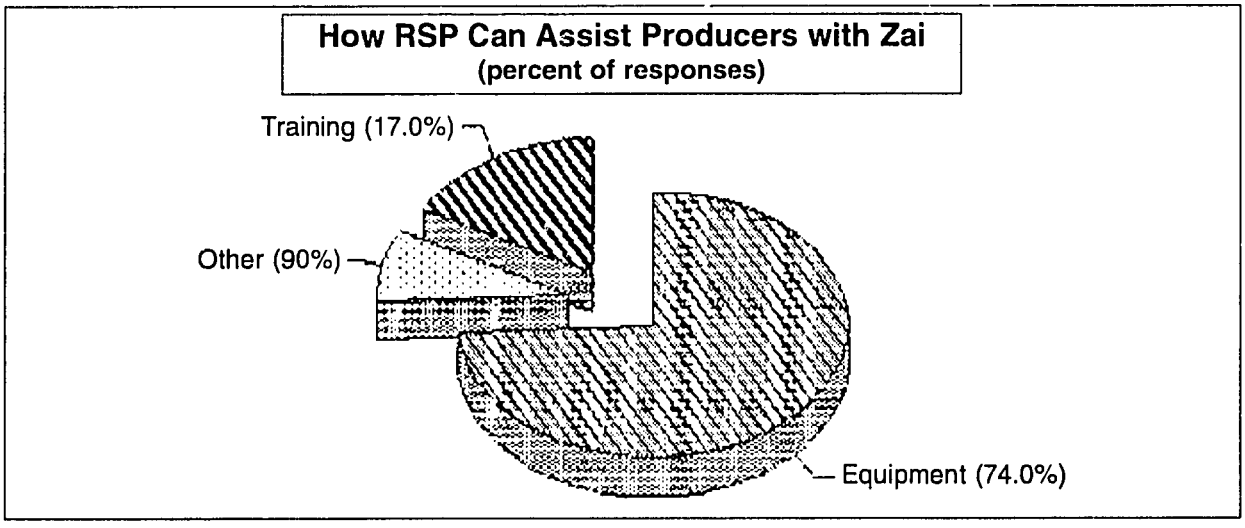

Figure 10.

The importance of strong hoes has already been mentioned. Wheelbarrows and carts are also important. A better functional knowledge was requested, i.e. how to make good compost, and knowledge of how to make the zaï themselves (specifications for digging the pits, how much manure to use, spacing, seeding, etc.). Questionnaires recorded equally dynamic and concrete replies from farmers who sought further knowledge of agroforestry. There were also requests like *"show our blacksmiths how to make the three-pronged hoe"*.

Conclusions and Recommendations. The interest of Donsin farmers in zaï has been firmly established. The villagers themselves decided to adopt zaï technology on a trial basis, even without the intervention of the RSP, whose role was limited to such things as facilitating the "farmer to farmer" visit, demonstrating how to recuperate a zi-pélé, and proposing that the 6 partners test zaï-mulching. The intention to use zaï next year has been clearly expressed. A growth of 15% by comparison with this year can be anticipated. This would mean that 80% of villagers will use zai in 1994.

The advantages of zaï for the population have been clearly expressed: the superior retention of moisture; better resistance to drought; good germination record as well as good yield; and the restoration of *zi-pélés* (exhausted land). However, the ultimate adoption of this technology depends on its resource requirements, in particular the labor and organic matter required. Hence the necessity for each farmer to make his own evaluation according to his particular priorities and the availability of the required resources.

Action to be taken. For the RSP program, there are still details about zaï technology that need to be communicated to the farmers, because this will be indispensable to ensure future success. Providing answers, for example, to questions such as:

- How to obtain the best level of profitability on parcels of quality varying from fertile arable land to eroded or "zi-pélé" parcels.

- Under what conditions is it better to mulch rather than use zai, or when should both methods be combined?

- In what form should the manure be and how should it be applied?

- How much reseeding is required with different zaï techniques?..."

Preparatory activities must also be considered, such as the availability of manure which implies animal management (stalling and feeding). Associated activities, such as the creation of rock bunds or agroforestry are also elements in this equation. Equally, there are actions to be taken to address equipment problems. The making of sturdier hoes, discussed above, is underway, as is the test of hand-pulled carts for transporting the organic matter.

Finally, the development of the villagers' awareness of the issues and methods is crucial. To date, the RSP plans a *feedback session* in Donsin, to be followed by a demonstration of the correct method for preparing zaï. For this, organizers plan to use the *"farmer to farmer"*

approach again. Group testing is also appropriate, promoting collaboration in the form of association or grouping of farmers.

One farmer suggested that the RSP could help villagers if it provided *"the goats and chickens that must be sacrificed In order to satisfy customary obligations"* (and thereby ensure rain). The RSP does not have the ability to provide rain, but it can conduct research. RSP's *goats* are their on-farm trials, and their *chickens* are the education programs. The *customary obligations* that the RSP will help the villagers satisfy are those which restore the land for future generations, and which leave a legacy which ensures agriculture of a truiy lasting nature.

Economic Analysis of Compost Production in Southwestern Burkina Faso

S. Amadou, M. Bertelsen, S. Ouédraogo

I. INTRODUCTION

Soils in Burkina Faso, and more specifically, in the West are being continually degraded. This is due to a number of factors, including the growth in surface area under cultivation as a result of emigration and the consequent demographic pressure on the land. At the same time, the withdrawal of input subsidies has meant that farmers have had to shoulder increasing expenses, while seeing their incomes drop.

There is ample research evidence that the use of organic matter, including the use of compost, contributes effectively to restoring soil fertility, whereas the continual use of mineral fertilizer ultimately leads to a loss of fertility.

However, very little is known about the economic aspects of composting. The latter should go hand in hand with the research undertaken on technical aspects, with a view to indicating the different users and eventually to directing researchers towards inexpensive innovations.

The object of this study is to make an economic analysis of the preparation of compost, as compared with the cost of buying mineral fertilizer, notably NPK, which is widely used. The projected results will:

- Provide information for researchers and decision-makers on the chances of adopting composting, considering the socio-economic difficulties which are associated with compost-making.

- Help interested farmers make the decision to adopt composting by making available to them the socio-economic data collected.

- Contribute to the identification of new directions for research, including research on the use of certain materials, with a view to reducing the cost of compost production.

- Help lift any constraints which discourage the adoption of composting.

II. METHODOLOGY

The site chosen for this study was the village of Kayao, situated in the Province of Mouhoun, in Burkina Faso. Kayao is one of the four sites chosen by the Western Zone Farming Systems Research Program (RSP), in the Western Zone of the Institute for Agricultural Study & Research (INERA- Institut d'Etudes et de Recherches Agricoles) of Burkina Faso's Western Zone.

As in most regions of Southwestern Burkina Faso, Kayao is a zone which receives significant immigration. According to INERA typology, it is representative of the Western zone's poorly equipped, cotton-producing areas. Cultivation methods are extensive ones, which under the pressure of emigration considerably reduces the availability of arable land; thereby provoking land conflicts between immigrants and indigenous peoples. (Ouédraogo, 1991)

Moreover, because of the extension of cultivated areas and the reduction of fallow land, Kayao lands have mostly been degraded, or are on the way to becoming so. (Sanou, 1991)

In order to address the challenges in this zone, the RSP has put in place a system which integrates crop and the livestock. production systems. This was done by testing feeding regimes on draft cattle and compost making.

In order to evaluate the profitability of compost by comparison with mineral fertilizers, a questionnaire was prepared which was designed to collect data on compost production. Researchers conducting the survey held weekly interviews with participating farmers to collect information on the following variables:

- labor involved for all operations
- inventory of materials used
- number of animals
- types of inputs used
- volume of compost pits.

A total of ten participant-farmers were chosen, selected according to their willingness to invest in this technology and acquire or possess the required cattle and plant material. These variables were supplemented by secondary data (bibliography and price surveys).

The infrastructure and the research technicians already in place enabled us to conduct these surveys with ease.

The research hypothesis is that the cost of soil improvement with compost is less than that with mineral fertilizer, and that the latter could be used more efficiently as a complement to, rather than a replacement for compost..

III. RESULTS

Equipment. The acquisition of appropriate materials constitutes the principal difficulty involved here. In fact, the necessary investment in materials for the first year appeared to be very costly for farmers whose income is limited. According to our data, acquisition of materials amounted to about 90,600 Fcfa. However, most farmers already possessed at least some of the necessary

tools, including carts, dabas[1], mattocks and buckets. By deducting the cost of materials already in the possession of the farmers, the cost of materials that still had to be bought amounted to 13,000 Fcfa. The latter represents the price of an pick, a spade, two basins and a barrel, none of which were generally owned by the farmers.

However, the annual depreciation cost is low given the long life of materials and the compost pit. In addition, some tools, such as the pick, are mostly used only when digging the pits.

Water. The survey makes clear that the availability of water constitutes a barrier to composting. Most of our participant-farmers were unable to follow the recommended composting techniques because of lack of water. According to the survey, the nearest water source was approximately 6 kilometers from the village where the compost pits were located.

Labor. The survey reveals that two kinds of labor are used including family members and paid labor.

The participating farmers depended on hired labor more for digging the pits (46% of total digging labor time) than for filling the pits. Only 4% of labor for filling pits was hired.The table below indicates the average time spent, in man-hours per cubic meter, on digging and filling operations, respectively.

Table 1. Average labor time for production of one cubic meter of compost in Kayao.

Task	Labor time (Hours)	Standard deviation
Digging out pit	8.88	2.48
Filling in	7.18	1.5
Total	15.96	

Number of observations = 10

It is clear from Table 1 that digging timevaries greatly. The cost of digging is estimated at 165 Fcfa/m^3. The cost of filling is estimated at around 19 Fcfa per hour of digging, averaging out costs for the duration of the operation. Even if this figure appears to be very low, in comparison to the opportunity cost (100 Fcfa) during the field work, this was expected, because the digging operation took place during the "hungry season. Sidibé (1993) found an even lower opportunity cost, for female labor (10 Fcfa per hour) in the village Yasso, in Kossi province situated in Southwestern Burkina Faso.

Analysis of the compost production costs: Hypotheses of the analysis.

- The pit is assumed to last for five years.
- Equipment depreciation.

[1] dabas are short handled hoes used in Africa

Table 2 indicates the projected equipment lifetime and the rate of use of the equipment for compost production. These elements served as a basis for calculating straight line depreciation.

Table 2.

Equipment	Price (Fcfa)	Number	Replacement rate/year	Rate of use (%)	Depreciation (Fcfa)
Pick	3,900	1	2 years	10%	975
Mattock	400	1	1 year	100%	400
Spade	1,000	1	5 years	100%	200
Basin	5,000	2	2 years	100%	2500
Daba hoe	800	2	1 year	100%	800
Bucket	1,500	1	2 years	50%	375
Cart	75,000	1	5 years	10%	1500
Barrel	3,000	1	5 years	50%	300

Opportunity cost of labor. For the digging, the labor cost used reflects the actual amount paid by producers, that is 165 Fcfa/m^3. To estimate the cost of filling in the pit, the opportunity cost of labor in Kayao was used, i.e. around 100 Fcfa throughout the cropping season. It is recommended that the compost pit be filled during the cropping season so that it can benefit from rain water.

Estimates of the amount of time taken to empty the pit were not available when the analysis was made. It was therefore assumed that the length of time taken to empty a pit was equivalent to half the time taken to fill it, i.e. 3.59 hours/m^3. The same applies to time taken to transport and spread the compost, for which secondary information was used.[2]

Comparative analysis of soil amendments. Table 3 shows that the production of one cubic meter of compost requires an investment of 2,476 Fcfa. To obtain the recommended amount of compost per hectare[3], which is 2.5 tons (CFA, 1991) requires an investment of 26,914 Fcfa (see Table 3). According to Segda (1991), crop yields comparable to those obtained using the above amount of compost were obtained in Sourou by using 300 kg/ha of NPK, at a cost of 28,500 Fcfa/ha, with subsidized NPK priced at 95 Fcfa per kg.

Table 3. Production costs of compost per cubic meter, in Kayao.

Category	Costs (FCFA)
Fixed Costs:	
Equipment[4]	115
Labor (digging)[5]	33

[2] Based on INERA/RSP Western Zone data on agricultural labor times.
[3] hectare = 2.471 acres
[4] Depreciation costs of equipment which lasts for the same length of time as the pit (5 years).
[5] Time taken to dig (8.8 hours) x primary tillage costs (19 Fcfa per hour)/5 yrs.

Variable Costs:	
Maintenance[6]	254
Filling[7]	718
Burkina Phosphate	552
Equipment[8]	765
Emptying	68
Total	2476

Given the transport and spreading costs for both fertilizers, Table 4 shows that there is very little difference between the investment required when using NPK as opposed to compost, at least for the first year of use, i.e.: 28,054 Fcfa for compost, and 28,614 Fcfa for NPK.

However, Segda (1991) has pointed out that compost remains effective for a two-year period. On the other hand, if mineral fertilizer is to be the sole soil amendment, it has to be applied annually.

To establish a proper comparison between investment costs, they must be actualized. Table 4 therefore shows the actualized costs of using NPK or compost, respectively, as soil amendments. This is based on the assumption that the capital opportunity cost is at 1000%[9].

Table 4. Comparative amendment costs: NPK versus Compost.

Category	Compost (2.5T/ha/2yrs)[10]	NPK Kg/ha/year[11]
Production or Purchase	26,914	28,500
Transport to field (5 km.)[12]	912	57
Spreading over 1 ha.	228	57
Total	28,054	28,614
Present value (c.op.1,000%)[13]	28,054	2,601[14]

[6] 10% of production cost

[7] Time taken for filling (7.18 hours) x opportunity cost of labor (100 Fcfa per hour).

[8] Depreciation costs of equipment whose lifetime is shorter than that of the pit (5 years).

[9] This hypothesis was based on the results of Lowenberg et al. (1993) which indicated that most of the small lucrative activities had an annual rate of profit of about 1000%.

[10] Calculation based on the assumption that one pit, with a volume of 10.87 m^3, to produce the recommended amount of 2.5 tons/ha of compost, which remains effective for 2 years.

[11] Recommended amount in order to obtain the same yield as produced by 2.5 tons of compost.

[12] Calculated on the basis that 16 carts-full of compost, each of which takes an average of 1.30 hr. to transport to the field.

[13] Opportunity cost of capital.

[14] Present value of the cost of NPK, for the second year.

Table 4 also shows that the comparative investment cost between these two amendments is only very slight. One notes that the cost of compost in this case is only 10% lower than that of NPK. The difference is approximately 3000 Fcfa.

In some cases, a discount rate of 1000% seems very high. This is why Table 5 shows the costs of NPK and compost, at several levels of opportunity costs (40%, 100%, 500%, and 1000%). Table 5 shows that there are very significant differences, related to the various opportunity costs. For an opportunity cost of 40%, for example, the amendment cost of NPK appears to be almost twice as high as that of compost (28,054 Fcfa for compost, as opposed to 49,053 Fcfa for NPK). Even so, Table 3 indicated that there was very little difference between these costs when the opportunity cost is at 1000%.

Table 5. Comparative costs of amendment: NPK versus Compost, according to opportunity cost of capital.

Capital opportunity cost	40%	100%	500%	1000%
Compost	28,054	28,054	28,054	28,054
NPK	49,053	42,921	33,383	31,215

IV. CONCLUSION

The economic analysis of compost production shows that, regardless of the bio-physical soil improvements, the use of compost for soil improvement is also more profitable than the use of mineral fertilizer (NPK).

However, this profitability is strongly influenced by the opportunity cost of capital. It is therefore very important to factor in the latter as decisive when calculating the present value of the cost of NPK. (The present value of the investment in NPK was used because two investments in a two-year period produce the same effect as only one investment in compost over the same period). Thus, the relative profitability of composting diminishes when costs of capital run very high (at 1000%, for example).

In spite of the fact that the financial profitability of composting has been demonstrated, there still remain other obstacles which may hinder its adoption.

- There are obstacles linked to the difficulties of acquiring the necessary equipment to make the compost pits. These obstacles are mostly due to the high investment required relative to the low incomes of producers, and to the fact that some equipment is used only the first year. However, this second problem could be solved by buying and managing equipment collectively.

- The scarcity of water during the dry season constitutes another obstacle to adopting composting for soil amendment. In fact, the distance from water sources is discouraging for

all but a few producers, who must first of all supply their own needs. It is indispensable that the decision-makers consider the problem of water availability as one which not only involves ensuring supplies for the population, but which is also vitally linked to improving soil management.

- The many interviews with producers revealed that a large proportion of them were unaware of the method and effects of composting. They preferred to wait and see for themselves the effects on soil fertility of this first trial of composting, that they would then compare with their own practices using manure from livestock corrals. It is therefore necessary to emphasize the importance of training and information using demonstrations.

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Use of Unconventional Products in Animal Health Care: The Case of Draft Animals in Burkina Faso

Y. Samandoulgou

I. INTRODUCTION

A survey conducted in 1990 in the four Western RSP village sites revealed a large cattle herd size in these villages. Herds of the two cotton-producing sites, where animal traction is widely used, include a large number of draft oxen (Badini 1990). The survey shows that no veterinary services are available in any of these villages. The national vaccination campaign is conducted every year in the villages between February and June.

During the agricultural season farmers are nevertheless faced with animal health problems during the agricultural campaign, which require assistance from a livestock or veterinary professional. In principle, farmers have had no training in primary care of animals and should consult a veterinarian. However, the closest animal health station is about thirty kilometers away from the village. What do farmers resort to during the agricultural season when their draft oxen are ill?

In order to address this question, a preliminary survey was conducted in Kayao[1], one of the RSP villages, which represented a sub-zone characterized by subsistence cropping with some cotton production and a high rate of animal traction in 1990. There are 223 draft oxen, 88 donkeys, and 1189 cattle, in the village and 34 % of the villagers use animal traction (Badini 1990).

The objectives of this survey were to:

- Gather knowledge on farmer practices,
- Inventory the unconventional products used for draft animal health care,
- List the supply sources for these products, application methods and treatment costs.

II. METHODOLOGY

Data was collected through informal interviews with farm family members possessing draft oxen. The interviews especially focused on young individuals who work with these animals and maintain them. These individuals monitor the behavior of draft animals and know them best. The survey was initiated during the 1991-1992 season and was completed in January 1994.

A questionnaire was used throughout the survey. However, it should be noted that this questionnaire was not uniformly administered because some questions dealt with sensitive issues. Most people interviewed found it difficult to answer the questions, sensing that they had to

[1]Survey participants: Sanou Sogo and Dabilou Salam, technician-enumerators Fandié Kankéki, village enumerator

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compromise their own interests. Clandestine vaccination is normally prohibited in Burkina Faso. Therefore, a combination of interviews and direct observations of farm practices was used.

Every year, the selected sample included 25 production units using animal traction and participating in RSP tests. However, observations were made on all farms having draft oxen.

Disease diagnosis by farmers. Farmers use their experience as a basis for diagnosing animal diseases. They do not have the necessary knowledge of specific pathogens, but often recognize aggravating factors such as change in climate, diet, work schedule, etc. Once an animal displays an abnormal behavior such as sadness, fatigue, lethargy, refusal of food, etc., farmers examine the animal (body temperature by touch, feces, eyes, snout, hair, nasal secretions, etc.). More knowledgeable farmers are called upon to determine the cause of the disease when they cannot do it themselves.

Reasons for the use of unconventional products. The survey results indicate that:

- To call the livestock agent of the village of Oronkua to Kayao is rather difficult, because appointments are often missed and the agent is often in field missions and so cannot be easily found at his office[2];

- Rarely can the prescribed remedy be obtained at the livestock extension station. Therefore, farmers have to go to a larger center such as the CRPA at 90 or 190 km distance. This causes a delay between the time of the visit and the beginning of the treatment. Additional problems arise when farmers cannot procure the product (because products are frequently out of stock) or when subsequent services of the agent are required, as in the case of injectable products.

Problems which discourage farmers from using conventional products are in order of importance:

- Difficulties of access to conventional products (70%)
- Unavailability of the livestock extension agent (20%)
- Confidence in unconventional products (10%)

Products used. Products used to treat draft animals are of various origins. They include drugs, pesticides, antibiotics and other illicit pharmaceutical products.

Table 1 indicates that none of the products used is specifically intended for animal care. Most pharmaceutical products are fraudulently imported from Ghana. They are confiscated by the police during checks of the local markets.

One of the advantages of unconventional treatments for farmers appears in Table 2. Treatment cost varies between 30 and 250 Fcfa, which is inexpensive relative to conventional treatments and affordable to those raising cattle.

[2]Little supervision

Antibiotics are all called "toupaï" (literal translation); This is because they are used to care for all diseases. They are of two kinds: Totapen and tetracycline, both in capsules.

Paracetamols identified are of several sorts:

- Daga: package of three 500 mg pills
- Alagme: package of twelve 500 mg pills
- Phenic: Paracetamol in 500 mg and 250 mg dosages

The range of paracetamols is quite broad.

Table 1. Percentage of farmers interviewed having used one of 6 unconventional products at least once to treat 8 frequent diseases (N=25)

Products	Diseases						
	Fever	Diarrhea	Wounds	Skin parasites	Fatigue	Skin disease	General ill-being
	%						
Antibiotics Totapen Tetracycline	75[a]	77	--	--	25	95	80
Paracetamols Daga, alagme	70	25	10	--	61	28	96
Sumicidine[b]	--	--	--	98	--	--	--
"Dissolution"[c]	--	--	84	--	--	--	--
Instant coffee	--	--	--	--	11	25	--
Undetermined other	5	--	--	--	--	--	6

[a]Nineteen farmers, for example, out of 25 (75%) said they used antibiotics against fever.
[b]Insecticide used in cotton production
[c]Manufactured to repair bicycle inner tubes

Table 2. Description of unconventional products and their costs

Disease	Product	Form/Unit	Unit cost (F CFA)	Dose	Cost (F CFA)
Fever	Totapen	Capsule	25	3	75
Fever	Tetracycline	Capsule	15	4	60
Fever	Daga	Pill	50	2	100
Fever	Daga	Pill	50	2	100
Fever	Alagme	Pill	25	4	100
Diarrhea	Totapen	Capsule	25	10	250
Diarrhea	Tetracycline	Capsule	15	14	210
Wounds	"Dissolution"	Bottle	150	1	150
Skin parasites	Sumicidine	Water jug	5000	<<1	200
Strepto-trichosis	Totapen	Capsule	25	6	150
Skin disease	Coffee	Packet	30	1	30
Gen. ill-being	Tetracycline	Capsule	15	8	120
Gen. ill-being	Totapen	Capsule	25	4	100

Directions for use. The directions for use of products depends not only on the manner they are administered but also on the disease to be treated, as one product can be used for the treatment of several diseases.

Products can be orally administered in three ways:

- Diluting it in drinking water. The animal is left for some time without drinking water, then, once thirsty, given a reasonable quantity of product-water mixture to be entirely drunk.
- Forcing the animal to swallow the entire product by pulling on its tongue
- Mixing it in food. This method is little used because of animal refusal.

The most widespread practice is intra-muscular injection in the shoulder or flank is also used. Some "specialized" farmers being especially skillful are called upon for injections. Two solvents are used to dilute products. Water is most widely used. Drinking water is used without any special treatment. It is not boiled nor filtered. "Koutoukou", an alcoholic drink derived from sugar distillation, is also used by some people. It is a popular drink and is sometimes called "who pushed me", or "zonzon", or "patècé". A liter of the sort with high alcohol content (about 90 degrees) costs 500 Fcfa, while the sort of low alcoholic content (9 to 20 degrees) is sold for 300 Fcfa a liter. The latter type is used as a solvent.

Syringes are generally designed for a single use, but they are used repeatedly until useless. Syringes sold in pharmacies have a capacity of 5 to 10 ml. When animals are familiar with the person doing the treatment, it is petted on the head for an easy intra-muscular injection. Otherwise, the animal has to be immobilized by the head or taken down.

Example of preparation of injectable products against fever. The origin of the fever is generally not identified. It is noted that the animal is sad with bristled hair and high body temperature. The treatment includes tetracyclines and "daga" paracetamol diluted in a bottle of "koutoukou" or water, which has to be strongly shaken for proper mixing. The solution is pumped into the syringe without the needle. Air is drawn out of the syringe before the intra-muscular injection.

In general, the dosage used is not well defined. It varies according to the person administering the treatment, the stage of development of the disease and the age of the animal.

Examples of products for external treatment.

Wounds. Mostly used for this purpose is the "dissolution", a glue product used to repair cycle inner tubes. It is an aseptic wound dressing. This product replaces Synexa and K'otrine more and more frequently. The glue is applied on the wound in a thin layer. A few moments later, the product is dry and protects the wound from flies and other insects. The dressing is repeated until the wound heals.

Tick control. There are two products used against ticks; both are pest control products used in cotton production: Sumicidine and decis. The first method consists in mixing eight to ten

volumes measured with a peanut shell (7 to 10 ml) in a bucketful of water and spraying the mixture on the body of the animal with a backpack sprayer. In the second method, fresh cattle feces are kneaded in the chemical liquid and the animal is coated with this paste.

General fatigue. The animal is tense. It cannot stand sustained effort. In order to give him a boost, three "daga" pills are administered orally or by injection.

Therefore, the main diseases treated which are commonly encountered are affections that do not require the intervention of a livestock specialist, with the exception of skin streptotrichosis.

Vaccination accidents. These medication practices are not without consequences. The use of products or treatment equipment can be traumatic to animals.

Solvents. Water used as solvent is not treated in any special way and may come from questionable sources. It may contaminate animals with other diseases.

Products. Antibiotics of unknown origin without written directions and known expiration dates may be dangerous. The use of bacteriostatic or bactericidal chemicals without the advice of a veterinarian can be overdone. Potential results include accidents and resistance to antibiotics.

Syringes. These can be sources of trauma and infection to animals, as they are not disinfected beforehand and are used repeatedly. Interviews revealed that there are accidents due to injections:

- Bleeding. A poorly practiced injection may result in bleeding which can then turn into swelling.
- Oedema. There is swelling where the injection was done. It can worsen and cause an abscess. Animals may even have reduced mobility on the side of the leg affected by the injection.

III. CONCLUSION

Interviews indicate that in order to care for their draft animals, farmers develop their own strategies and use fraudulent pharmaceuticals, pesticides, and other products (coffee, glue, etc.). The difficulty of access to veterinarian services and the high cost of conventional remedies (including transportation costs to Diébougou or Bobo-Dioulasso) on one hand, and, the availability of products and solvents (water, local alcohol) and of soiled equipment (used syringes) on the other hand make these practices easier and help to perpetuate them. Even though these practices are applied to animals, they give rise to serious problems for farmers and risk the health of their livestock.

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Evolution of Sedimentation, Surface Micro-Morphology, and Millet Production in Response to Soil Conservation Practices on an Eroded Site at Yilou, Burkina Faso

N. F. Kambou, S. J.-B. Taonda, R. Zougmoré, B. Kaboré, and J. Dickey

I. INTRODUCTION

Land degradation is widespread in Burkina Faso. Approximately 24% of the country's land area is highly degraded, and most of this land is concentrated in central Burkina on the Mossi Plateau (Figure 1). Current land management practices and population pressure contribute to the high rate of arable land degradation, and therefore threaten environmental quality and food security in the short and long run. Applied research in the area of on-farm soil and water conservation is a priority activity of the Water, Soils, Fertility, Irrigation, and Agricultural Machinery program of the National Institute for Agricultural Studies and Research.

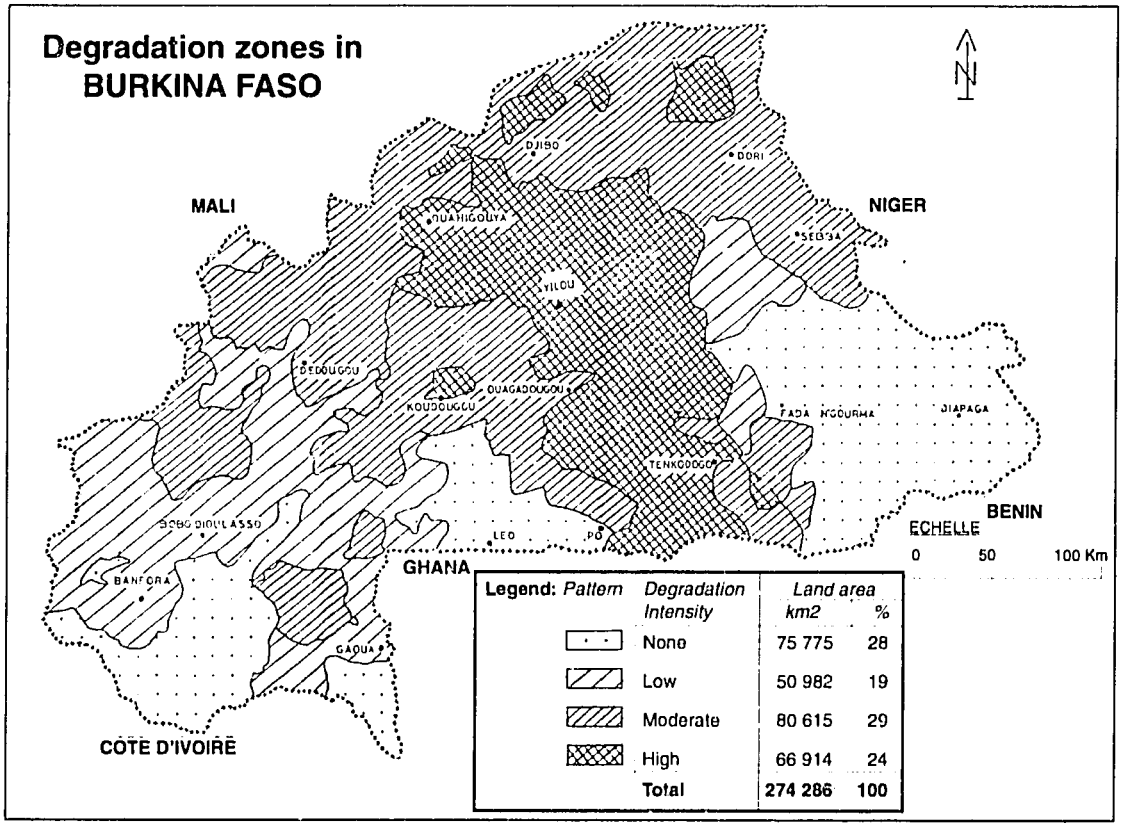


Figure 1.

Years of farming without adequately protecting land from intense rainfall and runoff have resulted in formation of extremely dense, bare surfaces capped by a one-to-two-cm-thick crust. These areas are known locally as zi-pelé, or literally "white places". A number of soil

reclamation practices have been successfully applied by farmers to these sites. Three of the most successful practices are:

- Rock bunds placed on the contour to slow runoff and encourage sedimentation
- Mulching with grass or crop residues to protect the soil surface from raindrop impact, encourages termite activity and porosity, reduces evaporation, and adds some organic matter
- *Zaï*, which are small holes that are filled with manure or compost, and then seeded with a cereal

Usually, a single practice is applied to a given land area, or rock bunds are combined with one of the other practices. Our objectives were:

- To begin to describe the mechanisms, rate, and extent of soil reclamation effects above and just below the first rock bund in a watershed

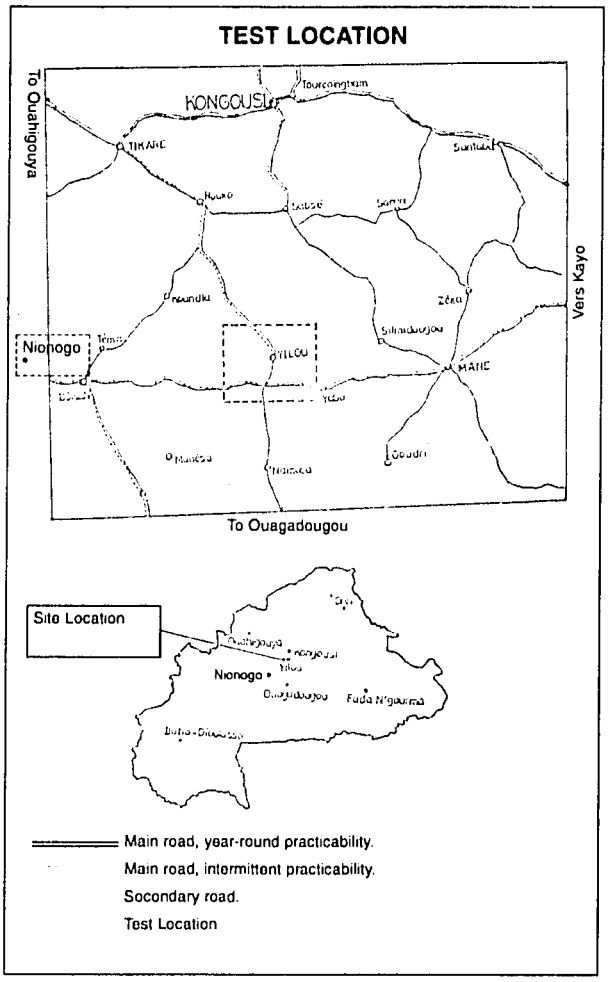
- To evaluate the impact of mulching and *zaï*, alone and in combination, on soil surface condition and millet production

II. METHODS

The sites chosen were *zi-pelé* (2% slope) at Yilou and Nioniogo (Figure 2), where highly variable annual rainfall averages about 600 mm (Figure 3). In general, the soil was approximately 30 cm of very compact sandy loam over a laterite pan. A (laterite) rock bund of about 30 cm height and 100 m length (Figure 4) was constructed on the contour, and an area (downhill) was fenced off for cultivation, since *zi-pelé* receive a great deal of domestic animal traffic during the growing season. The following soil management treatments were applied during the 1991 to 1993 seasons at Yilou in three randomized complete blocks (RBCD's), and in 1993 in 4 RBCD's at Nioniogo inside the fenced areas (Yilou site shown in Figure 4):

* Direct sowing into the bare soil
* Grass mulching before sowing
* *Zaï* dug on an 80 cm x 80 cm square grid (*zaï* in lines), then grass mulching
* *Zaï* dug on an 80 cm x 80 cm square grid
* *Zaï* at a similar density, but scattered irregularly

On each plot at Yilou, the same treatment was applied in each of the three years. Millet stover from each plot was harvested, stored, and reapplied to the same plot just before the next season. The millet variety IKMV-8201 was planted each year. All plots received 100 kg/ha of 14-23-14-6-2 (N-P-K-S-B) at planting and 100 kg/ha of urea (46-0-0), for a total of 60-23-14-6-2. Weeds were hand-pulled before they competed with the crop during 1991 and 1992 at Yilou and in 1993 at Nioniogo. Weed pressure at Yilou in 1993 required a weeding with a hand hoe. Soil surface condition and sedimentation were observed in the plots after the 1992 season at Yilou, as was millet growth and yield in all years at Yilou and in 1993 at Nioniogo.



SOURCE: IGN, 1959, TOPOGRAPHIC MAP OF WEST AFRICA, 1/500,000

Figure 2.

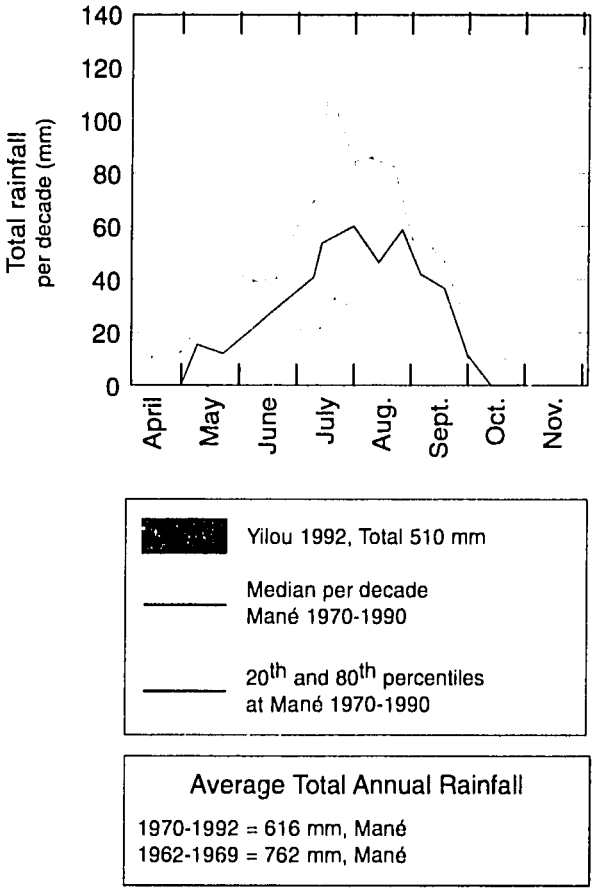


Figure 3.

After the 1992 season, we described the sedimentation and micro-profiles in 5 shallow soil pits on a 30-m transect above the two-year-old rock bund at Yilou (Figure 4).

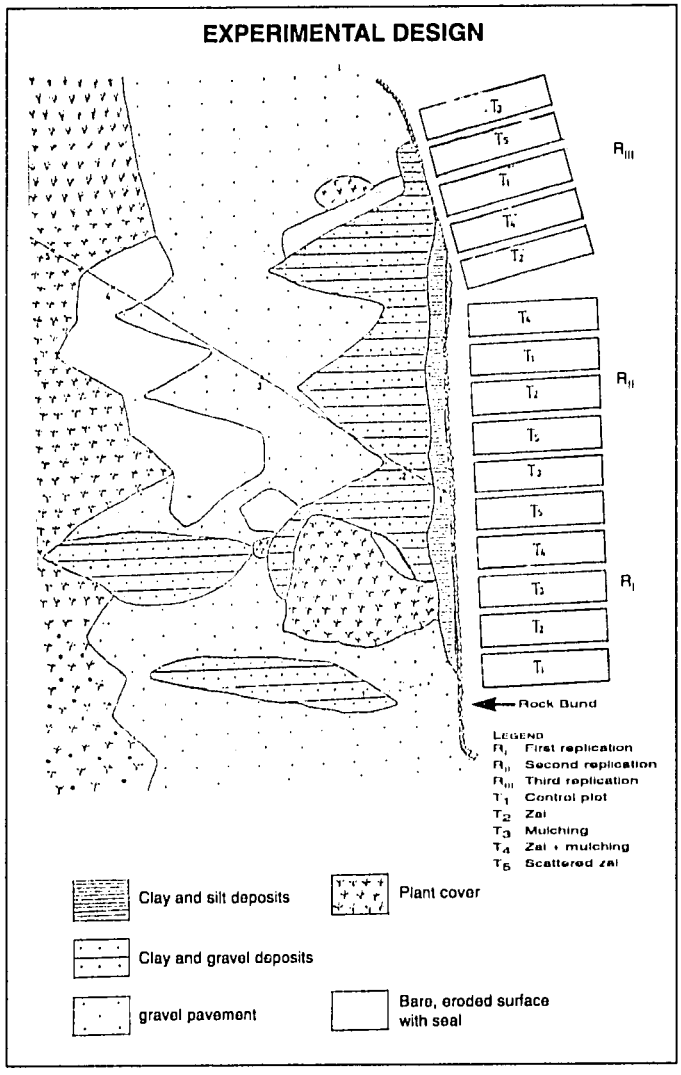
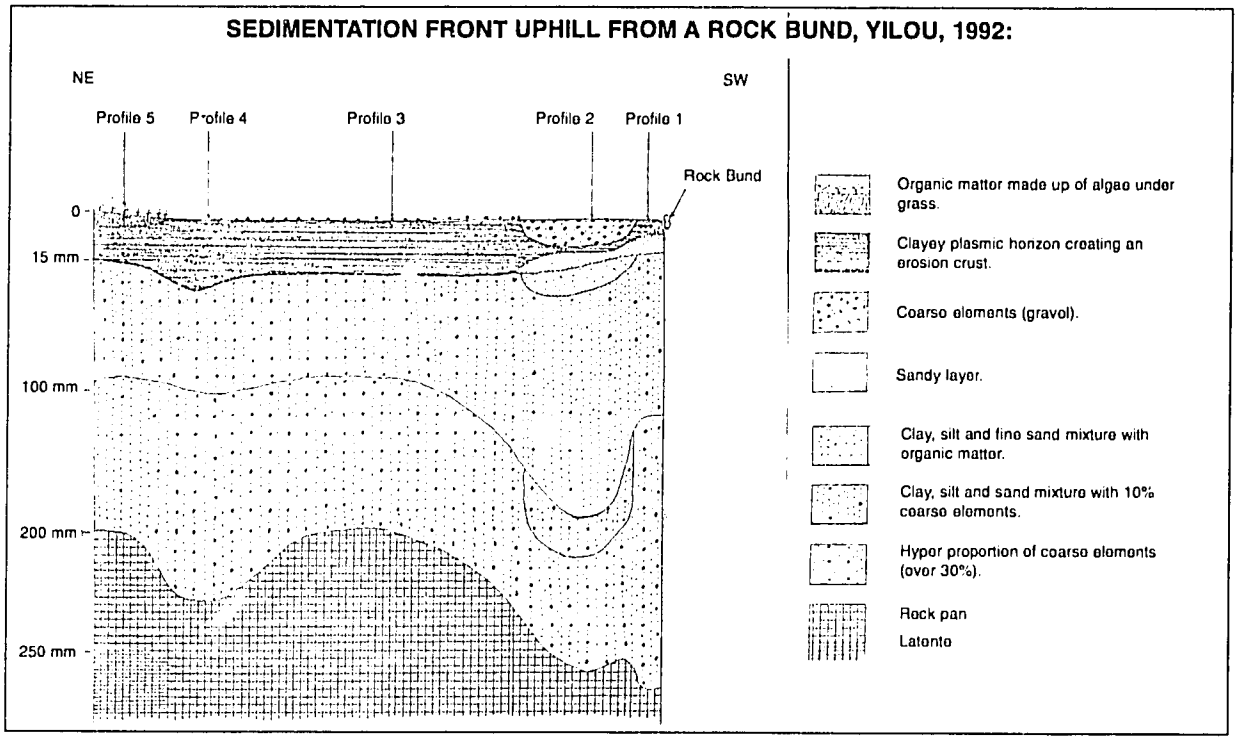


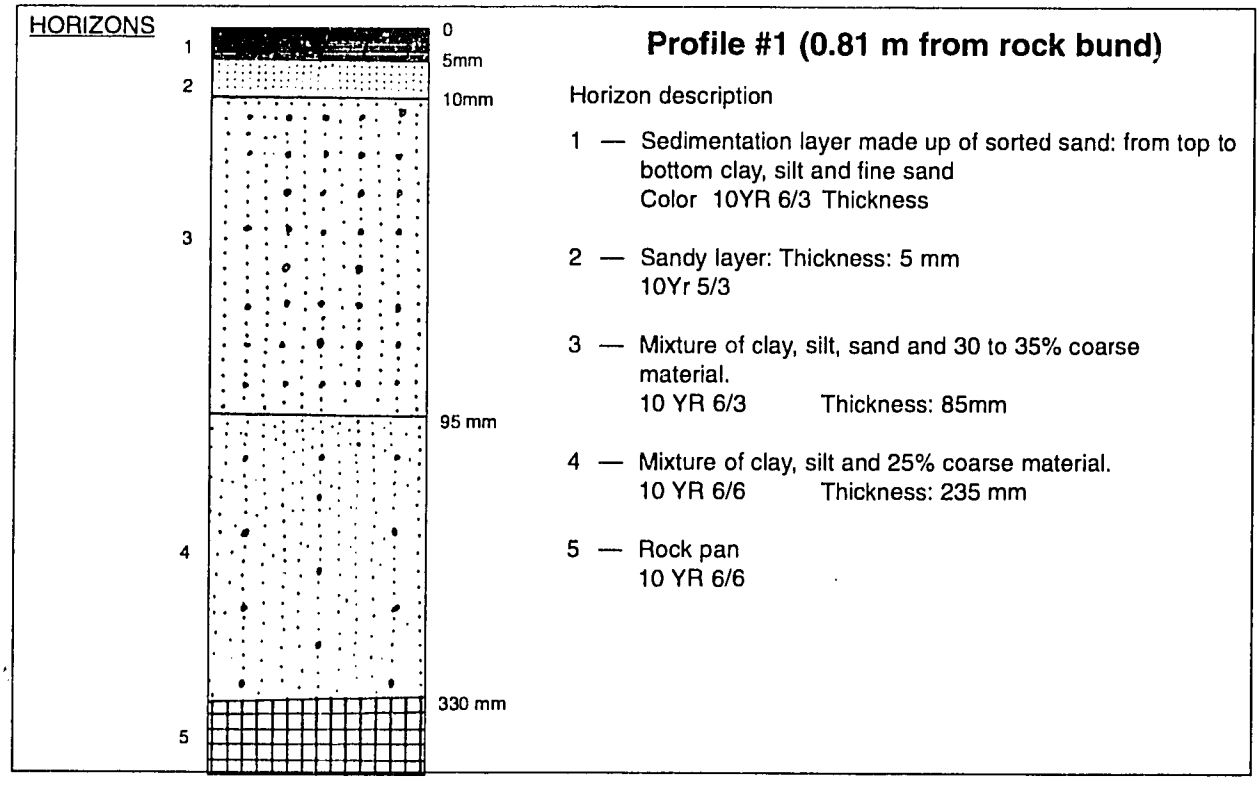
Figure 4.

III. RESULTS AND DISCUSSION

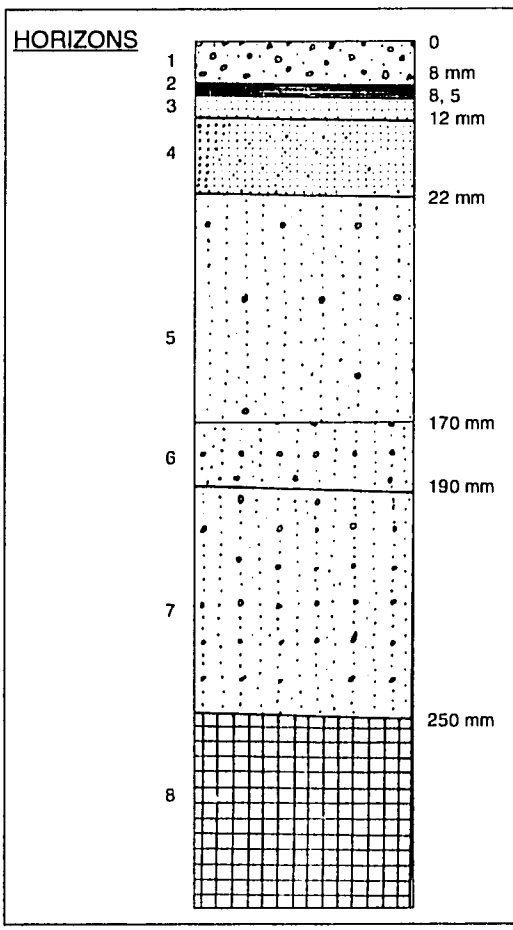
The pattern of sedimentation uphill from the rock bund at Yilou was approximately as follows (Figure 5):



- Profile 1 (0.81 m from bund): Several mm of clay underlain by layers of silt and fine sand to 5 mm, fine and medium sand layers to 10 mm. Underlain by gravelly sandy loam. (Figure 6).



- Profile 2 (6.2 m from bund): Laterite pea gravel to 8 mm, underlain by a 0.5-mm clay deposit, another 4 mm of fine sand, and 10 mm of sandy loam with significant organic matter, for a total depth of 22 mm. This underlain by gravelly sandy loam (Figure 7).



Profile #2 (6.2 m from rock bund)

Horizon description

1 — Coarse gravelly material
8mm

2 — Plasmic film of clayey texture.
Color: 10 YR 7/3 size: 0.5 mm

3 — Fine sand on sorted material.
10 YR 5/3 size: 3.5 mm

4 — Mixture of silt and fine sand with high organic matter content.
10 YR 6/2 Size: 10mm

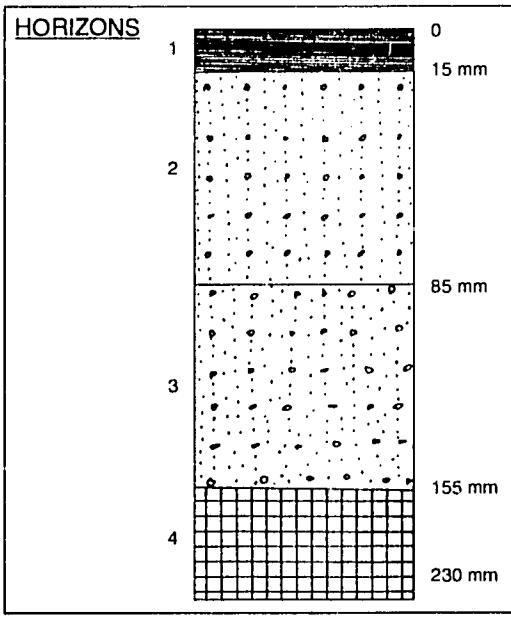
5 — Mixture of fine (clay, silt and fine sand) and less than 10% of coarse elements
10 YR 6/3 Size 168 mm

6 — Coarser elements than in 5. Transition zone with change of color
10 YR 6/6

7 — Higher (35 to 40%) proportion of coarser elements.
10 YR 6/4 Size: 60 mm

8 — Rock pan
10 YR 6/6

- Profile 3 (27.7 m from bund): Pea gravel scattered thinly on top of 15 mm of massive, sandy loam, the surface sealed in a crust of very low porosity. This over gravelly loam (Figure 8).



Profile #3 (27.67 m from rock bund)

Horizon description

1 — Highly compacted clayey layer (Thickness = 15mm). Erosion crust preventing all infiltration. Plasmic horizon. Presence of roots of 10 YR 5/8 color
Horizon color = 10 YR 6/2

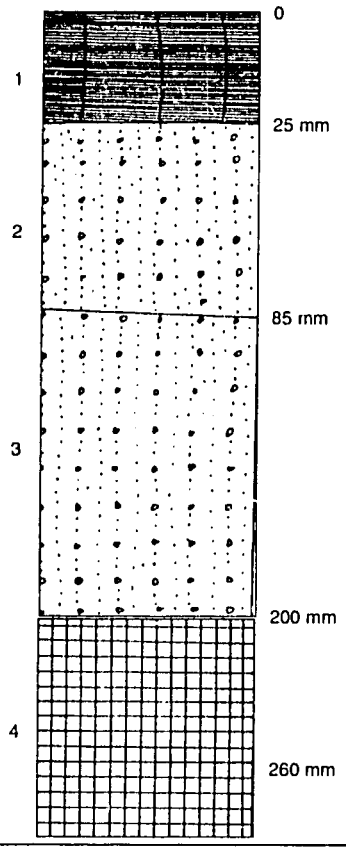
2 — Thickness = 70 mm. Over 60% coarse material. Clay silty cement with organic matter. Grey color = 10Yr 6/3

3 — Thickness = 70 mm. Over 40% coarse material. Clay-sandy cement with organic matter. 10 YR 7/6

4 — Rock pan with ferruginous modules. Thickness = 75 mm
10 YR 7/8

- Profile 4 (40.8 m from bund): Massive sandy loam to 25 cm, the eroded surface sealed. This overlaying gravelly sandy loam (Figure 9).

HORIZONS



Profile #4 (40.81m from rock bund)

Horizon description

1 — Highly compact clayey layer forming an erosion crust preventing all infiltration. Plasmic horizon. Thickness - 25 mm
Color 10YR 5/2

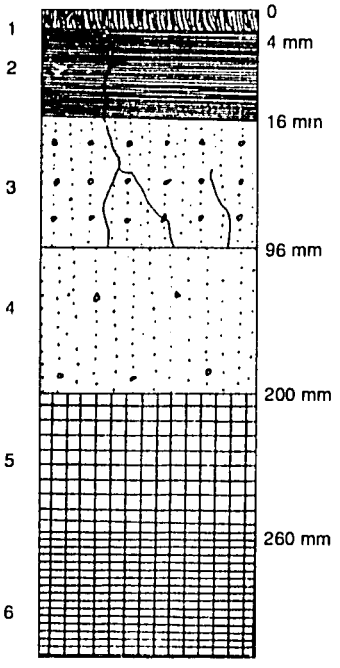
2 — Thickness = 60 mm. Over 60% coarse material. Clay-silty cement with organic matter. Grey color 10 YR 6/5

3 — Over 40% coarse material. Clay-silty cement. Thickness = 115 mm
10 YR 6/4

4 — Rock pan Thickness = 60 mm 10 YR 7/6

- Profile 5 (50.8 m from bund, beginning to leave the *zi-pelé*): Surface layer (4 mm) of organic material, including algae under a layer of low, dead vegetation. This underlain by 12

HORIZONS



Profile #5 (50.81 m from rock bund)

Horizon descriptions

1 — 4 mm - thick micro-horizon. Organic matter made up of algae
Color 10YR 4/2

2 -- Clayey plasmic horizon - Thickness = 12 mm 10Yr 5/3

3 — Mixture of clay, silt, sand and 30 to 40% gravel. Thickness = 80 mm Roots 10YR 6/3

4 — Thickness 104 mm. Horizon layer is darker than horizon 3 and lighter than horizon 4. 5% small gravel. Kaolimitc clay of 1/1 type
10 YR 4/3

5 — Rock pan. 40% or more small gravel
10 YR 7/6

6 — Horizon harder than horizon 5. Laterite.

mm of clay loam. Gravelly sandy loam begins again at 16 mm. First presence of plant tops or roots in transect (Figure 10).

Most of the deposits that can benefit plant life are within a few meters of the bund. This zone gradually gives way to the sealed, massive, eroded surface that characterizes the zi-pelé, which in turn gives way to surfaces covered with some topsoil at the top of the zi-pelé.

Below the rock bund, the erosive force of the water is reduced, but the surface conditions created by the soil and water conservation treatments in the trial influence surface characteristics and how much of this water actually infiltrates. The surface soil conditions in the 5 treatments can be summarized as follows:

- Direct sowing: Massive, sealed, eroded surface remains, some gravel deposit on surface.

- Grass mulch: Surface protection by the mulch and termite activity under the mulch allowed rehabilitation of porosity in the surface layer, and there were several mm of deposition of clay to fine sand.

- *Zaï* with grass mulch: Conditions between the *zaï* much as above, but surface local to *zaï* had higher porosity and reduced crust formation, and of course higher organic matter.

- *Zaï* in lines: Surface local to *zaï* had higher porosity and reduced crust formation, but this effect was less than where *zaï* were combined with mulch. Areas between lines of *zaï* eroded, massive, sealed.

- Scattered *zaï*: Much as above, but scattered *zaï* seem to slow surface flow enough to increase deposition and reduce crusting of surfaces between *zaï*.

Only rainfall data for 1992 at Yilou is available. Total annual rainfall in 1992 (510 mm) was well below the post-1969 average of 616 mm (Figure 3). Dry conditions were primarily at the beginning of the season, when rains began some weeks late, and during two dry mid-season decades, one in mid-July and one in mid-August. Such conditions provide an opportunity to evaluate the ability of soil and water conservation measures to reduce crop drought stress.

Yield and harvest index means and mean comparisons for individual site/years and for all 4 site/years grouped together are presented in Table 1. In general, all treatments but direct sowing allowed for locally acceptable levels of cereal production on this otherwise baren land. The various levels of grain and stover productivity indicate the rate of site reclamation for crop production under the various practices. Table 1 also presents F values and probability levels for comparisons among groups of treatments. The nature of these comparisons is illustrated in Table 2 for the example of grain yield in the combined analysis. In the example, an F value of 80.8 is associated with a probability level of less than 0.001 for the comparison of direct sowing with all other treatments taken together, suggesting a clear difference between grain yield under direct sowing and under the other treatments. The only other comparison that is significant for that analysis was between aligned and nonaligned *zaï* (F=6.8, P=0.03).

Table 1. Yield and harvest index means and mean comparisons for individual and grouped site/years.

	Grain yield (kg/ha)					Stover yield (kg/ha)					Plant height				
	Yilou			Nion iogo	Tous	Yilou			Nion iogo	Tous	Yilou			Nion iogo	Tous
Treatment	1991	1992	1993	1993	Avg.	1991	1992	1993	1993	avg.	1991	1992	1993	1993	Avg.
Dirct vs. others	0	161	253	49	111	0	539	777	83	329	0	123	*	36	51
Mulching	0	1334	829	37	614	73	2038	1553	247	921	0	200	*	124	110
Zaï & mulching	118	1553	680	232	449	1142	2084	914	1345	1369	137	202	*	165	168
Zaï lines	86	722	876	195	510	987	1170	1453	1492	1292	130	189	*	174	165
Zaï not scattered	121	1084	1109	146	579	1854	2358	2328	2029	2133	139	192	*	153	160
Average	65	971	749	132	453	811	1638	1638	1039	1209	81	181	*	130	131
Comparison	F value														
Direct vs. others	14.5	65.9	27.0	12.1	80.8	71.3	41.5	21.6	14.4	70.9	306.3	31.9	56.7	59.1	113.7
Mulching vs. any zaï	5.0	15.5	0.2	25.3	0.1	1.9	1.1	0.0	17.8	8.0	62.0	0.4	0.0	6.4	58.9
Zaï+ mulching vs. zaï	19.6	10.0	5.7	3.5	2.9	105.0	1.4	27.9	1.4	5.1	448.5	0.5	38.9	0.0	0.6
Zaï lines vs. . scattered zaï	1.7	5.3	2.4	1.7	6.8	32.6	19.4	16.8	1.8	37.8	1.6	0.0	24.1	1.2	0.3
Probability of an orthogonal comparison															
Direct vs. others	0.005	<.001	<.001	0.005	<.001	<.001	<.001	0.002	0.003	<.001	<.001	<.001	<.001	<.001	<.001
Mulching vs. any zaï	0.06	0.004	0.6	<.001	0.8	0.2	0.3	0.95	0.001	0.02	<.001	0.6	0.98	0.03	<.001
Zaï+ mulching vs. zaï	0.002	0.001	0.04	0.009	0.13	<.001	0.3	<.001	0.3	0.05	<.001	0.5	<.001	0.9	0.5
Zaï lines vs. scatterd zaï	0.2	0.05	0.2	0.2	0.03	<.001	0.002	0.003	0.2	<.001	0.2	0.9	0.001	0.3	0.6

Table 2. F Probability of an orthogonal comparison

Treatments	Direct sowing	Mulching	*Zaï*+ mulching	*Zaï* in lines	Scattered *Zaï*
All years and sites Grain Yield					
Direct Sowing	⇄			<.001	
Mulching	←	→		0.8	
Zaï+mulching	←		→	0.13	
Zaï in lines	←			→	0.03

The following observations can be made:

- During 1991 at Yilou and 1993 at Nioniogo, none of the treatments produced much grain, however stover production was mostly between 1000 and 2000 kg/ha for all treatments that included *zaï*, and less than 300 kg/ha for other treatments.

- In 1992 and 1993 at Yilou, all treatments except direct sowing produced average grain yields greater than 600 kg/ha. All of the treatments except direct sowing, therefore, can provide acceptable levels of crop production under the rainfall and fertility conditions of this experiment, but mulch alone cannot do so during the first year of reclamation.

- Direct sowing means were the lowest in every analysis (except for grain yield of the mulch-only treatment at Nioniogo), and is not suitable for soil reclamation, even below a rock bund with adequate chemical fertilizer.

- Considering the grain and stover yields (stover is also of value for fuel, construction, and basketry in Burkina), and the possibility to have at least some grain the first year, (100-kg/ha grain yields are not uncommon in the region), the treatments with *zaï* offer some advantage during early reclamation. If no fertilizer had been added (often the case in farmers' fields), the relative fertility contribution of the *zaï* would probably have been more pronounced.

- The combination of grass mulch with *zaï* gave the highest average grain yield (1550 kg/ha in 1992), a truly astonishing level of productivity on this type of land by local standards. In a drier year, the potential for superior water conservation by this practice (relative to *zaï* without mulch) might produce greater differences, making it a possible risk-reduction farming strategy. This advantage is not sustained in all conditions as reclamation progresses, and did not hold at Yilou in 1993.

- There appears to be some merit in scattering *zaï* as opposed to putting them in lines (all three years at Yilou, not at Nioniogo), probably due to the elimination of wide, unobstructed inter-row spaces for surface water flow.

IV. CONCLUSIONS

The evolution of the soil surface above the bund included (1) deposition of several alternating layers of fine and coarse materials near the bund, (2) deposition of coarse materials, including gravels further away from the bund, and (3) formation of a surface seal on compact, eroded surfaces farther from the bund. In general, a significant increase in porosity of the surface layer was observed where significant sedimentation occurred, and the soil was beginning to support plant life again. Below the bund, *zaï* augmented soil porosity and reduced crusting locally. Mulching encouraged termite activity, having the same type of effect as *zaï*, but to a lesser degree and over the whole soil surface. Scattered *zaï* increased sedimentation between *zaï*. Millet production was between 0 and 250 kg/ha the first year in all treatments. In the second and third years of reclamation, yield relationships among reclamation practices varied, but all reclamation practices retained a clear advantage over direct sowing. Maximum average annual treatment grain yield was 1550 kg/ha.

Characterization of the Soil-Plant System in Bush Fields in the Tropical North Sudanian Region of Burkina Faso

S. J.-B. Taonda, J. Dickey, P. Sédogo, and K. Sanon

I. INTRODUCTION

The economy of Sahelian countries is mostly based on traditional subsistence agriculture. There are two kinds of fields in the land management system of Burkina Faso, namely village and bush fields. Local organic inputs such as crop residues, animal droppings, household refuse or compost are applied on village fields which are located next to the residential areas. In rare cases, exogenous inputs such as mineral fertilizer are used there. More and more frequently, fields are protected from erosion caused by very intense rainfall events by erosion control practices. Production in village fields represents a minor part (10%) of total production.

Remaining crop production comes from bush fields. However, extensive agriculture based on nutrient mining is practiced. Fallowing used to be the only form of soil fertility restoration. In most Sahelian countries, demographic pressure has resulted in the reduction or elimination of fallow periods. In the absence of viable systems of fertility restoration, this land management trend has been accompanied by soil degradation.

Burkina Faso's lands are a part of this crisis, which is particularly acute on the Central Plateau, where 2 to 20% of the population (depending on the region) has permanently emigrated during the last decade (INSD, 1985). Emigration is directed toward neighboring coastal countries and especially toward southern and southwestern Burkina Faso. Migrants preferentially settle in less populated or newly settled zones where land is available and soils are fertile (Milleville, 1988).

In frontier zones, the intensive and extensive land management systems (of village and bush fields from the Central Plateau respectively) are replicated. Lack of means precludes viable application of intensive management of bush fields. The fundamental question to be addressed is the following: How can production be sustained while maintaining or improving land and soil resources? This question can only be answered by taking into account the socio-economic, biological, physical, and chemical dimensions of the dynamics of the soil degradation process.

Authors such as Nye and Greenland (1960), Charreau (1972), Siband (1972) and Pichot (1974) have studied changes in soil physical and chemical properties of cultivated and fallowed fields in research station and farm environments. This study focuses on on-farm soil degradation in a frontier zone of Burkina Faso's southern Central Plateau.

Hypotheses which underlie the study are the following:

- A frontier zone presents the opportunity to analyze changes in soil physical and chemical properties at various stages of field evolution, whereas this process has run its course on degraded lands, or has not yet begun on untouched natural lands.

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- Diverse agricultural practices, which will induce different types of field evolution, may coexist in a frontier zone.

In order to control variability in the study, only bush fields cultivated with animal traction were selected. Most farmers in frontier areas use animal traction. Furthermore, intensification of production, which is becoming more pronounced, must rely on animal traction because labor availability is limited. Some farmers in the studied village cultivate by hand.

The objective of the first part of this study, which is discussed in this paper, is to characterize soil physical and chemical property changes during the years after clearing of cultivated soils on farms in semi-arid zone (700 to 900 mm of rainfall).

II. MATERIALS AND METHODS

Chemical and physical properties of soil were studied on a soil chronosequence.

The Soil "Chronosequence". Thiougou, a frontier village in the Southern part of the Central Plateau was selected. It is located between 11°29' and 11°24' north latitude and 0°49' and 0°54' west longitude. A study of village soils was carried out and a physiographic map of the village was drawn.

Among the village's soils, modal leached tropical ferruginous soils (sols ferrugineux tropicaux lessivés modaux, probably Paleustalfs after U.S.D.A., 1975) were selected for this study due to their dominance of Thiougou's land area. Moreover, they are the most widely cultivated soils in the village and the surrounding region. A map of all village fields and fallows was developed, from which fields belonging to this soil mapping unit could be listed. These fields were grouped according to duration of cultivation, including fields of ages 0 (fallow), 1 (new field), 2, 4, 5, 7, 9 and 17 years. Several studies were undertaken on this chronosequence, including: x A study of soil physical and chemical properties on eleven farmer fields described in this paper x A study of soil productivity on 30 plots which will be reported elsewhere (Taonda et al., 1995).

Measurement Methods for Physical Properties. Bulk density was measured on undisturbed soil cores. Textural separates were measured by the Robinson pipet method and texture was characterized according to the textural triangle. Moisture content at various pF levels was measured by weight after equilibration on a membrane press. These samples had been sieved to less than 2 mm diameter and repacked into cylinders. Field moisture content was based on auger sampling and oven-drying at 105°C.

Roughness of the soil surface was measured using the Guillobez method (1991). In this method, a one-meter-long frame containing a series of moveable, straight vertical rods which can be freed to match the irregularities of the terrain is levelled above the highest ground surface along its length. The standard deviation of prodruding rod lengths as measured from the base of the frame provides an index of soil surface roughness. Measurements were replicated at three locations per observation date and in each plot. The first observations were taken

immediately after ridging and subsequently after each rainfall event. Runoff was measured from 1 m^2 plots bordered by vertical tin sheets. Water from the runoff plots was channeled through a plastic pipe into an open barrel. Water depth in the barrel was measured after every rainfall event and runoff depth was calculated. Rainfall amount was measured in rain gauges adjacent to each plot. Runoff water depth was calculated as follows:

(Volume in barrel - Volume of rainfall directly into barrel)/1m^2

Measurement Methods for Chemical Properties. Soil pH (in water and 1N KCl) was measured with a glass electrode in a 1:2.5 (by weight) suspension of soil and solution. The pH-meter has glass electrodes. Total carbon was obtained by the Walkley-Black method (Walkley and Black, 1934). Nitrogen was measured by the Kjeldahl method (Jackson, 1958). Total phosphorus was determined after Olsen and Dean (1965). Available P was obtained by the Bray I method (Dickman and Bray, 1941). Exchangeable bases and CEC were measured using the IITA Playsier (1978) method, in which exchangeable cations are displaced from exchange sites with a silver thioure (AgTu) solution. AgTu provides total soil saturation due to its preferential adsorbtion. Silver content in the extract is determined. The amount of silver retained in the soil, which indicates CEC, is deduced through comparison with a standard soil sample.

III. RESULTS

The Evolution of Soil Physical Properties. Table 1 shows that surface horizons in almost all plots were of sandy-loam texture according to the USDA classification. Plots of ages 0 and 17 years were of loam to sandy loam texture. Bulk density was intermediate in surface horizons, increasing with depth on all plots.

The decrease in soil surface roughness is the difference between roughness after ridging before planting and roughness at the end of the season. This difference increased exponentially and reached a plateau of 15% reduction at around 7 years of field age (Figure 1).

Figure 2 shows that for plots of ages 0 and 17 years, the greater the rainfall event, the greater the depth of runoff from the plot. This figure also illustrates that the difference in runoff depth between old and young plots was large for large events. However, old and young fields lost a relatively similar water volume during small storms. The slopes of the first order polynomials relating runoff water depth to the size of rainfall event, shown in Figure 2, was positively related to field age when considered for all of the fields in the study (Figure 3). The slopes approached a constant value of 0.6 at a field age of 9 years.

Table 1. Physical and chemical soil properties of the chronosequence in Thiougou

Age (years)	Depth (cm)	Silt to 20 (%)	Silt 20 to 50 (%)	Sand 50 to 250 (%)	Sand 250 to 2mm (%)	N (No.)	Texture (USDA)	Sand (%)	Silt 950	Clay 950	ND.A. (No.)	D.A. (g/ml)	Moisture at PF 2.5 (%)	Moisture at PF 2.5 (%)	Moisture at PF 4.2 (%)	Available moisture (%)
0	0-20	7	32	14	37	1	L	51	39	10	6	1.56	11.1	6.9	3.9	7.2
	20-40	7	28	13	41	1	LS	55	35	11	6	1.55	10.2	7.4	3.9	6.3
	40-60	*	*	*	*	0	*	*	*	*	5	1.60	*	*	*	*
1	0-20	8	29	16	38	2	LS	53	37	10	3	1.50	12.1	7.0	4.1	8.0
	20-40	7	28	16	38	2	LS	54	35	11	3	1.53	11.2	6.8	3.9	7.3
	40-60	9	24	12	37	1	LS	49	34	17	3	1.60	14.9	18.0	6.4	8.5
2	0-20	7	27	19	40	2	L	59	34	7	3	1.44	10.3	4.8	2.6	7.7
	20-40	8	25	17	40	2	LS	58	33	9	3	1.45	10.0	5.6	3.4	6.6
	40-60	8	23	15	390	2	LS	54	31	15	3	1.57	13.4	7.9	5.4	8.0
4	0-20	9	27	18	39	1	LS	57	36	7	3	1.47	9.9	5.7	3.3	6.6
	20-40	8	25	16	42	1	LS	58	34	9	3	1.57	11.5	5.8	3.2	8.3
	40-60	11	23	13	44	1	LS	57	34	9	0	*	11.7	5.2	3.1	8.6
5	0-20	7	27	19	39	3	LS	58	34	7	3	1.53	11.8	5.4	3.1	14.5
	20-40	8	26	15	41	3	LS	57	34	9	3	1.58	11.3	6.7	3.7	13.8
	40-60	9	23	12	38	3	L	50	32	17	0	*	14.4	8.8	5.7	14.1
7	0-20	10	27	16	39	1	LS	55	37	8	3	1.57	10.5	6.4	4.0	6.5
	20-40	9	25	14	41	1	LS	55	34	11	3	1.67	11.3	6.5	3.9	7.4
	40-60	9	20	10	39	1	L	49	29	23	0	*	16.1	10.7	6.9	9.2
9	0-20	8	21	18	46	1	LS	63	29	8	3	1.50	9.0	5.5	2.7	6.3
	20-40	9	20	16	45	LS	61	28	11	3	1.56	11.1	7.7	5.3	5.8	
	40-60	9	18	10	38	LAS	48	27	25	3	1.61	18.3	14.6	9.2	9.1	
17	0-20	8	32	20	31	1	L	51	40	9	3	1.56	9.9	6.2	3.3	32.5
	20-40	11	29	17	31	1	L	48	40	13	3	1.56	13.9	7.6	4.6	28.6
	40-60	12	25	15	30	1	L	45	37	18	3	1.65	14.9	9.1	6.5	8.5

Table 1 (Cont.)

Age (years)	Depth (cm)	pH water p(molar)	pH KCl p(molar)	Org. M. (%)	C.O. (%)	N total (%)	C/N (-)	P total (mg/kg)	P avail. (mg/kg)	Ca (meq/100g)	Mg (meq/100g)	K (meq/100g)	Na (meq/100g)	Bases (meq/100g)	CEC (meq/100g)	Sat. Base (%)	Pse (%)
0	0-20	6.7	6.3	1.09	0.63	0.37	17	49	3.0	2.03	0.49	0.15	*	2.67	3.73	72	*
	20-40	5.7	4.8	0.50	0.29	0.17	17	40	0.9	0.68	0.26	0.02	*	0.96	1.71	56	*
	40-60	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1	0-20	6.3	6.1	0.80	0.47	0.41	13	60	2.4	1.98	0.52	0.16	0.07	2.77	3.98	66	1
	20-40	5.4	4.9	0.42	0.24	0.21	12	54	1.1	0.98	0.27	0.08	0.07	1.36	2.10	64	2
	40-60	4.9	4.7	0.43	0.25	0.21	12	56	0.9	1.46	0.38	0.07	0.07	1.98	2.51	79	3
2	0-20	6.2	5.8	0.56	0.32	0.27	12	75	2.0	1.31	0.33	0.14	0.05	1.83	3.36	54	2
	20-40	5.3	4.6	0.38	0.22	0.16	14	57	1.1	0.92	0.29	0.07	0.04	1.30	3.22	41	1
	40-60	5.2	4.3	0.23	0.16	0.12	13	64	0.8	1.14	0.35	0.10	0.07	1.63	3.52	49	2
4	0-20	5.8	5.8	0.86	0.50	0.15	33	63	0.5	1.80	0.51	0.07	0.04	2.42	3.92	62	1
	20-40	4.9	4.7	0.43	0.25	0.16	15	49	1.4	1.76	0.36	0.02	0.04	2.18	4.89	45	1
	40-60	4.4	4.2	0.22	0.13	0.13	10	64	0.5	0.96	0.30	0.05	0.04	1.34	1.49	90	3
5	0-20	5.7	5.5	0.45	0.26	0.27	10	66	1.5	1.09	0.32	0.09	0.04	1.52	3.46	44	1
	20-40	5.0	4.4	0.40	0.23	0.18	49	67	0.9	1.18	0.36	0.08	0.04	1.63	3.52	48	1
	40-60	4.9	4.4	0.51	0.32	0.17	22	67	0.6	0.91	0.28	0.07	0.05	1.28	3.12	41	2
7	0-20	5.3	5.4	0.64	0.37	0.29	13	60	1.6	1.01	0.39	0.10	0.04	1.53	1.78	86	2
	20-40	4.2	4.1	0.33	0.19	0.17	11	49	0.9	0.98	0.21	0.05	0.10	1.34	2.67	50	4
	40-60	4.0	4.0	0.29	0.17	0.17	10	49	0.3	1.18	0.33	0.07	0.07	1.65	2.92	56	2
9	0-20	6.4	5.7	0.40	0.23	0.22	10	71	1.4	1.27	0.32	0.12	0.07	1.78	3.64	49	2
	20-40	5.7	4.3	0.40	0.23	0.16	15	71	0.9	0.76	0.30	0.12	0.07	1.24	1.78	70	4
	40-60	4.8	3.9	0.62	0.36	0.19	19	85	0.5	0.83	0.19	0.15	0.10	1.27	2.37	54	4
17	0-20	6.4	5.7	0.59	0.34	0.29	12	78	2.3	1.49	0.36	0.15	0.07	2.07	4.28	48	2
	20-40	5.0	5.0	0.40	0.23	0.26	9	64	0.9	1.57	0.45	0.07	0.07	2.14	3.85	55	2
	40-60	6.6	5.1	0.71	0.41	0.16	26	71	0.7	0.95	0.39	0.05	0.04	1.42	3.46	41	1

Figure 4 shows that water infiltration decreased significantly after first cultivation, and total seasonal infiltration was drastically reduced at a field age of 17 years. Soil moisture profiles recorded on several plots during the season (Figure 5) illustrate that surface horizons under fallow were rapidly saturated at the time of the first measurements early in the season. Fields cultivated for a long time, such as the 17-year-old field, only reached saturation toward the end of the season in mid-September. The trend was not clear for fields of intermediate age. Texture and plant extraction differences among fields may account for this.

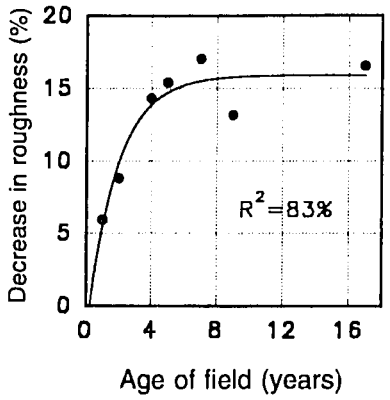

Figure 1. The decrease in soil roughness over the season for fields of various ages.

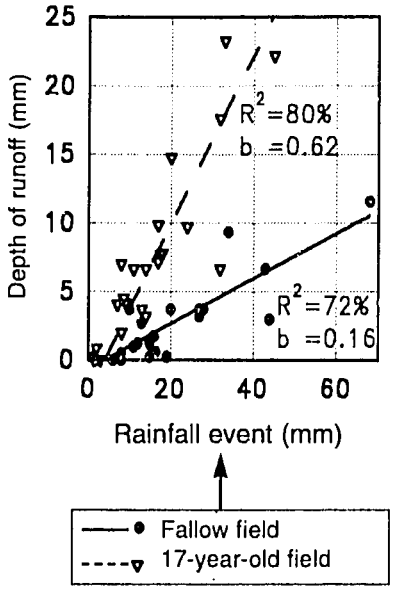

Figure 2. Runoff/rainfall per storm event for fields of ages 0 and 17 years.

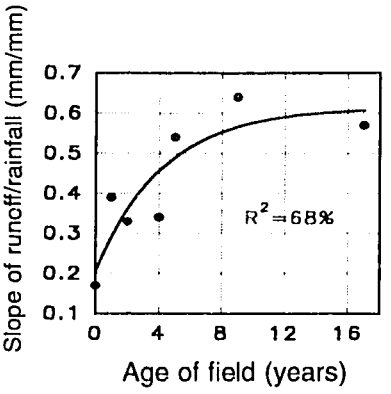

Figure 3. The increase of the slope of the runoff/rainfall curve (see Figure 2) with field age.

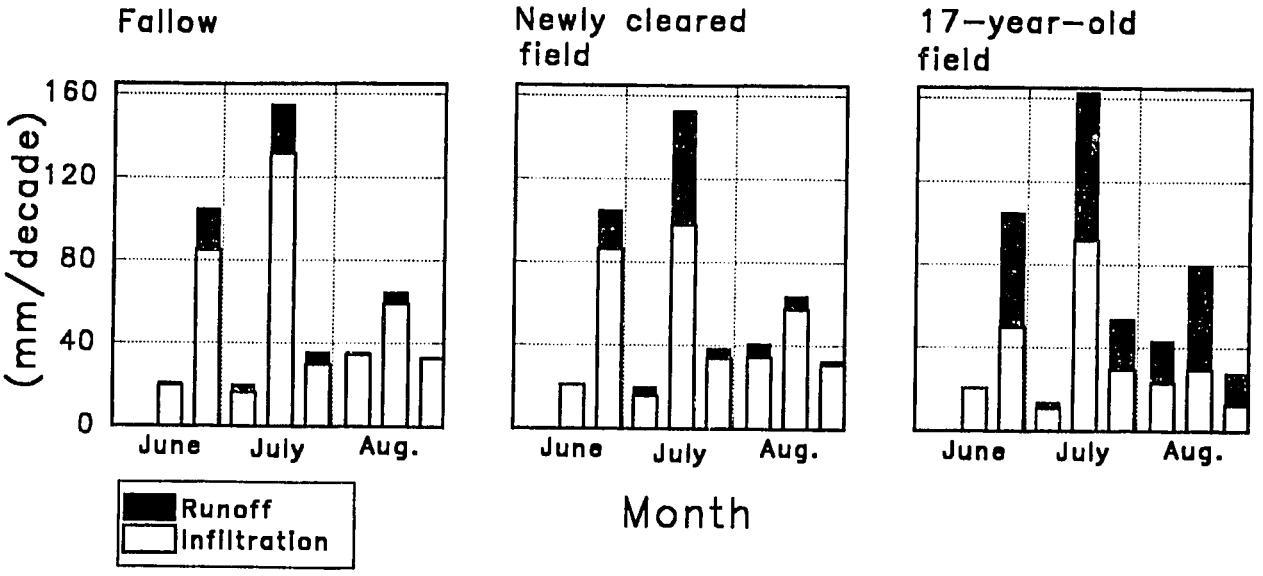

Figure 4. Distribution of infiltration and runoff for fields of 0, 1, 9, and 17 year of age.

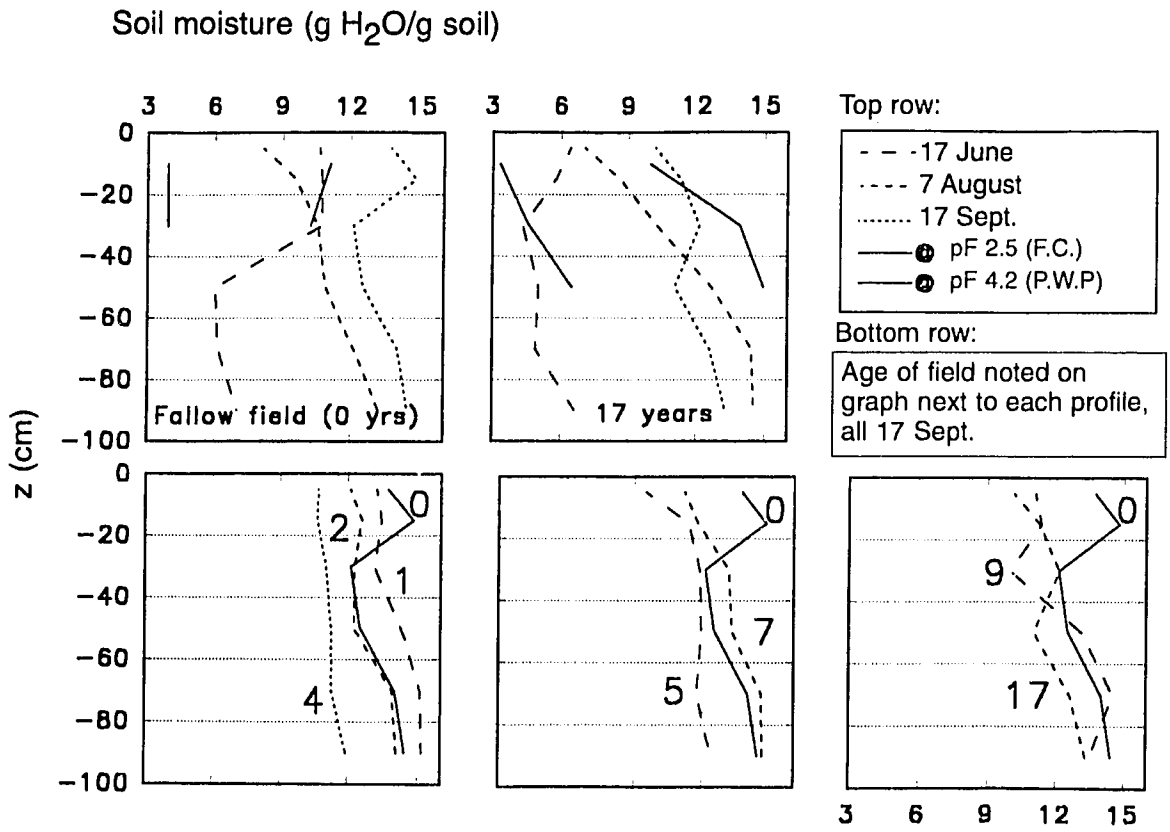

Figure 5. Moisture profiles for fields of various ages.

The Evolution of Soil Chemical Properties. Organic matter in these soils was generally concentrated in the surface soil. Organic matter content was less than 1% in the surface 20 cm in all fields sampled, except in the fallow field (1.09%). Organic matter content declined exponentially (Figure 6), and at 4 to 5 years of age equaled half of the fallow field's level. Later on, the decline in organic matter content slowed and became somewhat constant at about 0.5%.

Table 1 shows that all field ages under study had a low (<1%) N content. Table 1 also shows that the evolution of nitrogen content was similar in shape to that the organic matter (Figure 6), but the exponential model did not explain as much of the observed variability (18% versus 53%). All soils studied were low in total P. No pattern of total P with field age could be detected (Figure 6). In contrast and more significantly for plant nutrition, soils were generally deficient in available P (Figure 6). In the 0-20 cm layer, from a value of 3 mg/kg in fallow, there was a decrease of 50% in the level of available phosphorus after 4 to 5 years of field age (Figure 6). Thus, the trend of available P with field age was also similar to that for organic matter.

Plots can be grouped in two categories regarding pH, CEC, and exchangeable (Ca, Mg, K, total) bases (Table 1). The first group includes fallow (0 years) and newly cleared fields (1 year). In this group, there was a drastic difference between the 0-20 cm layer and the 20-60 cm layers, which matches the pattern for organic matter. The second group contains all the older

fields of the chronosequence. Bases and CEC, on the other hand, were largely similar between the surface and bottom layers.

The ratio Na: CEC (exchangeable sodium percentage) was an average of 3%. Alkalinity is therefore not a problem.

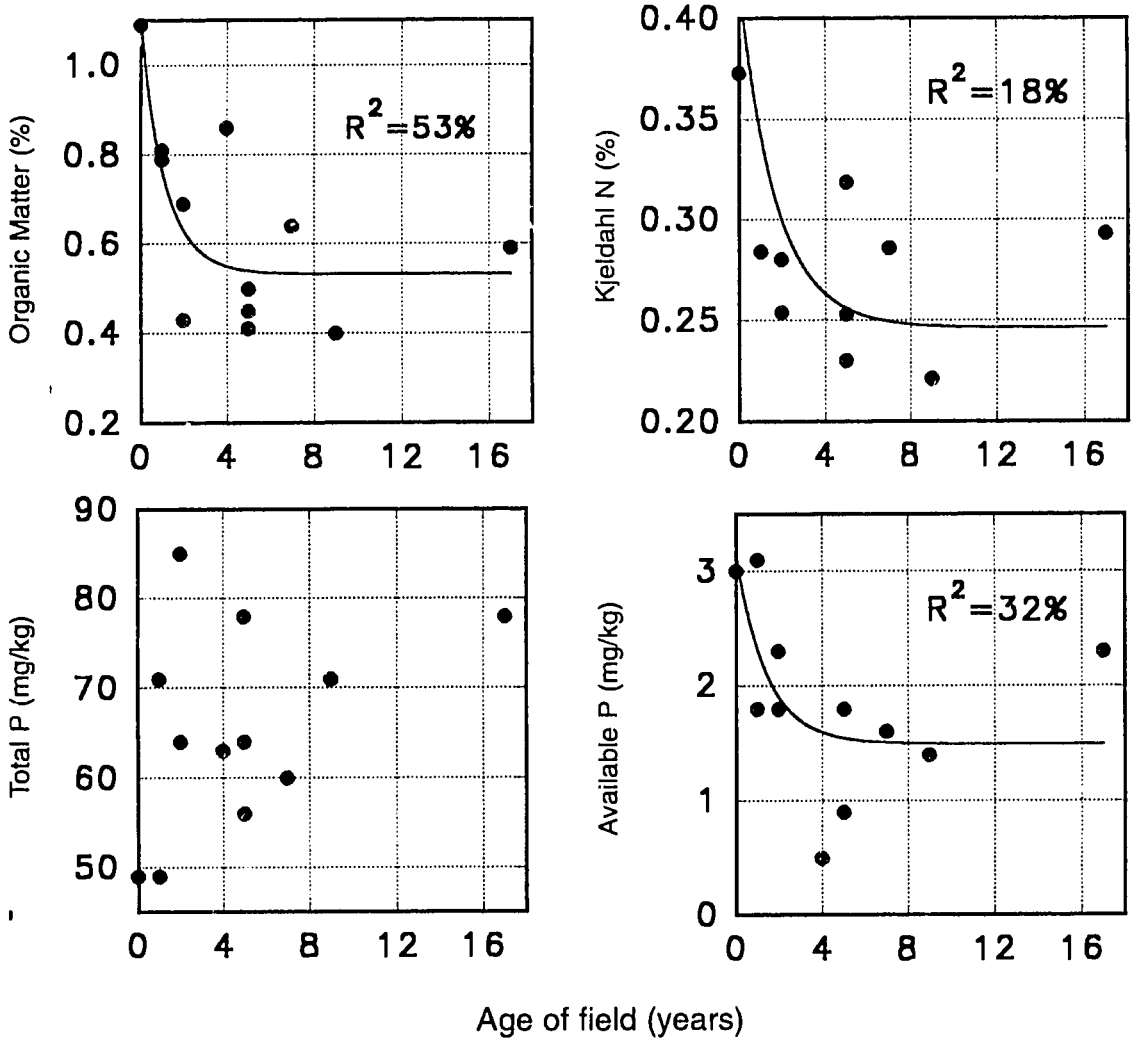

Figure 6. Change in several chemical properties (organic matter, N, K, and available P).

IV. DISCUSSION

The Methodology. Several studies have been undertaken to describe the evolution of soil physical and chemical properties on cultivated, tropical soils. Most were conducted on research stations. Experimental designs were often difficult to execute, complex, multi-annual, and very costly. Unfortunately, this high level of investment did not ensure that conditions and results encountered are those which farmers face. In order to succeed, three challenges had to be addressed in the on-farm research work: environmental variability, study complexity (and

therefore the cost of execution), and duration of the study. In order to reduce environmental variability, a single soil mapping unit (modal leached tropical ferruginous soils) and a single group of cultural practices (farming with animal traction) were considered. In order to minimize design complexity and cost, field devices were designed to consume recycled materials (e.g., old tin sheets, plastic pipes, motor oil barrels). The duration of the study, which would have necessarily been long in order to track individual fields over time, was shortened through the selection of a "chronosequence", or a series of field ages since clearing. Nevertheless, the number of plots was limited by two major constraints. First, researchers had to monitor plot management over a large geographic area Second, observations for a variety of field ages were conducted on the different fields during a single agricultural season, effectively concentrating the workload into this season. Despite these constraints, the data analysis revealed significant trends and results can be compared to those obtained on research stations and those resulting from monitoring of individual plots over time (Nye and Greenland , 1960; Sédogo, 1993). Therefore, this approach is well suited to studies of soil degradation and could be employed in other regions.

The Soils. Based on field observation, the soils became progressively sandier as field age increased. Farmers also call soils on the older fields "bisri", meaning sandy. A textural analysis of the 0-5 cm layer probably would have revealed this increase in the percentage of sand, but was not carried out.

The rapid decline of organic matter is consistent with Hien (1990), who found a 60% decrease of organic matter content after 15 years of continuous cultivation in the more humid cotton-producing zone of Burkina Faso. The rate of mineralization is remarkably fast during the weeks after clearing, when 33% of the organic matter is lost. (Soil samples in the fallow - 0-year-old field were taken at the end of the dry season 10 weeks before sampling of the same and older fields after tillage and planting.) Since part of the fallow was cleared before the first rains to become the one-year-old field, the fallow and the one-year- old field represent a monitoring of the same plot over time. The organic matter in the fallow is rapidly mineralized because of a high level of microbiological activity, which results from the combination of moisture from the first rains, high soil temperatures (averaging 28°C), relatively coarse soil textures, and the use of animal traction to mix and aerate the soil to 8 to 12 cm of depth. This is consistent with Sédogo's (1993) statement that management of sandy soils with no or low organic amendment eliminates the soil's pool of organic matter through mineralization.

Nitrogen levels are comparable to those reported by Sédogo (1989), Sohoro (1992), and Bambara (1993). Table 1 shows that N content in the 0-20 soil layer in the fallow (0-year-old) and new (1-year-old) fields is twice that of the 20-40 cm layer. After two years of cultivation, this ratio declines to about 1. The same observation is valid for the organic matter content, the principal source of N in these soils. Thus, rapid mineralization of organic matter in the 0-20 cm layer after land clearing is concurrent with rapid N loss. This N is either leached, volatilized as ammonia, denitrified, or taken up by crops and weeds. Since N is not typically added in organic or mineral form, this loss continues each year.

The trend for available P is very similar. The ratios of available P in the 0-20 cm layer to available P in the 20-40 cm layer are 3.3, 2.2, 1.7 for the fallow, 1-year-old and 4-year-old

plots respectively (Table 1). The presence and decay of available P in the surface 20 cm is therefore also correlated with organic matter content. After organic matter is mineralized, available P content in surface layers approaches levels of available P in deeper layers, where organic matter, N, and available P are low regardless of field age.

Similar comments can be made for pH, CEC, and exchangeable bases. The high correlation between these factors and organic matter can be explained by the high percentage of CEC on the organic matter in these soils (Jones and Wild, 1975).

Organic matter plays an important role in the soil is structural stability. The relatively high level of organic matter in years 0 and 1, possibly including dead roots and soil flora and fauna, probably stabilizes structure, maintaining a more constant soil roughness. Consequently, the decline in soil roughness over the season for young fields was less significant. On older plots, the degradation of plant and microbial biomass and lower levels of organic matter affect soil structural stability. Any sort of roughness created by tillage cannot withstand substantial raindrop impact. This is why initial soil roughness in fields cultivated for over 4 years decreases by 15% during the agricultural season. The causal relationship between soil roughness and runoff, whereby soil roughness slows water runoff, is well established (Stallings, 1957). Soil roughness also allows for more infiltration of rainwater, which is then available to plants. The rapid smoothing of older fields, therefore, leads to more runoff and less infiltration.

To summarize, the change in organic matter content governs the evolutionary trend of soil chemical and physical characteristics, at least in the 0-20 cm layer. The trend is negative, that is, it corresponds to a rapid decline in fertility of leached tropical soils. In a span of 10 years of cultivation, the land is no longer productive. Beyond this time, cereal production and farmers' livelihoods are jeopardized. Taonda et al. (1995) show that sorghum productivity on these soils, which was 1300 kg/ha on newly cleared plots, declines to 250 kg/ha in 5 to 6 years, amounting to an 80% decrease.

Migrants have settled in the frontier zone in search of land with fertile soil, only to find fragile soils. The vicious cycle of immigration, continuous cultivation, land degradation and emigration repeats itself in the frontier zone. Should this process continue at its current pace, the whole region of the southern part of the Central Plateau may lose much of its agricultural production potential. This would be disastrous, considering the fundamental role this region plays in the nation's food supply. It is therefore imperative to stop or even reverse this degradation.

Any successful soil restoration technology for older fields must include a combination of improved organic matter management and erosion control practices. Indigenous farmers, aware of the potential for degradation, have begun fertilizing village fields with various local organic amendments, such as household refuse, farmyard manure, or compost. In addition, they have constructed several types of erosion control structures in village fields, such as earth dikes, rock bunds, and vegetated strips, the latter being the least costly and perhaps the most suited to the frontier regions. Bush fields, on the other hand, are cultivated without the benefit of either organic amendments or erosion control structures. However, Taonda et al. (1995) showed that the application of a low rate of farmyard manure (2.5 t/ha) on a bush field protected by erosion

control structures increased the productivity of the 17-year- old plot (from this study). It rose from 13% to about 70% of the sorghum productivity (1300 kg/ha) obtained on 1- and 2-year-old plots.

Several constraints restrict restoration of degraded soils. First, individual farmers have to produce a sufficient quantity of organic amendment. This, in turn, requires labor, farm animals, and an integration of livestock and crop production. Second, there are many thousands of hectares of bush fields. The treatment of whole watersheds with erosion control measures cannot be achieved at the level of individual farm families. Therefore, construction of such structures should be handled by whole village communities.

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Economics of Rock Bunds, Mulching and Zaï in the Northern Central Plateau of Burkina Faso, A Preliminary Perspective

D. Kaboré, F. Kambou, J. Dickey, and J. Lowenberg-DeBoer

I. INTRODUCTION

In response to national policy and farmer requests, the Farming Systems Program (RSP) of the Institute of Agricultural Research and Studies (INERA) of Burkina Faso is conducting research on soil conservation and fertility restoration techniques. Soil erosion, compaction, crusting and declining fertility are common problems in the Central Plateau of Burkina Faso. These soil problems are particularly acute at the Donsin RSP site in the province of Namentanga, about 103 km northeast of Ouagadougou (but 230 km by road). Rock bunds, zaï and mulching are being tested. The objective of this report is to provide a preliminary perspective on the cost of implementing these techniques and on yield effects. The data presented here are necessarily incomplete, but it is hoped that they will help guide future research.

Rock bunds (cordons pierreux) are low rock walls that are laid on the contour. The purpose of these bunds is to slow runoff, increase infiltration and reduce soil erosion. Rock bunds are a proven technology and have been constructed in many parts of the central plateau. They are included in this analysis for the benefit of comparison.

Mulching is a traditional soil conservation and fertility restoration technique in the central plateau. During the dry season grass cut from uncultivated lands is spread on crop land that suffers from slow water infiltration and consequently from drought. When rains start, the mulch reduces runoff and helps hold soil moisture. Termites colonize the mulch and soil beneath it, increasing porosity and speeding decomposition. Decomposition of the grass adds to soil fertility.

Zaï is an intensive manure management and water conservation technique. During the dry season a shallow hole is dug for each hill of sorghum or millet that will be planted when rains start. Each hole is partially filed with manure or compost which is less prone to crusting and compaction than soil. The holes trap rain water and reduce runoff. The organic matter helps retain moisture and has a "starter fertilizer" effect on plant growth. Zaï has long been practiced in Yatenga, but is a new technique at Donsin. The primary purpose of this report is to compare the economics of zaï to the better known techniques of building rock bunds and mulching.

The data collection methodology is presented in section 2, a presentation of the data and results in section 3, discussion in section 4 and researchable issues in section 5.

II. METHODS

Primary data was collected in interviews with farmers who use the techniques under study. This interview data was supplemented by information from the Soil Management and Resource

Conservation Project for the Central Plateau (PATECORE), the Soil and Water Conservation and Agroforestry Project (CES/AGF) and Foster Parents Plan (PPI).

The farmer interviews were conducted on Sept. 10 and 11, 1993, at Donsin. The interview team was composed of Daniel Kabore, Economist and Coordinator of the RSP central team, John Dickey, agronomist on the Agricultural Research and Training Support (ARTS) project technical assistance team, Salif Boena, RSP technician at Donsin, and J. Lowenberg–DeBoer, economist and ARTS campus coordinator. The interviews were conducted in Mooré, with translation by Boena into French for the benefit of Lowenberg–DeBoer. The interviews were free form. No questionnaire was used because the initial information was inadequate to formulate appropriate questions.

Three farmers provided most of the information, but 5 other farmers added certain details. These three farmers were chosen because they employ at least two of the practices studied and because they cooperated with RSP at Donsin. In addition to the interview, planting density was measured in the fields of each farmer.

The information from PATECORE was supplied primarily by Robert Delma, head of the Development and Follow--up Unit, in an interview on Sept. 14, 1993, at the headquarters in Kongoussi. Fredéric Kambou, researcher in the INERA fertilization, soil, water and mechanization program (ESFIMA), and Lowenberg–DeBoer participated in this discussion. In addition, PATECORE reports for the years 88 to 92 were consulted. PATECORE is a German financed project. It does not participate in bund construction directly, but offers technical and material assistance to government agencies (primarily the Regional Centers for Agricultural Production (CRPA)) and non– governmental organizations (NGO).

The information from CES/AGF was supplied by Gouyahali Son, project coordinator in INERA/ESFIMA on Sept. 16, 1993, at the research station at Kamboinsé. Kambou and Lowenberg–DeBoer participated in this discussion. The International Fund for Agricultural Development (FIDA) finances CES/AGF.

The information from PPI was supplied by their agent at Donsin. In addition, the Sanou and Ouedraogo report on soil management at Donsin was consulted.

III. RESULTS AND DISCUSSION

Rock Bund Background – Many techniques for the construction of rock bunds have been developed in Burkina Faso. They differ in the way contours are laid, preparation of the soil where the bunds are to be built, the arrangement of the stones and management of construction labor. Three basic types outlined by Son are:

I) The three stone system – also called the FEER system for the Rural Water and Equipment Fund (FEER) which did much of the development of this system. In its classic form the FEER system had 6 steps:

1) Tracing of contours by a topographical team composed of 3 persons using surveying methods.

2) One pass by a tractor and disk plow with soil thrown up slope.

3) Collection of stones by farmers in piles of about one truck load, roughly four cubic meters. Tools used are pick, digging bar and wheel barrow.

4) Stones are manually loaded on trucks by farmers, hauled to the construction site and dumped.

5) Farmers lay the stones on the contour in two layers. On the soil surface two parallel rows are laid next to each other. A single row of stones is laid in the second layer overlapping the middle half of each first layer stone. A cross section of the bund would show three stones (Figure 1).

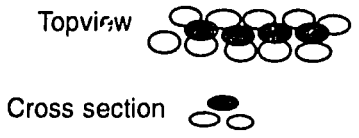

Figure 1. Top and cross section views of a rock bund built according to the three stone system.

6) Upslope from the bund farmers pile soil loosened by the plow against the foot of the bund.

This procedure has been modified by some organizations, in particular NGOs, to reduce costs. NGOs often use water levels made of clear, flexible plastic hose with 2m at each end attached to graduated poles to trace the contours. They train a few farmers per villages to use the levels. These farmers then help their neighbors trace contours. This eliminates the use of trained surveyors and their travel costs. In addition, the NGOs often eliminate the preparation of soil where the bund is to be built and manually earthing–up the upslope side of the bund.

According to Son the disadvantages of the three stone system are:

1) large holes between the stones allow a substantial flow of water between the stones, thus permitting some soil to be transported beyond the bund.

2) if the stones are badly aligned, channels can be created that turn into ravines.

3) soil deposits between the two rows of stones can reduce infiltration and thus cause flooding upslope from the bund.

Soil conservation efforts in Burkina Faso have largely switched from earth bunds to rock bunds. Initial work in the late 1970s focused on earth bunds. The soils of the Central Plateau often have slow rates of water infiltration. Thus water was retained behind the bunds and crops upslope were flooded. In some cases, farmers intentionally opened the bunds to save their crops from flooding. In other cases the water overtopped the bunds. In either case gullies were

created. Properly constructed rock bunds allow water to pass, but in a diffuse manner which does not create gullies.

Earth bunds are still used in some areas where stone is not available within a reasonable hauling distance (about 15 km) to the fields. In those cases, there is an effort to include a section of rock every 30 to 50 meters, to allow filtration.

III) Erect stones with subsoiling (PDS) – This system was developed by CES/AGF in response to problems identified with the three stone system. The procedure follows 6 steps:

1) Tracing of contours by a topographical team composed of 3 persons using surveying methods.

2) Two passes by a tractor and two shank subsoiler. Three furrows are created because one subsoiler shank passes through the middle furrow twice.

3) Collection of stones by farmers in piles of about one truck load, about 4 cubic meters. Tools used are picks, digging bars and wheel barrows.

4) Stones are hand loaded on trucks by farmers, hauled to the construction site and dumped.

5) Stones are laid by farmers. Large stones are set upright in the middle furrow with the smallest end down and the flattest side upslope. Small stones are fitted between the erect stones from the upslope side so that water forces the small stones into the gaps between the upright stones. If the small stones were placed below the erect stones, water would tend to scatter them. Downslope of the erect stones, large stones are laid flat at the foot of the bund to help hold the stones erect (Figure 2).

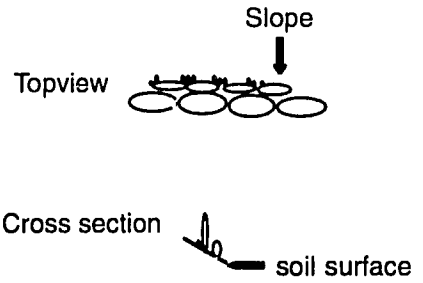

Figure 2. Top and cross section views of a rock bund build according to the PDS system.

According to Son, advantages of the PDS method include permeability maintained over a longer period, improved establishment of wild grasses and lower stone requirement. The classic three stone method requires 20 to 22 cubic meters of stone per hectare. The PDS method requires about 12 cubic meters per hectare. This is important because wide spread installation of rock bunds is exhausting stone supplies close to cultivated areas. According to Son, hauling distances were commonly 5 to 7 km. for the CES/AGF in 1989.

IV) Aligned stones – The simplest rock bund system consists of large stones aligned along the contour (Figure 3). Small stones are often placed on the upslope in the gaps between the large stones.

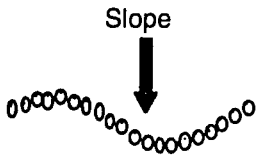

Figure 3. Top view of a rock bond built according to the aligned stones system.

Of the three systems outlined, the aligned stones bund requires the least stone, but it also allows the greatest runoff. Stones are vulnerable to being dislodged by water or animal traffic.

Any of the rock bund systems can be built by community or individual action. Burkinabé government agencies tend to favor community action. The CES/AGF and the CRPAs usually work with communities to protect a designated slope or watershed. Relatively large groups of village residents are mobilized on designated work days.

The government approach may include protection of bushlands upslope from fields. According to Son, the benefits of anti-erosion work in upslope bushlands include protection of lower toposequence structures and pasturage improvement. Heavy runoff from unprotected upper toposequence areas can overwhelm lower slope bunds. In addition, improved water infiltration in the bushlands provides moisture for plant growth and can help replenish ground water.

Many NGOs work with individual farmers to control erosion on their fields. They often concentrate on lower toposequence (and thus more productive) fields.

Rock bund labor times – Labor times were collected for bund construction by an individual farmer at Donsin and for PATECORE community work during the 1993 season (Tables 1 and 2). It should be noted that these times relate to specific construction approaches. Labor times for other systems may differ. The Donsin farmer used a modified three stone system without preparation of the soil. Most PATECORE sites use a modified three stone system without soil preparation, but a few use the PDS method.

Table 1. Donsin Farmer Labor Times for Construction of Rock Bunds, hr/ha.

Item	Men	Women	Children	Total
Labor time				
Gathering stones	25			25
Hauling stones	18			18
Tracing contours	4			4
Laying stones	13	38		50
Total labor	60	38		97

Table 2. PATECORE Labor Times for Construction of Rock Bunds, hr/ha.

Item	Men	Women	Children	Total
Labor time				
Gathering stones	70	56	47	173
Loading trucks	70	56	47	173
Tracing contours	8			8
Laying stones	130	104	86	320
Total labor	278	216	180	673

According to Delma, the average PATECORE bund density is 500 m/ha, which translates to bunds spaced about 20 m apart. At the time of the writing of this report the bund density for the Donsin farmer was not available. The farmer labor times assume the 500 m/ha.

Rock bund construction on a large scale is a relatively new development in Donsin, thus rock is available relatively close to fields. The farmer in Table 1 benefited from the availability of stone next to his field. Some stone was broken with a digging bar. He hauled the stone with a borrowed wheelbarrow.

The family labor available in the farmer's case was three men and six women. Men gathered and hauled stones. The women helped in laying the stones. The work was done during the hot season. Because of the heat, the usual work day was from 6 a.m. to about 9 or 10 a.m. Thus the 60 hours of work by the three men represents about one week of activity.

The farmer received the help of a PPI trained neighbor in tracing the contours. A mason's level supplied by PPI was used.

The PATECORE community work (Table 2) was usually in about 7 hour days. According to Delma, a typical workday would start at 8 a.m. and continue until 4 or 5 p.m., with a break a midday. Their construction season starts in October and continues until the rains come (usually in June), but because of the heat and fasting during Ramadan, it becomes increasingly difficult to organize workdays after January. The seven hour workday is important for efficiency in use of the truck and project personnel time.

According to Delma, the average workforce composition in 1993 was 30 men, 24 women and 20 children. Women helped in all activities except tracing the contours. The work time of truck drivers and project personnel are not included in Table 2.

The labor times estimated by Sanou and Ouedraogo for PPI activities at Donsin are intermediate between the farmer times and PATECORE averages. Their total is about 432 hr/ha (assuming 8 hour workdays), with 240 hr/ha for gathering stones, 96 hr/ha for laying out the contours and 96 hr/ha for laying the stones. The PPI activities at Donsin are concentrated on individual farmer fields, but some coordination at the community level is needed to insure efficient use of the truck. The truck is sent to the village only if a sufficient amount of stone has been collected for a day's hauling.

The value of labor used for rock bund construction depends on other labor opportunities available. Because construction occurs in the dry season, agricultural labor rates are not relevant. Dry season wage labor is rare in rural areas and almost nonexistent for women and children. Study of nonagricultural activities at Donsin (Lowenberg–DeBoer, 1993) suggests that the opportunity cost of labor is 50 FCFA/hr or less during the dry season. At 50 FCFA/hr the opportunity cost of labor for the work time estimates are: the farmer in Table 1, 4,850 FCFA/ha; PPI labor times estimated by Sanou and Ouedrago, 21,600 FCFA/ha; and PATECORE average labor times, 33,650 FCFA/ha.

Labor time Differences – A comparison of Tables 1 and 2 indicates that PATECORE labor times are substantially higher than those of the Donsin farmer. There are several hypotheses which might explain the labor time difference:

1) The amount of stone used by the farmer was less than the 20 to 22 cubic meters/ha used by PATECORE.

2) The individual farm family was more motivated than the workers mobilized in a community workday. The farm family benefits directly if their soil is improved. The community work benefits some people only indirectly.

3) Because the farmer did not use a truck, he was able to concentrate the heavy work of gathering, moving and laying rock in the relatively cool mornings.

It is hypothesized that the labor times collected by Sanou and Ouedraogo are intermediate between the two other cases because individual fields were being protected, but truck use efficiency forced some changes in the work schedule. The key changes are a latter starting time and work in the afternoons. Because of travel time to the work site, work days for truck hauling start about 8:00 a.m. Farmers often start work at dawn (about 6:00 a.m.). Efficiency in truck use requires work to continue into the afternoons in spite of the heat.

Hauling Cost – The truck use costs reported by PPI and PATECORE (Table 3) are comparable. Both projects rent trucks. According to Delma, PATECORE also has some of its own trucks, but finds rental less expensive. Diesel fuel cost is 245 FCFA/l.

Table 3. Truck Cost for PATECORE and PPI.

Item	PATECORE	PPI
Area treated per day, ha	2.5	2.5
Rental, FCFA/day	27500	27500
Fuel, FCFA/day	18865	19600
Cost per day, FCFA	46365	47100
Cost per hectare, FCFA	18546	18840

The importance of using trucks for full days can be seen in comparing per hectare hauling cost for full days (2.5 ha/day) and half days (1.25 ha/day). For example, the PATECORE hauling

cost per hectare rises from 18,546 FCFA/day to 32,976 FCFA with half day work, a 78% increase. Fuel cost are reduced by half day work, but travel to and from the work site is unchanged.

Rock hauling with animal or human powered carts has been tried with limited success. The volume of rock that can be hauled in a cart is small and hauling time is long for the 5 to 10 km distances often involved.

Rock Bund Subsidy – Most rock bund construction in Burkina Faso is subsidized by donors. The case of the farmer in Table 1 is unsubsidized, except for the water level and the PPI training of the neighbor in tracing contours. The farmer's case is useful as a pure case of estimating labor times, but it is relatively rare because stone is usually not available close to fields.

Hauling costs are an important part of the subsidy. The PATECORE and PPI data indicate that this subsidy is about 19,000 FCFA/ha.

Other subsidies come in the form of project personnel time and small equipment. PATECORE provides about 200,000 FCFA per village in the form of small tools: shovels, picks, digging bars, wheel barrows. The bund construction systems which use soil preparation on the bund construction site have another subsidized element. Many of the projects involved in rock bund construction are multifaceted. Separation of rock bund costs from other activities is not easy.

Mulching – Most farmers at Donsin mulch at least a small area of cereal crops with grass collected from uncultivated fields. Mature grass is collected in the dry season with a rake. In most cases, a sickle is not used to cut the grass because it requires bending over in the dust raised by the cutting. Use of a rake allows the individual to stand erect and above much of the dust. The rake breaks the brittle grass stems, leaving the root crowns in place.

The grass is collected in bundles and transported to the field. The farmers all mentioned the competition for grass close to the fields. Early in the dry season farmers collect the grass in bundles, leaving the bundles in the bush for later transport. Collecting the grass in bundles establishes an individual's claim to the grass. Later in the season bundles are collected and transported in a single activity.

Near the end of the dry season, farmers walk up to 2 hours from the village to find mulch grass. Farmers state that their interest in zaï is partially due to the fact that mulch sources have been exhausted.

The experience of Farmer 2 (Table 4) suggests that availability of a cart can substantially reduce labor times, though interpretation needs to be made with care because of differences in coverage per bundle.

The density of mulch application appears to vary from farmer to farmer (Table 4). Because the interviews took place in the rainy season it was not possible to weigh bundles. Bundle size may be a factor in the coverage area differences. Farmer 2 uses two coverage rates, one for average soils and one for small depressions and other more humid spots. For average soils the mulch application rate varies from 15 to 44 m2 per bundle (Table 4). The rate for humid soils is much lower, one bundle covering 77 m2.

Table 4. Mulching Experience at Donsin, 1993.

Item	Farmer 1	Farmer 2	Farmer 3
Density, hill/ha	30769	37104	26667
Area per bundle, m sq	15	44	30
Mulch, bundles/ha	686	227	333
Transport	Carry by bundle	Cart 12 bundles	Carry by bundle
Max Walking Time, min.	120	120	4*
Dry season labor time			
Gather mulch, hr/ha	69	166	56
Transport, hr/ha	412	Combined with gathering	Combined with gathering
Distribution, hr/ha	137	35 **	37
Dry season total	618	201	93
Rainy season labor time relative to unmulched, flat planting			
Planting	x2	x3	x3
1st Weeding	x3	x5	x3
2nd Weeding	?	?	x2
Expected yield effect relative to unmulched, flat planting	x2	?	x1.75

* Estimated based on farmer statement that mulch was cut close to field and by subtracting the gathering time of other respondents from total time given.

** Farmer unable to quantify time. Average time per bundle of other respondents used to complete labor estimate.

Planting density in mulch appears to be the same as in unmulched crops (non–zaï), planting time is increased because mulch must be moved aside to make the holes for planting. Farmers commented that all mulch must be kept from the planting hole to avoid termite damage to seed.

First weeding work time is from 3 to 5 times higher in mulched than in unmulched fields because mulch must be moved aside to hoe the soil. Second weeding work time is also increased.

Farmers expect yields on mulched soil to be approximately double those on unmulched fields.

Zaï – Many farmers in Donsin used the zaï technique for the first time during the 1993 rainy season. Some farmers had seen zaï on a trip to Yatenga organized by RSP. Many of them had seen the single field of zaï in their area in 1992, near Bonem (about 15 km).

The willingness to try zaï should be seen in the context of rapidly declining soil productivity at Donsin. The most extreme examples of erosion are found on the zipelé, barren areas of baked

subsoil on which even the hardiest plants have trouble gaining a foothold. Based on aerial photos, Sanou and Ouedraogo (1993) estimate that between 1990 and 1992, the zipelé area at Donsin grew by 1% annually.

But declining soil productivity by itself is not enough to convince farmers to adopt a new practice. For example, farmers in the Donsin area have not adopted chemical fertilizers and tied ridges, though these practices have been shown to improve yields. The innovations must use available land, labor and capital more efficiently than alternative practices.

PATECORE has tried since 1990 to introduce zaï as an accompanying practice in fields protected by rock bunds. Relatively few farmers have adopted the practice in the areas where PATECORE works. Delmar indicated that the low adoption rate could be linked to the level of extension effort. Another hypothesis is that farmers are not convinced that zaï is a good use of their limited resources.

Zaï production practices varied from farmer to farmer (Table 5). Farmers reported trying several variations of zaï, consciously experimenting in an effort to find the right technique for

Table 5. Zaï Experience at Donsin, 1993.

Item	Farmer 1	Farmer 2	Farmer 3
Density regular, hill/ha	30769	37104	26667
Density zaï hills/ha	25641	23050	31888
Manure per hole, kg	0.6	0.6	0.6
Manure per ha, kg	15385	13830	19133
Transport Type	Bicycle	Donkey Cart	Bicycle
Dry season labor time			
Dig holes, hr/ha	206	162 *	191
Transport Manure, hr/ha	1923	869	3587
Distribute manure, hr/ha	427	Combined with transport	266
Dry season total	2556	1031	4044
Rainy season labor time relative to unmulched, flat planting			
Planting	slower	faster	slower
1st Weeding	faster	x3	x4
2nd Weeding	?	faster	x0.66
Zaï seed placement	in soil	in manure	in soil
Zaï reseeding relative to non–zaï	reduced if planted in soil	none in zaï	less than non–zaï
Expected yield effect with manure broadcast relative to unmulched, flat planting	x2	no effect	x3

* Farmer unable to quantify time. Figure based on average time per hill of other respondents.

their situation. The variations included differences in hole size and shape, the amount and type of manure, density and seed placement. The variations were based on information that they had gathered in Yatenga, what they had seen in the field near Bolza and their understanding of soil–plant relationships.

Holes for zaï may be round or rectangular. Farmer 1 dug holes that were roughly the shape of an inverted cone about 25 cm in diameter at the surface and 10 cm deep in the center. Dirt from the hole was place just down slope from the hole. Farmer 3 used a similar technique, but with slightly larger holes, about 36 cm in diameter. Farmer 2 used a roughly wedge shaped, hole, about 17 cm long across the slope, 20 cm in the down slope direction and nine cm deep along the down slope edge. Farmer 2 piled the dirt from the holes in the space between two row of holes to form a low earth bund (Figure 4):

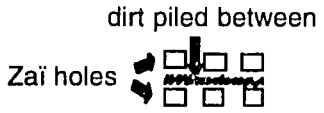

Figure 4. Top view of zaï arrangement used by farmer 2.

Factors in the choice of hole size and shape seem to be the effort required to dig it and the ability of the hole to trap rain water.

All the farmers interviewed said that they thought a double handful of manure (about 0.6 kg) per hole was best. Farmer 3 had run short of manure and had used a single handful in some zaï. Farmer 2 had intentionally left some holes without manure to determine the relative impacts of the soil preparation and the organic matter. At the time of the interview sorghum planted by Farmer 2 in zaï was uniformly about 3 m tall and forming grain. Sorghum planted in zaï holes without manure was about 1.5 m tall, somewhat uneven and only beginning to flower. In the flat planted fields sorghum was highly uneven, with the tallest plants about 1.5 m and flowering.

Estimates of total manure use ranged from 14,000 to 19,000 kg/ha. Mark Powell, International Livestock Center for Africa (ILCA), has conducted research on manure production by corralled livestock grazing bush and crop residue in Niger. He estimates that the average daily production of fecal dry matter per animal is: cattle, 1.28 kg; sheep, 0.37 kg; and goats, 0.2 kg (Personal communication). Using Powell's estimates, the midpoint application of 16,500 kg/ha would represent the full year's production (365 days) for 35 cattle, 122 sheep or 226 goats. Few farms at Donsin would have enough livestock to do zaï on one hectare with pure manure. These estimates suggest that lack of manure would limit the zaï area per farm to less than one hectare, unless ways are discovered to increase manure supply or extend it by using other organic matter sources. for example by composting.

Farmer 2 had a compost pit (4mx2mx1m) near his compound. He said that it required about 56 hours to dig. He composted livestock manure, wild grass (like that used for mulch), compound sweepings and wood ashes. Keeping the compost pit moist requires a major commitment of labor. He said that pumping and hauling twelve 50 liter containers each day required about 3

hours per day (1 hour by three men using a donkey cart) from January to May. Farmer 2 had learned about composting during a visit to Zoundweogo Province organized by RSP.

Plant density measured in the fields showed that farmers 1 and 2 reduced plant population in zaï. Farmer 3 increased population slightly. The amount of labor per zaï hole is probably about constant, thus one way to reduce per hectare labor requirements is to reduce density.

Farmer opinion was divided on the best seed placement. Farmers 1 and 3 hoed through the manure to plant the seed in the soil. The seed was covered with a mixture of soil and manure. They said that seed planted in the manure was subject to insect damage. Farmer 2 planted directly in the manure. He said that soil covering the seed tended to crust and to interfere with emergence.

In general, farmers said that seedling survival was improved by zaï. In the 1993 season, many flat planted fields were replanted 3 times. Given the short growing season, reseeding has a major impact on yield potential. Second and third plantings are often not sufficiently mature at the end of the rains to make grain. Zaï appears to reduce the need for reseeding and to have major implications for yield distributions, and hence the risk characteristics of the cropping system.

Zaï requires large amounts of dry season labor. Estimates based on the interviews range from 1000 to 4000 hours per hectare. Digging requires substantial labor, but transporting manure is the major element in the labor time. Farmer 2 was able to reduce his labor time by using a donkey cart and because the corral from which the manure was hauled was near the field. Manure transported by bicycle is put in a sack.

Farmers are divided on the impact of zaï on planting time. Part of the disagreement may be related to the lack of experience with the new technique. Two of the three respondents said that planting in zaï as slower. Farmer 1 said that in zaï he could only plant one row at a time, compared to 3 rows in flat planting. Farmer 2 said that planting in zaï was easier because the soil was already prepared.

They all said that the first weeding in zaï required extra time, mainly because weeds grew vigorously in the zaï hole and had to pulled out by hand for fear of damaging the young sorghum plants. The second weeding was faster in zaï because the sorghum grew quickly and dominated weeds.

Because this is the first year of zaï in the village, the farmers were not able to provide yield estimates. Their estimates of yield effects of manure broadcast on flat planted fields vary from no effect to 3 times as high as yields from unmanured fields. Farmer 2 remarked that heavy rains often washed away manure spread on flat planted fields.

Zaï also has potential as a soil reclaimation technique for zipelé (denuded lands). RSP had a demonstration plot in the center of a zipelé area. Only a few farmers have used zaï on zipelé and then only next to existing fields to reduce damage from wandering livestock. Most Donsin farmers have applied zaï to improve productivity on existing fields.

IV. DISCUSSION

The economic reasons for farmer interest in zaï as a soil management technique at Donsin are related to:

1) higher yields with Zaï.

2) potential for risk reduction – zaï appears to favor early establishment and reduce the need to repeatedly reseed crops.

3) low capital investment – in general there is no initial cash outlay. Tools already available on the farm can be used initially. Experience on Yatenga indicates that farmers eventually invest on sturdier pick axes for digging.

4) most of the labor occurs in the dry season – alternative labor opportunities in the area are scarce during this period.

Farmers are interested in zaï for many of the same reasons that they have already adopted mulching. They say that they would expand mulch area if mulch materials were available. Two hours walking distance is about the practical limit of mulch collection. Beyond that travel times become too long. They recognize that zaï and mulching could be complementary practices. Farmer 2 planted a small area of combined mulch and zaï. But making the most of limited mulch and manure will probably force farmers to apply either one or the other on a given area.

Rock bunds, mulching and zaï are complementary practices. Bunds are somewhat effective in keeping soil in place and increasing infiltration, but without accompanying improvements in soil fertility and physical properties, the impact on yield is limited about 10% to 30%. Combination of these practices can increase yields by up to 300%.

Rock for bund construction is becoming a scarce resource. The use of trucks has increased the practical hauling distance for rock, but it appears to force some inefficiencies in the use of labor. Other strategies for increasing the supply of usable rock include the use of explosives.

Zaï has a much more immediate effect on yields than rock bund construction. The main effect of rock bund construction in the first year is reducing rainfall runoff and increased infiltration. Yield effects from the build up of sediment behind the bund show up in the second or third year. Zaï also has a carry over effect. The manure does not decompose entirely the first year and crop residues produced in the first year can act as mulch if left on the field. Soil physical and chemical properties may be improved for several years after application. Farmers will probably rotate zaï over their fields.

Rock bunds have a long, but probably limited useful life. Their ability to hold soil and water may be reduced if sediment deposits behind the bunds build up near the level of the top of the bund though the terrace thus farmed is less erodible than the original slope. Clay deposits between the rocks on some types of bunds (Three stone system) may reduce water filtration

through the bund and create flooding. The growth of grasses and trees along the bund may turn it into a vegetative strip and effectively lengthen its useful life.

Both zaï and the construction of rock bunds use large amounts of dry season labor. The farmer may be faced with a difficult choice between the two techniques. In general, the labor requirement of bund construction is relatively low compared to zaï. But because zaï benefits are more immediate, they may be much more important to the farmer. However, the possibility of covering relatively more area with rock bunds given the same labor may continue to make bunds an attractive investment.

At 50 FCFA/hr, the midpoint value of dry season labor time for zaï, the required 2500 hr/ha, is valued at 125,000 FCFA/ha. A crucial parameter in the decision to use zaï is the opportunity cost of labor. A farmer who could earn 50 FCFA/hr in another dry season activity may be hard pressed to justify zaï. At a harvest time price of 50 FCFA/kg of grain, a yield increase of 2.5 metric tons per hectare would be required to breakeven. In addition, dry season earnings from commerce or artisanal activities would probably be less risky and provide a more even cashflow than zaï. Therefore, to the extent that other renumerative activities are available, they may be preferred, but zaï offers a potentially profitable use of surplus labor.

Constraints – The primary constraints to zaï use are the supply organic material and labor. The manure available on most Donsin farms would be enough for only a fraction of a hectare of zaï. There is already evidence of a limiting supply. Farmer 2 said that several people have already asked for a sack of manure. He commented that before the 1994 crop season people will start to steal manure. Farmers commented that they were beginning to manage their animals to increase the amount of recovered manure. For instance, animals were being tethered at night during the dry season, instead of being allowed to roam at will.

Use of compost may help increase the organic matter supply for zaï. All types of organic materials can be composted, including crop residues. The evidence gathered here suggests that water hauling is a major constraint to use of compost pits in the Donsin area.

The increased value of manure in zaï may have wide ranging effects on the whole farming system. Livestock production especially small ruminants, is a well developed enterprise in the Donsin area. Many of the Donsin animals supply the Ouagadougou market. Increasing the value of manure may make livestock production more profitable. But more ruminant livestock means more forage. RSP tried dual purpose (grain/forage) cowpeas in Donsin in 1992, but farmers favored varieties bred for grain. If zaï can stabilize cereal yields and increase the profitability of livestock production, the forage question may have to be reconsidered.

In Yatenga, where there is a longer history of zaï, manure has been extended in some cases by reducing the amount per hole and adding a small amount of commercial fertilizer. This retains the physical benefits of organic matter application (for instance in improving water holding capacity and reduced crusting around the young plant), but allows part of plant nutrition function to be taken over by mineral based products. The disadvantage of commercial fertilizer is the capital required for purchasing the product.

The combination of manure (or compost) and rock phosphate has some advantages. The acid in the manure increases the solubility of the phosphate. In the manure mix, the dustiness and handling problems associated with rock phosphate are reduced. As with commercial fertilizer, the capital required for rock phosphate purchase is a constraint.

For farms without animal traction and a cart, labor may be more limiting than manure in some cases. If zaï work is done during the period from January to May period, 6 days per week, with a work day of 6 to 10 a.m. because of the heat, the total work time per person is 512 hrs. The farmers interviewed said that most of the zaï work was done by men. Women and children helped mainly in distribution the manure to the zaï holes. If women and children did all of the manure distribution, a farm with one man and no cart could have from 0.14 to 0.25 hectare of zaï (using labor times from farmers 1 and 3). In a similar circumstance, a farm with a cart (and/or a corral close to the field) could provide the labor for 0.75 hectare of zaï.

In the current system, rainy season labor is fully utilized, especially during first weeding. The higher labor requirements for zaï implies that something else will go undone. The lower replanting rate for zaï may offset some of the higher first weeding time. Composting may also have an impact on first weeding, because weed seeds are killed by the heat in properly prepared compost.

V. RESEARCHABLE ISSUES

Farmers and researchers have much to learn about zaï and how it fits into the farming system of the central plateau. Most of the issues involve both agronomic and economic factors (Table 6).

Table 6. Economic Research Issues Related to Zaï

Problem	Economic Aspect*
Plant density	Labor time
Zaï hole, shape and depth	Labor time
Choice between zaï and rock bunds	Labor time
Amount of manure per hole	Link to capital investment in livestock production, also transport time
Benefits of manure vs compost	Labor time for composting, water hauling, weeding
Mechanization of zaï including soil preparation and transporting manure	Labor time and capital investment in equipment and draft animals
Animal production techniques that increase usable manure	Labor for extra livestock handling, capital for corrals, etc.
Forage production	Profitability of livestock Food security
Composting techniques that reduce water use	Labor time, capital investments needed
Manure extending techniques	Labor time and capital
Manure fertilizer mixes	Capital and/or cashflow

* All of the research issues here potentially affect the distribution of yields and profits, and hence risk

For example, the optimal plant density is a function of both plant response and labor availability. The appropriate quantity of organic matter depends on soil characteristics, plant nutrition, labor times, capital costs and the profitability of livestock production.

This is a case where a systems perspective is essential. The current system is geared toward grain production for home consumption. Cash inputs are limited because the opportunity costs of capital are high and because the crops do not usually produce a cashflow to help pay for the purchases. Livestock are raised extensively and only a small proportion of animal waste is recovered for use as a soil amendment.

Zaï has the potential for creating a chain reaction within this extensive system. If zaï improves yields and increases yield stability, farmers can starting thinking about other crop products, such as forage. The need for manure motivates farmers to confine livestock, but confined livestock need to be fed, increasing the demand for forage. If livestock production is made more profitable because of its link to zaï, cashflow generated by animal sales might be used to pay for fertilizer to extend manure availability. The interest in composting to extend manure supply and reduce weed pressure is also likely to increase.

Research requires foresight. RSP needs to be ready not only to address current problems, but also to be preparing itself for the problems that farmers will have in a few years. Research that addresses current problems will always be behind. In the case of zaï a forward looking research strategy requires information on the direction of system evolution. The simplest tools for analyzing changes in a cropping system are farmer interviews and representative farm linear programming models.

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The Value of Research on Indigenous Knowledge: Preliminary Evidence from the Case of *Zaï* in Burkina Faso

M. Bertelsen and S. Ouédraogo

I. INTRODUCTION

Indigenous knowledge (IK) refers to the institutionalized but usually informal practice or practices which have evolved within a community in response to a particular problem or constraint. In the context of developing-country agriculture, whether IK is or is not anything more that just a new name for farmer practice (Erinle, 1993), it is clear that IK has achieved scientific respectability[1]. There are good, practical reasons for this. IK practices are virtually always more "low-tech" using relatively plentiful and cheap labor more intensively than relatively scarce and expensive capital. Also, IK practices have evolved over many years and are therefore implicitly "sustainable": they are well adapted to the long-run local social, economic and environmental conditions. For this reason IK has attracted much attention in the natural resource management literature (Erinle 1994; Ouédanou 1994).

Two aspects make the study of IK especially interesting in a developing-country agriculture context. First of all, IK practices can be very localized reflecting evolved solutions to constraints imposed by conditions in a small area. Due to the lack of infrastructure and other factors which hinder information flows, the practices may not be adopted even in similar, nearby areas. Secondly, because IK practices were developed by farmers, they inspire confidence in other farmers and are therefore relatively easy to extend. Thus, the study of IK practices may provide large potential net social benefits: IK practices can have much to offer and can be extended relatively easily without incurring large costs.

The great majority of the scientific effort involving IK has so far been concentrated on the documentation of practices (see for example, Akinlosotu 1993, Ojeniyi 1993, Obi 1994, Maigida 1994). This necessary first step has been followed by attempts to adapt IK practices to new technologies with the intention of increasing production and returns to farmers (see for example, Otegbeye 1994, Gefu 1993). Until now, little effort has been directed toward estimating the value of IK practices themselves and, implicitly, the research which has brought these practices to light. This is what we propose to do in this paper; evaluate the potential impact of a particular IK practice in Burkina Faso with emphasis on the social value of the research which has made broader adoption possible.

Background. *Zaï* is an agricultural practice which evolved in the central Sahelian Region of West Africa sometime during the first half of the 20th century. While its exact origins are unknown, it

[1]Theodore Schultz (Schultz, 1969) first pointed out the relative efficiency of peasant agriculture. According to Schultz, the peasant farmer was '... relatively efficient in using the factors of production at its disposal" and that the key variable in explaining the differences in agricultural production was the level of acquired capabilities of farm people.

first appeared in the Yatenga Province of Northern Burkina Faso before 1950. *Zaï* is a technique for improving the viability of sorghum and millet plantings. It involves the preparation of a small hole in the ground of about 25 - 30 cm in diameter and 10 cm deep (Kaboré et al., 1993). Into this hole approximately 0.2 - 0.3 kg of manure or compost is placed before planting. Planting occurs in the hole after the first viable rains of the season. The effects of both the hole, which serves as a small reservoir for the plants, and the organic matter apparently combine to enable *Zaï* plantings to vigorously establish themselves. As a result, re-plantings and the consequences of early, mini-droughts are often avoided. Increases in yield are dramatic. And although *Zaï* demands the use of a great deal of additional labor, these demands occur during the dry season when the opportunity cost of labor is low relative to other times of the year.

Aithough *Zaï* has been practiced in Yatenga Province since at least 1950, the practice has not spread beyond this limited area. Farming Systems Researchers (RSP) of the Burkinabè National Agricultural Research Institute (INERA) became interested in the practice and decided to test the innovation in the similar RSP village site of Donsin. RSP transported a small group of Donsin farmers to Yatenga Province early in 1993 to see and discuss *Zaï* with local farmers. Upon their return, this group very effectively extended the innovation to their neighbors. Approximate 70% of Donsin farmers tried *Zaï* during the 1993 growing season (Robins et. al. 1994). RSP monitored the results of a random sample of these farmers during the season. RSP also established a *Zaï* demonstration plot on highly degraded land to demonstrate the potential of this technique to reclaim land.

II. METHODOLOGY

The methodology adopted for this study follows closely that developed by Akino and Hayami (1975). In the following figure, the adoption of an innovation causes the supply curve to shift out from a_0S_0 to a'_0S_1. As a result of this supply shift along the same demand curve D_0, changes in social welfare occur. These changes are measured by changes in 'economic surplus'. Economic surplus is composed of two elements; consumers' surplus and producers' surplus. Consumer's surplus arises from the fact that a consumer pays only the marginal value of the last product sold in the market (market price) even though it is known from the law of diminishing marginal utility that previous units purchased were worth more (see any introductory economics text such as Samuelson, pp 448-449). Thus, at the initial market price of P_0, consumers' surplus is equal to the area of triangle P_0dp in Figure 1. Similarly, producers'surplus arises from the fact that a producer receives the marginal cost (market price) for the last unit produced despite the fact that earlier units cost less to produce (law of diminishing returns). This corresponds to the area of triangle P_0pa_0 in Figure 1.

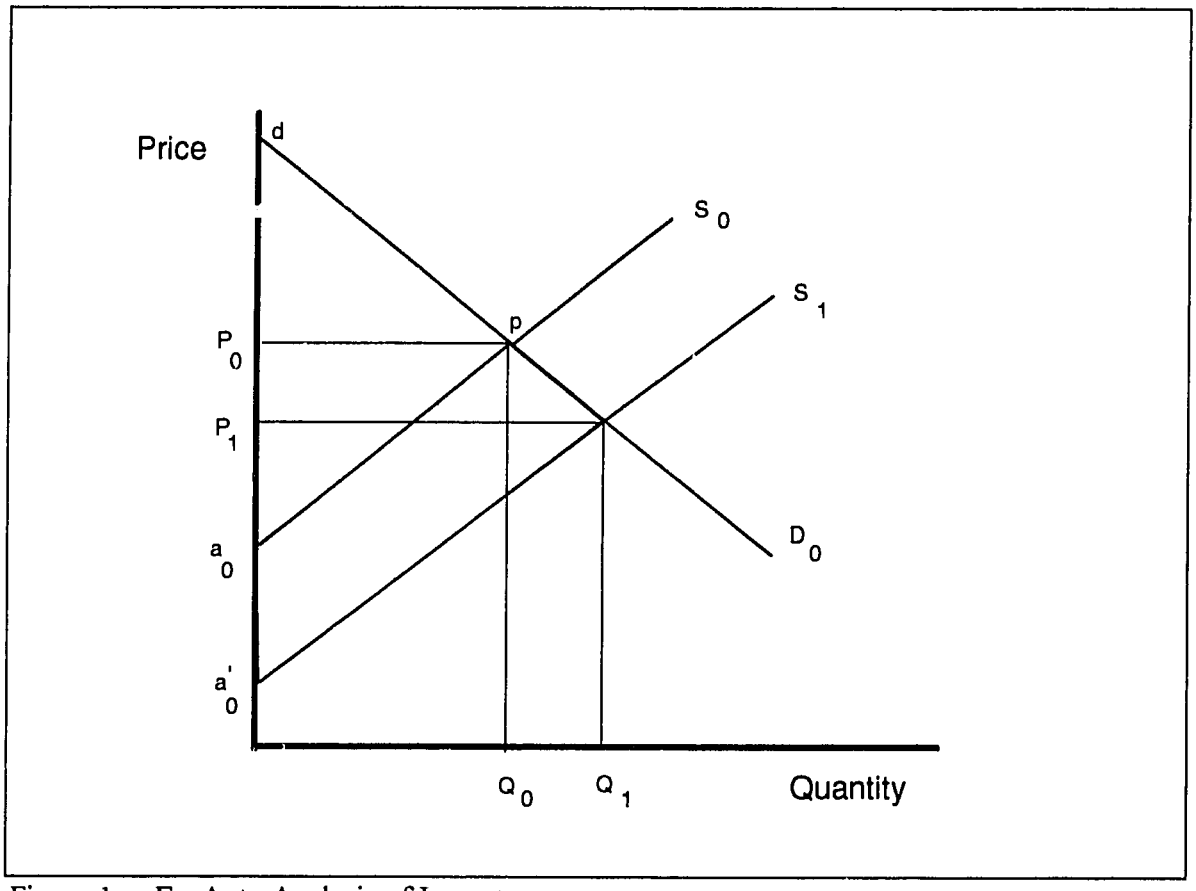

Figure 1. Ex-Ante Analysis of Impact

The total net change in economic surplus occasioned by the change in supply is represented in the figure by the lightly shaded polygon. This area represents the total, ex-ante increase in social benefits (without partitioning between consumers and producers) and is equivalent to the theoretical measure described by Akino and Hayami.

Data. In order to estimate these social benefits, a great deal of data must be obtained. Specifically, data on price indices, market prices, quantities and estimates of the elasticities of demand and supply must be obtained. These are combined with estimates of adoption rates and yield increases in order to estimate probable changes in prices and quantities. Changes in costs of production and the costs of the research and extension programs must also be estimated. These baseline estimates are presented in Table 1 below.

Table 1. Baseline Data for the Analysis

1. Price of sorghum/millet Kg[2]	65
2. Price of soghum/millet stover/Kg[3]	10
3. National production of soghum & millet/yr (000 t)[4]	1,505,143
4. Potential Zaï area in the North Zone	
a) Cattle (15/Ha/yr)	68,000
b) Sheep (53/Ha/yr)	44,000
c) Goats (97/Ha/yr)	30,000
d) Total hectarage in North Zone (Ha) Assumption: Utilization of 10% total	142,000 14,200
e) Assumed adoption (Ha)/yr	
1995	444
1996	888
1997	1,775
1998	3,550
1999	7,100
2000	14,200
2001	14,200
2002	14,200
5. Estimated cost of zaï research program 1990-1995[5]	5,000,000
6. Estimated cost of extention program 1995- 1999[6]	10,000,000
7. Ave. Percentage increase in production/Ha[7]	84%
8. Elasticity of supply (sorghum/millet)	0.8
9. Elasticity of demand (sorghum/millet)	0.4

Additionally, we assume that 'off-season' household labor costs provide the only relevant costs differences for this analysis. The average opportunity cost of labor assumed for this period of time is 25 F CFA/hour. Any down-stream labor differences such as differences in weeding time stemming from the use of *zaï* are ignored. No potential external costs are examined. Finally, we assume the productivity effects of *zaï* last for two years and remain constant over this time period.

Some items in Table 1 require additional clarification. One limitation of the *zaï* technology is the availability of manure (4). Using a conservative scenario, RSP researchers have estimated that some 15 cattle, 53 sheep or 97 goats are required to provide the manure sufficient for an average zaï application (>8 tons/Ha). The GIS database indicates that there are sufficient livestock in the North Zone to provide manure for some 142000 hectares at this application rate. We suppose, however, that only about 10% (14,200) of this potential will be realized. This translates to about 6 hectares per village or about 0.04 hectares per exploitation in the North Zone.

[2] Estimated average post-devaluation farm-gate price for soghum and millet.
[3] Average estimated post-evaluation farm-gate price of soghum and millet stover.
[4] Average of last nine years of sorghum and millet production. Source: Ministry of Agriculture.
[5] Source: Estimate provided by RSP Program.
[6] Source: Estimated provided by RSP Program.
[7] Source: RSP monitoring survey, 1993-1994.

The adoption rate specified in (4e) assumes a doubling of hectarage in the North Zone every year for five years as a result of the extension program. The enthusiastic response of farmers in the RSP village site indicates this may also be a conservative assumption.

The most problematic estimations for the analysis are those for the elasticities of demand and supply (items 8 and 9). There are simply not any reliable and consistent estimates available. In the case of demand, it is highly likely that the real, "average" estimate we seek is less than one (inelastic) and probably much less than one. We accept 0.4 as a realistic estimate. Similarly, the supply elasticity is expected to be somewhat inelastic. We accept 0.8 as an reasonable estimate. Both estimates have been used in similar, regional analyses of impacts (Masters and Sanders, 1994). The results indicated below are much more sensitive to changes in the elasticity of supply than the elasticity of demand. As the elasticity of supply increases, the internal rate of return falls.

III. RESULTS: POTENTIAL VALUE OF *ZAÏ* AND IK RESEARCH

Table 2 presents an evaluation of the potential value of the *zaï* technique. It is assumed that the *zaï* technology can be extended throughout the RSP North Zone, a homogeneous zone identified by the RSP Geographic Information System (GIS) unit. It was in this zone that the technology was developed and tested. The zone includes 10 provinces with a total area of over 7 million hectares (see zone map).

Table 2. Economic evaluation of Zaï

1. Average Net Profit (Zaï over control, F CFA/Ha)	31,125
a) Total increase in profit per year by the 6th year	441.98 mil
b) Value of the Zaï technology	944.87 mil
1. Adoption rate doubles each year for 5 years	
2. Present value discount rate = 20%	
2. Increase in National Agricultural GDP (6th year)	503.04 mil
Percentage of Total AG GDP	0.07%
Percentage of total value of Sorghum production	1.10%

The average returns to *zaï* have been estimated by RSP at 31125 F CFA/Ha (assuming an opportunity cost of off-season family labor at 25 F CFA/Hr). Accepting this value and the manure availability limitation, the regional net increase in farmer income is estimated to be about 442 million per year by the end of the 6th year (1a). The stream of income into perpetuity has a present value of some 945 million (1b) if one assumes a discount rate of 20% per year and the adoption rate assumed in Table 1 above.

Another way to express the potential benefits of *zaï* is to consider the potential impact on Burkina's agricultural gross domestic product (GDP). Assuming the same levels of adoption in the same zone, agricultural GDP would rise some 503 million or by 0.07% of agriculture GDP by the end of the 6th year (2a). This figure represents an increase of 1.10% in the total value of national sorghum production (2b).

Rate of return to research. While the above figures indicate that *zaï* has important potential, even with the conservative assumptions we have used, they say nothing about the social value of the RSP research which has made these results possible. Given the integrated nature of the RSP program and the large number of research themes addressed by RSP researchers during any given year, any allocation of the RSP budget to a specific theme is somewhat arbitrary. However, if one allocated a 5 million F CFA portion of the RSP research budget to *zaï* each year from 1990 and through 1995 and one assumed a 10 million/year extension program to extend *zaï* beginning in 1995 and lasting though 1999, the resulting internal rate of return to research would exceed 50% for the 15 year period 1990 - 2004. This is illustrated in Table 3 below where estimated net social gains are also presented. If twice as much land were put into *zaï* due to (say) collecting 20% of the manure instead of 10%, the returns would rise to almost 70% and the value estimates in Table 2 would double.

IV. CONCLUSIONS

Our analysis of *zaï* indicates that there may be very high potential social benefits stemming from the current trend towards studying

Table 3. Estimated program costs and net social gains*

Research Year	Costs (nominal)	Total Extension	Real Cost (1994 CFA)	Net Cost (1994 CFA)	Social Gain (1994 CFA)
1990	5.0	0.0	5.0	6.26	-6.26
1991	5.0	0.0	5.0	6.19	-6.19
1992	5.0	0.0	5.0	6.26	-6.26
1993	5.0	0.0	5.0	6.19	-5.95
1994	5.0	0	5.0	5.00	-4.61
1995	5.0	10	15.0	15.00	-6.30
1996	0	10	10.0	10.00	7.39
1997	0	10	10.0	10.00	24.76
1998	0	10	10.0	10.00	59.53
1999	0	10	10.0	10.00	129.08
2000	0	0	0.0	0.00	278.20
2001	0	0	0.0	0.00	278.20
2002	0	0	0.0	0.00	278.20
2003	0	0	0.0	0.00	278.20

Internal Rate of Return: 52.71%

*Real Cost = nominal cost/price index
Net Social Gain = Gross Social Gain - Real Cost

The RSP group identified *zaï* as a potentially important IK practice, facilitated its transfer to another village and studied the impact. This relatively small investment has born very promising results. Using conservative assumptions, we estimate an internal rate of return to research on *zaï* exceeding 50%.

The need to find sustainable solutions to agricultural and natural resource management problems compels development-related scientists to include IK in their research programs. In Burkina Faso as elsewhere, there are almost certainly other IK practices which are as promising as *zaï* but which need to be identified and extended to wider user groups. The RSP group in Burkina Faso plans to continue this important work.

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The Economics of Rock Bund Construction on Sorghum and Millet Fields in Burkina Faso

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ABSTRACT

Properly constructed, rock bunds (diguettes or cordon pierreux) can be an effective technology for controlling soil erosion as well as a means of harvesting water for crop production. This paper investigates the economics of rock bund construction on sorghum and millet fields in Burkina Faso. Gross benefits of rock bund construction are estimated by presenting an analysis of data collected from a large multi-year, multi-site fertilizer experiment on farmers' cereal fields. Because researchers collected data on many variables other than just yield and treatment levels, the data offer an unique opportunity to study the interactions of many different factors, including rock bunds, on cereal production. The analysis indicates that annual increases of 10%-17% in sorghum and millet production may be brought about by investments in rock bunds. These benefits are compared to rock bund construction cost estimates developed by researchers from the Production Systems Research (RSP) Unit of the Burkinabé Institute of Agricultural Studies and Research (IN.E.R.A). Policy implications of the results are also discussed.

I. INTRODUCTION

Among the challenges confronting Burkina Faso today, those affecting her soil resources have perhaps the most important implications for the future. The rapidly growing population, slow economic growth and climatic change are together putting tremendous pressure on the fragile soil resource base. Adequate and sustainable soil conservation techniques are often beyond the meager financial resources of Burkinabè farmers. The result is falling productivity which in turn forces change in the traditional fallow system, leading to more continuous cropping and the expanding use of marginal lands. These changes have the most serious implications for cereal production. Cereal production is the single most important agricultural activity in Burkina Faso: during the 88/89 campaign, some 2.1 million tons of cereal grain were produced (Savadogo and Lariviere 1992), representing over 63% of the value of all crop production measured in constant 1985 F CFA.

Due to the importance of cereals and the present, deteriorating soil resource base, factors affecting cereal production are the subjects of much scientific research and policy debate. While traditional types of research on most factors of cereal production can inform this debate and lead to improved policy decisions, the very nature of some inputs precludes a traditional research approach. The diffuse benefits, large-scale nature and variability of rock bund construction on farmers' fields, for example, imposes practical limitations on traditional methods of evaluation. Nevertheless, it is known that properly constructed rock bunds can be an effective technology for controlling soil erosion and a means of harvesting water for increased crop production. It is important therefore, that the benefits be studied, quantified where possible and compared to costs so that the economic aspects of diguette construction can be taken into account in any relevant policy debate.

The objective of this paper is to present estimates of the average contribution of rock bunds on farmers' fields to cereals production. Specifically, production functions for sorghum and millet are estimated using regression analysis of data drawn from a large, multi-year, multi-zone on-farm-trial data set assembled during the period 1989-91 by the Food Crops Fertilizer Project. These benefits are compared to rock bund construction cost estimates developed by researchers from the Production Systems Research (RSP) Unit of the Burkinabé Institute of Agricultural Studies and Research (IN.E.R.A). Implications for agricultural policy and research strategy are discussed.

This report is organized into three remaining sections: the next section describes the methodological approach used, the third presents the results of the regression estimation, the last outlines conclusions and policy implications. The data collection methodology for this study has been reported elsewhere (Hien et al., 1990, 1991, Hien and Youl, 1992) and will not be repeated here. Similarly, see Hien et al. (1992) for a discussion of the economic and risk aspects of the fertilizer treatments.

II. THE PRODUCTION FUNCTION APPROACH

The Production Function. A production function is a mathematical representation of a production process. It is the foundation of all production economics (see Henderson and Quandt (1971) for a comprehensive discussion of production theory). In a statistical sense a production function describes the average yield response to a given set of inputs. Production functions may be estimated by unit area of crop, per animal or per farm (see Heady and Dillon (1961), or Dillon (1977) for examples). They may also be estimated for an entire region or sector of the economy (see Griliches, 1963; Bertelsen, 1975). Because of the goal of this study is to determine the farm level productivity effects of rock bunds on cereals crops, this study will focus on production per hectare of cereals.

The production function approach was chosen as the simplest way to achieve the study objectives. The popular "dual" approach was not used because the available data covered physical inputs and outputs, and the objectives focus on physical productivity response. The dual approach uses accounting data to estimate profit or cost functions and thereby indirectly assesses productivity.

Greater detail in response modeling can be achieved with simulation modeling but at the cost of a much larger investment in time, data collection and human capital. Production functions have the advantage of being relatively quick and inexpensive to develop and may summarize production relationships which would be lost in the detail of simulation. They are an appropriate technology for an agricultural research situation in which a rapid, low cost response is needed to urgent problems.

Estimating Production Functions. Because of their fundamental nature, a vast and rich literature on estimating production functions exists. See, for example, Heady and Dillon (1961) and Dillon, (1977). Traditional methods involve using Ordinary Least Squares (OLS) regression techniques to estimate the function based on either experimental or survey data. Research station experimental

data is useful in determining the potential of new technologies, but often overestimates the input response obtained in farm fields. Survey data may provide information on actual farmer practices, but difficulties in data collection and the inherent variation between farmers may result in "noisy" data with much unexplained variability. For studying input productivity, on-farm-trial data is a compromise between research station experiments and survey data collection. On-farm-trial data are observations on farmers' fields with the structure supplied by the research design acting to improve data quality. To minimize bias when estimating a production function, three basic types of production factors should be included in the analysis: decision variables (under management control), predetermined variables (variables whose values or conditions are known beforehand), and uncertainty variables (variables whose values or conditions are unknown beforehand).

The Data. The agronomic data collected from the experiment included grain yields of sorghum and millet. The four treatments were organized into a randomized complete block design (each farmer treated as a block) consisting of a control (no fertilizer), natural phosphate plus urea and potassium, partially acidulated natural phosphate plus urea and potassium, and NPK (14-23-14) plus urea. The fertilizer quantities for the different treatments varied slightly according to the general agroecological zone of the trial. The quantities are given below in Table 1. Three agroecological zones were represented in the experiment; less than 600 mm rainfall, 600-800 mm rainfall, and greater than 800 mm rainfall. Other variables included in the analysis included predetermined variables (i.e., soil type, toposequence), uncertainty variables (i.e., planting date) and decision variables (i.e., plowing technology, water harvesting technology). Farmers chose their own seed and managed the experiment. See Hein, et. al. (1992) for a complete description of the experimental protocol.

It is unfortunate that data concerning a major decision variable - labor - was collected for only a small sub-sample and consequently could not be included in the analysis. The possible bias this may impart to the analysis is discussed below.

Table 1. Fertilizer applied for millet and sorghum by agroecological zone 1989-1991.

Treatment and Zone	Rock Phosphate	Partially Acidulated Rock Phosphate	NPK	Urea	KCL
Low Rainfall					
T1	0	0	0	0	0
T2	200	0	0	67	12
T3	0	50	0	65	12
T4	0	0	50	50	0
Medium Rainfall					
T1	0	0	0	0	0
T2	200	0	0	74	19
T3	0	66	0	72	19
T4	0	0	75	50	0
High Rainfall					
T1	0	0	0	0	0
T2	200	0	0	83	25
T3	0	87	0	79	25
T4	0	0	100	50	0

The Statistical Model. The choice of the specific functional form for the statistical model is often of critical concern for studies of this type. However, in the present case the choice was limited by the nature of the data. For example, estimating polynomial functions would not be feasible due to the large number of discrete (and few continuous) variables in the model and the large number of coefficients which would be required. Linear functions were estimated but performed less efficiently with lower R-squares and lower levels of significance than the power (or Cobb-Douglas) functions.

Power functions have been used extensively in production function estimation (see, for example, Heady and Dillon, 1961). Their multiplicative nature takes into account factor interactions. Also, they have the additional advantage of being able to directly yield coefficients which may be interpreted as production elasticities. Production elasticities indicate the percentage change in yield given a percentage change in input, all other factors held constant.

Power functions have been criticized in per unit area or per animal applications because they never reach a maximum. For the power function, the marginal increase in productivity with each unit of input may decrease, but will always remains positive. Experience suggests that most biological production processes have a maximum beyond which additional inputs have no effect (reach a plateau) or have a negative effect thus leading to negative marginal productivities. If this is the case in the present analysis, the use of the power function is clearly not appropriate. However, if the data range does not include a range of negative marginal products, power functions can be used as a valid approximation for that range. In these cases, care must be taken not to extrapolate effects beyond that range. Given the relatively low input usage levels in Burkinabè agriculture and in the Food Crops Fertilizer project design, it is highly unlikely that inputs in the data set reach the range of negative marginal products. Consequently, the power function can appropriately represent the true underlying production structure.

A generalized power production function may be specified:

$$Q = b_0 X_1^{b1} X_2^{b2} .. X_n^{bn}$$

where:

Q = quantity produced per unit of time and space
X = inputs (1..n)
b_i = parameters to be estimated

For estimation purposes, the linear version of the power function becomes:

$$\log Q = A_0 + b_1 \log X_1 + b_2 \log X_2 + . . + b_n \log X_n$$

where A_0 is the intercept term and all other symbols are as above and the estimated b_is are individual production elasticities.

In statistical estimation of production functions, theoretical constructs must be adapted to fit the available data and resources. Also, complications which develop within the statistical model itself may affect the particular combinations of variables included in the final model. Two complications, multicollinearity and autocorrelation are discussed below.

Multicollinearity. When one or more explanatory variables are highly correlated with another explanatory variable, severe multicollinearity is said to exist. 'Perfect' multicollinearity exists when the correlation is perfect (i.e. equal to 1). The effect of perfect multicollinearity is to destroy the analysis: a singular matrix obtains from which no information can be extracted. The effects of severe multicollinearity are to increase the variance and thereby reduce the significance of the parameter estimates. The parameter estimates themselves remain unbiased although it may be extremely difficult to isolate and interpret the effects of individual estimates. See any standard econometrics text such as Theil (1971) for a thorough discussion of multicollinearity.

Since the significance of variables is an important outcome of a regression analysis, usually steps must be taken to diagnose and reduce the effects of multicollinearity. Collinearity is evident if high simple correlations between variables exist. Regressions of one variable on combinations of others may indicate the presence of multicollinearity. In the present case, both procedures indicated that the zonation variables (Low rainfall, Medium rainfall) were highly correlated with rainfall. As a result, despite the fact that rainfall is an obvious 'uncertainty' variable, it was decided to eliminate rainfall from the analysis. (It should be noted that some rainfall effects are indirectly captured by the model through the inclusion of the planting date variable.) Multicollinearity is not judged to be a problem for other variables.

Autocorrelation. When successive error terms are correlated, autocorrelation exists. As long as the error term is uncorrelated with explanatory variables, autocorrelation (or, in time series analyses, serial correlation) results in unbiased, but inefficient estimators. Autocorrelation problems may be detected by calculating Durbin-Watson statistics (for time series data) or by studying the

plots of standardized residuals for any obvious pattern. The presence of autocorrelation problems generally indicates the model has been mis-specified (e.g., important variables have been omitted, simultaneous equations must be estimated, etc.).

In the present case, it was expected that the absence of a labor variable in the models would cause significant autocorrelation problems and thereby bias the results. However, an examination of the residual plots did not evidence any strong pattern for either model indicating that severe problems with autocorrelation probably do not exist. It is fortunate that such is the case since had such problems existed, no corrective measures could have been undertaken since labor information is simply not available. See Theil for a thorough discussion of autocorrelation.

Effects of 'Dummy Variables'. Qualitative variables usually enter the analysis as '0' or '1' indicating the absence or presence of a particular attribute associated with the observation. In the log formulation, '0' and '1' are replaced by '1' and 'e' which yield the same results after the natural logs of each variable are taken. The effect of a dummy variable is to act as a function intercept shifter, raising or lowering the entire production surface due to the effects of the qualitative variable. To prevent 'perfect' multicollinearity (see above) from developing due to the explicit inclusion of all categories of each qualitative variable, one category is omitted from each qualitative variable in the analysis. For example, if there are two variables possible to explain a qualitative situation (say, presence or absence of rock bunds in a field), only one new variable is created (say, rock bunds present) and is coded '0' or '1' depending if there are or are not rock bunds. The effects of the omitted categories are said to be confounded with the effects of all other non-included variables implicit in the estimated equation's intercept term. Great care must be taken in interpreting the elasticities of the dummy variables since they deal with large changes (all or nothing) rather than the small changes normally considered.

In addition to the fertilizer combinations, other dummy variables included in the analysis are:

Low Rainfall Zone = e if in the low rainfall zone, 1 otherwise
Medium Rainfall Zone = e if in the medium rainfall zone, 1 otherwise
Plateau = e if topography is plateau, 1 otherwise
Slope = e if topography is sloping, 1 otherwise
Soil-gravel = e if gravel soil, 1 otherwise
Soil-Sandy = e if sandy soil, 1 otherwise
Soil-Loam = e if loam soil, 1 otherwise
Rock Phosphate = e if fertilizer is T2, 1 otherwise
Partially Acidulated P = e if fertilizer is T3, 1 otherwise
Cotton Fertilizer = e if fertilizer is T4, 1 otherwise
Rock Bunds = e if rock bunds, 1 otherwise
Ridging = e if field was ridged, 1 otherwise
Tillage = e if manual, 1 if animal or mechanical traction

III. RESULTS

Estimated Models. Table 2 presents the results of the analysis. Coefficient estimates for each crop are presented.

Table 2. Power Functions Coefficient Estimates by Crop

Variable	Sorghum	Millet
Low Rainfall Zone	-0.0413	-0.2211**
Medium Rainfall Zone	0.1421**	0.1494
Plateau	--	0.1861**
Slope	0.1357**	--
Soil-gravel	0.0035	-0.4605***
Soil-sandy	-0.1043*	-0.2945***
Soil-loam	-0.0637	0.0815
Rock Phosphate	0.3322***	0.3821***
Partcially Acidulated Phosphate	0.4121***	0.4147***
NPK	0.5478***	0.5671***
Manual Tillage	0.1678***	-0.0571
Planting Date	-1.2579***	-1.3458*
Rock Bunds	0.1067*	0.1692*
Ridging	0.0178	0.1676**
Constant	12.9548***	13.1970***
Number of Obs.	405	156
R^2	0.2723	0.5192
F Statistic	11.2709***	11.7952***

* - Statistically significant at the 10% alpha level.
** - Statistically significant at the 5% alpha level.
*** - Statistically significant at the 1% alpha level.

The possible bias imparted to the analysis due to the lack of a labor variable has already been discussed above. This lack may also be responsible in part for the relatively low R-squares in the analyses. The fact that the R-square for millet, the hardiest and least labor demanding of the two crops, is much higher than for sorghum lends some support to this hypothesis. Nevertheless, the R-square range (27% - 52%) is acceptable for on-farm-trial data: the F tests indicate a significant percentage of the variability is explained by each equation.

Sorghum. Sorghum in the Medium Rainfall Zone yields significantly higher than in the High Rainfall Zone (confounded in the intercept term). All fertilizer treatments give large and significant increases in yields with NPK + urea giving the largest.

Manual tillage significantly increases sorghum yield. The effects of higher labor values and smaller parcel sizes may be correlated with this variable but the data set does not permit testing this hypothesis.

Delaying the date of planting negatively (and significantly) effects production. The decrease averages about 1.27% decrease in yield for each 1.8 days of delay.

The anticipated effects of toposequence and soil type are borne out by the analysis. Fields in the middle of the toposequence (slope) yield around 13% higher than the bottom land (confounded in the intercept). Similarly, yields in sand average 10% lower than higher potential clay soils (also confounded in the intercept term).

Finally, the construction of rock bunds significantly increases production. Increases average around 10% per year.

Millet. Millet yields are significantly lower in the Low Rainfall regions of the country.

Millet shows a fertilizer treatment response very similar to that of sorghum: the magnitudes of yield increases are virtually the same (38%-56%).

Since millet is sensitive to poor drainage, the significant 20% increase in yield due to a plateau toposequence position is expected (bottom land confounded in the intercept term). Poorer (gravelly and sandy) soils negatively and significantly affected millet production. The presence of rock bunds increased yields nearly 17% on the average. Similarly, ridging increased yields around 17% although this latter could be due to confounding with the third weeding during which time the ridging occurs.

IV. POLICY IMPLICATIONS AND CONCLUSIONS

The policy implications of these results depend upon the relationship between the magnitude of productivity increases and the associated cost of those increases. Farmers will make investments in soil fertility and conservation technologies only if they are better off investing their scarce resources in these as opposed to other activities. For making comparisons across sectors of the economy, the rate of return is often used. The rate of return is calculated as the ratio of net benefits to investment and is comparable to the interest rates in the financial markets.

Opportunity cost of capital. Small scale non-farm activities in West Africa often have very high returns to investment (Vijverberg (1991), Lowenberg-DeBoer et al. (1992)). Relatively wealthy individuals may have opportunity costs of capital around 50% annually. That is to say if they invest in fertilizer or soil conservation they forego an annual return equal to 50% of their investment. Poor individuals may have rates of return over 1000%. Consequently, for poor farmers the effective cost of fertilizer may be more than 10 times the price because of the relative value of other economic opportunities they must forego. By comparison, farmers in developed countries often have opportunity costs of capital in the 5% to 15% range. Developed country governments and developing countries with access to donor credit may have costs of capital in the neighborhood of 1% to 7% annually.

Wealthier individuals often have lower opportunity costs of capital because they have funds left after exhausting their highest return investment opportunities and thus must accept some lower return activities at the margin. Poor individuals concentrate their meager resources on only the highest return activities and may not have the funds to exhaust the investment opportunities there.

Economic analysis of rock bunds. Construction of rock bunds is a long term investment in the productive capacity of the soil. The useful life of the bunds is not well studied, but a well constructed bund may be effective for over 20 years. The useful life may be lengthened by regular maintenance to repair breaches and by allowing wild grasses and trees to colonize the bund.

Bund construction requires very little farm capital. The primary farm investment is in the form of off-season labor. Depending on the availability of stone, the density of bunds per hectare and how the work is organized, rock bund construction may require from 100 hr./ha to 1280 hr./ha (Vlaar, 1992; Kabore et al, 1993). The 100 hr/ha figure applies to construction by a farm family on their field with stone very close by. The higher labor times occur when stone must be transported long distances and when labor is organized in community work days.

The value of off-season labor is difficult to evaluate because off season labor markets, especially for women and children are not well developed in Burkina Faso. The data collected by Lowenberg-DeBoer et al.(1993) suggests that the opportunity cost of labor in non-agricultural activities is at most 50 FCFA/hr. Using the 50 FCFA/hr figure, the investment in labor time in bund construction may be valued up to 64,000 FCFA/ha.

In certain cases farmers construct rock bunds privately (see Kabore et al, 1993 for an example), but governmental and non-governmental organizations are often involved in laying out contours and transporting the stones. The cost of professional staff for tracing the contour lines and designing bunds is difficult to separate from general agency and project costs, but the transport costs are well known. Vlaar cites a range of 12,200 FCFA/ha to 26,300 FCFA/ha. Kabore et al. (1993) indicates a cost of about 18,700 FCFA when trucks are rented.

The policy issues can be focused by comparing the value of bund related yield increases with the two construction cost scenarios outlined by Kabore et al (1993) for the northern part of the Central Plateau of Burkina Faso (see Table 3 below). One scenario involves a farmer who had stone available next to his sorghum field and constructed bunds with family labor and tools available on his farm. The only outside involvement was the help of a neighbor with a water level supplied by a private voluntary organization. He and his family spent about 97 hrs/ha in construction. At 50 FCFA/hr this is worth 4850 FCFA/ha. The annual benefit of bund construction would be the sorghum yield increase for the low rainfall zone. If it is assumed that the benefits not valued (e.g., recharge of ground water, environmental improvement) and the costs not quantified (e.g., value of PVO training of the neighbor, the water level, the depreciation of farm tools) balance each other, and that the useful life is 20 years, the simple rate of return is 112%.

Table 3. Simple Rate of Return Estimates for Rock Bund Construction - Two Scenarios[1]

Item	Private Construction	Community Workdays
Sorghum Yield Increase, kg/ha	75	75
Value of Yield Increase, FCFA/ha	5690	5690
Value of Construction Labor, FCFA/ha	4850	33650
Trucking cost, FCFA/ha	0	18700
Initial Investment, FCFA/ha	4850	52350
Simple Rate of Return, percent	112	6
Internal Rate of Return, percent	117	9

Because of questions raised about the reinvestment rate assumption inherent in internal rate of return calculation (Lowenberg-DeBoer, 1993), the simple rate of return is used here as a conservative estimate of the rate of return[2]. In this case the internal rate of return is only slightly higher than the simple rate of return.

A second scenario involves construction by community labor with the assistance of outside agencies. The average labor required is 673 hr/ha, with a value of 33650 FCFA/ha at 50 FCFA/hr. The truck cost was 18,546 FCFA/ha. If it is assumed that benefits not valued and unquantified costs balance each other, the simple rate of return is 6% and the internal rate of return is 9%.

Depending on who supports the costs, private and social rates of return may differ. In both scenarios all quantified benefits are private. In the first scenario the private and social rate of return would be about equal because the quantified costs are private. In the second scenario, the private rate of return to bund construction may be substantially higher than the social rate of return calculated. Because community labor is involved and not all the fields farmed by community members are affected by bund construction, the private investment of a given farm family in the construction of bunds on their fields may vary. In some cases, families may contribute labor to bund construction entirely on the fields of others.

The estimated rates of return indicate that when stone is available private bund construction will be attractive for wealthier farmers. When outside organizations are involved, if the farm family contributes labor to the community workdays in proportion to the area of their fields protected, the rate of return is probably too low to compete with other activities. However, as a social investment, the 6%-9% rate of return on bund construction is slightly above the cost of capital to donors and governments with access to concessional credit.
The rock bund rate of return examples developed here indicate that greater social investment in bund construction might be justified, especially if the required labor could be brought closer to the

[1] The scenarios were developed under the following assumptions: the sorghum is grown without fertilizer on gravelly soils on a slope withoutmechanical soil preparation or ridging. Estimated average yields under these assumptions are 665 kg/ha without bunds and 740 kg/ha.

[2] The simple rate of return here is calculated as the annual benefit, minus straight line depreciation of initial cost, all divided by the initial investment.

level observed for private bund construction. Rock bunds provide substantial social benefits in the form of environmental protection and ground water recharge that were not quantified here. Bunds are a technology that is relatively accessible to poor farmers because they do not require a monetary investment. The subsidization of rock hauling costs currently provides an administratively feasible mechanism for supporting bund construction.

In addition to research on improving the efficiency of rock bunds, it may be useful to consider the question of how subsidization would be increased in an administratively manageable manner. Kabore et al (1993) identify the scarcity of loose stone with an acceptable hauling distance as an growing constraint. It may be necessary to use explosives and excavating equipment to expand the supply of stone. They also hypothesize that labor requirements with truck hauling may be higher than those with private labor because efficient use of the truck forces inefficient labor scheduling. If stone were mechanically loaded and hauled by truck to the field it is possible that labor requirements could be reduced and more area be protected by rock bunds.

Conclusions. Due to the importance of cereals and the present, deteriorating soil resource base in Burkina Faso, research into factors affecting cereal production are a high priority. This research is needed to inform the debate surrounding future policy options. Production function research can provide valuable insight into the productivity effects of some inputs which traditional research methods may find difficult or impractical to study. The analysis of the economics of rock bunds is one example where production function research is indicated.

Production function analysis of the Food Crops Fertilizer Project data set shows that within the constraints imposed by soil, topography and rainfall, substantial possibilities for increasing sorghum and millet yields exist. Among the results of presented, the analysis indicates the use of NPK fertilizer and urea increases average millet and sorghum yields by some 55%. Rock phosphate products also show substantial and statistically significant yield increases.

The analysis also demonstrates the potential of rock bunds. On the average, rock bunds increase yields of millet by more than 17% and sorghum by more than 10%. These increases may translate into simple rates of return to investment of between 6% and 112%, depending upon specific circumstances of construction. The rock bund productivity effects suggest that greater social investment in bunds may be justifiable. Rock bunds have substantial environmental benefits and, because they do not require a large monetary investment, are accessible to a wide range of the farm population. Research is needed to better quantify environmental and yield benefits, to evaluate "hidden" costs of agency time and to determine if changes in stone loading and hauling arrangements could improve labor productivity and reduce costs.

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Section II
Cropping Systems

Farmers' Evaluations of On-Farm Tests and the State of Village Natural Resources Results of the Farmer Opinion Surveys 1990-1994, Central Zone, Burkina Faso

E. Robins

I. INTRODUCTION

This paper summarizes the findings of the *Enquête d'Opinion*, or *Farmer Opinion Survey*, conducted annually by the *R.S.P. (Production Systems)* program of Burkina Faso's Institute for Agricultural Research and Studies. This survey has become an indispensable research tool for *R.S.P.*, involving agricultural producers directly in the evaluation of research. The results of the survey have informed *R.S.P.* researchers of farmers' interests, needs, and constraints and, in so doing, have helped to assure the relevancy of each year's program of on-farm tests at village research sites.

The opinion survey as a research activity has been refined by *R.S.P.* researchers and others according to the needs of the research program and the competencies of its personnel. The diverse contributions of village-based field technicians, who serve as enumerators for the survey; technician supervisors; and researchers from several disciplines have improved the quality and usefulness of survey results since the first opinion survey was conducted in December 1990. The survey has developed to become a central *R.S.P.* activity: that is to say, it evidences the problems *R.S.P.* researches, the methods *R.S.P.* employs; and the manner by which *R.S.P.* conducts its business with villagers. It is less a boilerplate "opinion" survey than it is an evaluation by farmers serving diagnostic ends for *R.S.P.*

The *Farmer Opinion Survey* is part of the annual core program of *R.S.P.* It is one evaluation of on-farm tests. Producer-partners experience the survey in the context of the *R.S.P.* research process in their village: test-evaluation-discussion-programming. They know that survey results will be presented to them and debated at annual meetings with *R.S.P.* which serve as occasions to review one year's research and plan for the coming year. Thus, farmers are assured of a dialogue, and an analytical role in that dialogue, which empowers them.

The *Farmer Opinion Survey* is conceptually uncomplicated but requires caution in how it is prepared, executed, and analyzed each year. This is so because it is a qualitative tool: easy to employ but generating results which are potentially difficult to interpret. This is discussed in greater detail in the section below on methodology.

The findings of five opinion surveys (four annual surveys plus a special survey on the zaï technology) are revealing of shifts in the orientation of the *R.S.P.* research program since 1990. They demonstrate as well how producer-partners have become increasingly interested in *R.S.P.'s* role in building awareness of potential responses to serious agro-ecological problems (*sensibilisation*) and providing instruction (*formation*) in the application of proposed interventions. This movement away from seeing *R.S.P.* as a provider of material inputs to a source of information and education is of fundamental importance because it brings farmers' expectations of *R.S.P.* in line with *R.S.P.'s* mission.

Below is a discussion of methods employed in conducting the opinion survey. It is followed by a summary discussion of findings since the first of these surveys was conducted in 1990. In a short concluding section the changing orientation of *R.S.P.* is discussed.

II. METHODS

The opinion survey is a qualitative research tool. The questions most often posed are open-ended and semi-directive. For example, a producer is asked to evaluate a tested variety of a basic food crop according to its productivity, characteristics, and difficulties encountered. Responses may be somewhat limited with regard to some inquiries, such as to the productivity of a new variety (e.g., *more or less* productive than local varieties). Questions about the characteristics or difficulties of tested varieties, on the other hand, may generate a wide variety of responses. In either case, the richness of the data base which ensues is derived from the open question format.

Closed-ended questions are sometimes used as well. Questions may be asked about the type and dose of fertilizer applied on fields, interest in varieties which also serve as fodder for livestock, or quantities of grain sold and sale prices. In these cases it is not an evaluation which is solicited, but information indicative of producer agricultural behavior. Closed-end questions may be used to evaluate precise agricultural practices, as in the 1991 opinion survey described below.

The majority of questions on the 1991 opinion survey, the second of the opinion surveys, were closed-ended. Sociologists worked closely with agronomists in preparing questions which would elicit evaluations of specific practices tested in researcher-managed parcels. Responses were qualitative: for example, the producer agreed that a specific cultural practice (e.g., the need for *tillage before sowing) was absolutely necessary, somewhat necessary,* etc. This format, while yielding useful information, was abandoned the following year in returning to open-ended questions. It was felt by the majority of researchers that open-ended questions provide more useful information overall to *R.S.P.* by permitting interviewed producers to follow their own lines of thought. These can vary widely among individual producers and differ markedly from researchers' expectations.

Whether open or closed, it is most important that the objective of the question is clearly understood by researchers and enumerators who must, afterward, interpret responses in light of the type of question posed.

Each year survey samples included all producer "partners," that is, producers who collaborated with an *R.S.P.* technician in conducting an on-farm test. The wives of these partners (it was not until 1993 that women became collaborating partners themselves with *R.S.P.*) were also asked specific questions. In the evaluation of the zaï technology conducted in Donsin village in December 1993, a random, stratified sample of household heads was used.

Table 1. Opinion Survey And Producer/Partner Sample Size By Year And Village

Year Village	1990	1991	1992	1993	1993 Zaï
Thiougou	31	44	24	46	
Donsin	11	32	26	34	42
Kamsi	20	16	—	—	
Tiano	—	—	—	22	
TOTAL	62	92	50	102	42

The number of producer partners has increased each year, indicating growing interest in working with *R.S.P.* (Table 1). An exception to this pattern is 1992, when activities in Kamsi were limited to the thesis research of one *R.S.P.* agronomist. Samples in Thiougou and Donsin were smaller that year as the *R.S.P.* program was temporarily disrupted by changes in the composition of the technical assistance team.

The surveys are conducted in a single passage by *R.S.P.*, village-based technicians and technician supervisors. Both technicians and supervisors are trained by *R.S.P.* researchers in the application of the questionnaire.

The questions which appear on each year's survey are prepared by *R.S.P.* researchers under the direction of program sociologists. Input is also provided by field technicians, supervisors, and producers. The survey is intended to respond to the information needs of researchers. That it succeeds is evidenced by the key role it serves in defining each year's research program.

R.S.P. sociologists perform the bulk of data analysis. Data are usually entered on a spreadsheet (e.g., *Quattro Pro*). The computation of simple statistics, e.g., response frequencies, are often performed on the spreadsheet. Statistical measures of association between variables require the use of statistical software, e.g. SPSS (*Statistical Package for the Social Sciences*).

Responses to open questions are recorded faithfully; similar responses are grouped together afterward to facilitate analysis. The richness of producers' observations often appear as anecdotes in the discussion of survey results. Their value is derived from their unique expressions and nuances.

Preliminary results of each survey are discussed among *R.S.P.* researchers. Final results are reported and presented at village meetings held annually before the onset of the next season. These dialogues are important determinants of *R.S.P.* research actions in village research sites.

III. FINDINGS

There have been important variations from year to year in the tests conducted on-farm, the numbers of partners participating in each kind of test, and the questions posed to solicit farmers' evaluations of tests. Opinion survey data tend to be complementary from one year to the next. Taken together they present an overall picture of, for example, a particular variety.

Strictly comparable data for the entire period 1990-1994 is lacking, however. What follows below are summary qualitative assessments of *R.S.P.* tested technologies derived from farmers' evaluations of them.

Often more than one factor is tested in a single test, such as variety and response to fertilization. In this discussion these factors are disaggregated. Thus, the presentation includes sections on: varietal performance and characteristics; fertilizer and insecticide treatments; intercropping; cultural practices; secondary varietal characteristics; and interest in adoption. Some observations are offered on response differences as a function of village affiliation and partner status (new versus continuing).

A separate section is devoted to producers' assessments of the state of village natural resources and actions they are taking to combat further resource degradation. Producers' interests in future collaboration with *R.S.P.* are discussed afterward.

In all cases agronomic tests respond to basic and derivative agricultural constraints in the Central Zone: insufficient and irregular rainfall; low productivity; limited pasture and fodder availability; infestation; and periods of food shortage. Through the opinion survey, producers' evaluations of varietal performance are obtained, as well as their views on the feasibility of adopting a particular variety given its needs for fertilizer or insecticide, its taste and processing attributes, and other characteristics of varietal performance. Thus the opinion survey offers an overall assessment of tested innovations; it is not a substitute for annual agronomic analysis which assesses performance according to soil type, rainfall pattern, or seasonal pest problems nor of economic analysis of profitability.

Varietal Tests. This section summarizes producers' observations of tested varieties. Table 2 summarizes information about the tests (see Table 2).

Sorghum. IRAT 204: This variety is adapted to low rainfall conditions where it offers a certain productivity and resistance to drought. It did not produce as well as the local variety when tested at Kamsi in 1990, nor was it appreciated when processed (e.g., poor quality *tô*, doesn't keep well, grain breaks easily). In 1991, this variety was evaluated according to 11 indices of varietal performance (e.g., germination, resistance to disease and infestation, and productivity). The tested variety was judged better than the local variety on 2 features: resistance to lodging and early maturity. It was judged worse than the local variety for production of grain and stover.

S-29: This variety was developed to be a good yielder of intermediate maturity. It was less productive than the local variety and susceptible to borers. It had good processing qualities. It was tested in 1990 and again in 1991. It was judged better than the local on 3 features: germination, production of stover, and maturity (early). It fared worse than the local variety with regard to resistance to humidity and grain production.

ICSV 1049. This early maturing variety has been tested annually since 1990. It is potentially high yielding for both grain and stover and offers rot resistance. Forage quality is good. When processed it produces an acceptable tô but it doesn't keep well. It was judged better than the

local variety for its germination, resistance to lodging, drought resistance, grain and stover production, and maturity. It was said to be less resistant than the local to disease, infestation, and humidity. This variety's performance was more appreciated at Thiougou than at Donsin in 1992 after relatively poor grain yields. At Thiougou, 60% of interviewed producers reported being satisfied with the performance of the variety and 40% said they would like to try it again the following year. In 1993, ICSV 1049 was judged more productive than the local by only 32% of the sample at Thiougou. Interest in substituting it for the local variety was nil.

Millet. Tested millet varieties have been less productive than local varieties and, because some of them are early maturing, are subject to attack by birds. Producers like the short cycle nonetheless, and have proposed a later planting date to avoid bird attack.

IKMP-3: This variety was tested in 1990 only. It offers resistance to mildew, ergot, and smut. Wives said it was easy to process and had a good taste. A relatively late maturing variety, IKMP-3 requires additional weeding according to those interviewed. It "burns" when organic fertilizer is used and rainfall is low.

IRAT P8: Another late variety, it is appreciated for the high quality *tô* it produces. It was judged better than the local for germination, grain and stover production, and maturity (late). It was worse than the local for resistance to lodging and drought. It was tested in 1990 and 1991.

IKMV 8201: Tested first in 1991 and again in 1993, this variety is better than the local for germination, resistance to disease and drought, grain and stover production, and maturity. It is worse than the local for resistance to lodging and insects. In 1993, its productivity at Donsin was judged to be worse than the local by 68% of the sample. There was no interest in substituting it for the local variety.

Maize. Tested maize varieties typically have been well-received by producers. In 1990, a total of 8 producers tried four early maturing varieties: KEB, KEJ, KPB, and KPG. All were well-regarded for their taste and productivity.

SR-22: Tested in 1993. It is high yielding and streak resistant. It was judged to be more productive than local varieties at Thiougou and Tiano by more than 80% of the sample. Some 75% of the sample at Tiano and 58% at Thiougou expressed interest in substituting it for local varieties.

DMR.W: Tested at Tiano in 1993. Judged to be more productive than the local variety by 77% of the sample. Plants are large and the grain provide high flour yield. This variety is streak resistant and withstands drought.

Cowpea. Producer interest in cowpea has been strong since 1990. The grain is often marketed. The plants are used as fodder. Dual purpose (*double usage*) varieties tradeoff grain production for production of biomass.

Three varieties were tested in 1990 only, all of which offered good productivity and taste: TVX 3236, Gorom Locale, and KN-1.

7/180-4-5: This is a dual purpose variety. In 1992, 88% of the cowpea tested was of this variety. It is early maturing and produces good quantities of grain and green forage. It is susceptible to insect damage if not treated with insecticide. This variety was appreciated at Thiougou, where 75% of the sample requested to try it again. 80% of the sample at Thiougou said they were ready to treat it with insecticide, an indication of the value of cowpea production in their eyes.

Interest in Donsin was considerably less, with only 24% wanting to try it again and no one interested in investing in treatment. Differences between the villages reflect the relative importance of livestock (for traction) at Thiougou and the preoccupation with food security at Donsin. Also, the variety suffered from excessive shattering at Donsin in 1992. In 1993, this variety was regarded as more productive than the local by 58% of the sample at Thiougou and was again appreciated for its production of green forage.

KVX 61-1: Tested by 5 producers in 1992, it was appreciated for high grain yield. Plants mature all at the same time and must be harvested quickly. This stresses available labor according to producers. If not harvested on time, the pod shatters.

KVX 396-4-4: Tested primarily in 1993 (there was a single producer who tried it in 1992), this high yielding variety was said to be more productive than the local by 74% of the sample at Thiougou and 65% at Donsin. It is relatively disease and insect resistant and striga tolerant.

Peanut. Four varieties were tested in 1990: QH 243C, KH 241D, TS 32-1, and CN 94C. The latter two were tried again in 1993. All were said to have a good taste and to offer good yield with some drought resistance. In 1993, 89% of the sample said that TS 32-1 and CN 94C both were more productive than local varieties. Fully 100% of the sample is ready to substitute them for local varieties next year. Grain and pods are large and the plants are resistant to insects. Commercial quality is very good. These are late maturing varieties.

Table 2. Varieties Tested By Rsp 1990-1994

Variety	Crop	Year(s) Tested	Number of tests	Observations
Sorghum	IRAT 204	1990, 91	6, 16	Less productive than the local. Poor quality tô. Resists lodging. Early maturing
	S-29	1990, 91	6, 9	Less productive than the local. Good taste. Good germination and production of stover. Early maturing.
	ICSV 1049	1990, 91, 92, 93	8, 25, 50, 32	More productive than the local for grain and stover. Good quality forage. Acceptable tô that doesn't keep well. Good germination and resistance to lodging and drought. Susceptible to disease and insects. Early maturing.
Millet	IKMP-3	1990	8	Less productive than the local. Easy to process with a good taste. Dried out when used with organic fertilizer and low rainfall. Late maturing, requiring additional field work.
	IRAT P8	1990, 91	8, 27	More productive than the local for grain and stover. Good tô. Susceptible to lodging and drought. Late maturing.
	IKMV 8201	1991, 93	15, 6	More productive than the local for grain and stover at Thiougou. Less productive at Donsin. Susceptible to lodging and pest (bird) damage.
Maize	KEB	1990	1	Good yield. More flour than the local.
	KEJ	1990	1	Good yield. Better than the local.
	KPB	1990	3	Good yield. Excellent taste.
	KPJ	1990	3	Good yield. Excellent taste. Sweet.
	SR-22	1993	23	More productive than the local. Good tô. Drought resistent. Keeps easily.
	DMR.W	1993	9	More productive than the local. Good tô. Drought resistent. Keeps easily.
Cowpea	TVX 3236	1990	10	Good yield. Good taste. Cooks-up easily.
	Gorom Locale	1990	12	Good yield. Good taste. Cooks-up easily.
	KN-1	1990	3	Good yield. Good taste. Average cooking time.
	7/180-4-5	1990, 92, 93	6, 44, 13	Good yield for grain and especially plant matter. Good taste but not very sweet. Cooks slowly. Pest damage a problem. Shatters.
	KVX 61-1	1992	5	Heavy yielder but requires immediate harvest. Shatters otherwise.
	396-4-4	1990,	6, 1, 46 92, 93	Heavy yielder. Excellent taste. Disease resistent.

Peanut	QH 243C	1990	5	Good yield. Good taste.
	KH 241D	1990	11	Good yield. Taste like the local. Produces more oil than the local.
	TS 32-1	1990, 93	1, 9	Very good yield. Good taste. Good marketability.
	CN 94C	1990, 93	4, 9	Very good yield. Good taste. Good marketability.

Fertilizer and Insecticide Treatments. Tests have been conducted to assess the results of fertilizer and insecticide on varietal performance. In general, producers recognize the positive impact of fertilizer and insecticide on productivity. This has been demonstrated agronomically as well. The concern of producers has been, rather, about investing their own resources in purchasing these inputs.

In 1990, a drought year, plants treated with organic fertilizer were said to have suffered more than untreated plants. In 1991, however, mineral fertilizer applications were said to be the principal reason why varieties (local and improved) performed better in researcher-managed tests. In 1992, producers were asked to fertilize test parcels of cowpea and sorghum if they so wished. Few did.

Treating cowpea with insecticide has been demonstrated to reduce pest damage. Some 80% of the sample at Thiougou in 1992 reported that they would treat cowpea themselves to obtain high yields. There was no interest at all in Donsin in doing this that year. During 1993, interest in treating cowpea in Thiougou dropped to 45% but rose to 40% in Donsin. At Donsin, this change can be attributed to the variety of cowpea tested in 1993 — KVX 396-4-4 — which is a high grain yielder and responds better than 7/180-4-5 to producers' food security concerns. At Thiougou, producers expressed concern about the availability of the insecticide when it is needed and the difficulty of freeing up cash for purchasing it at a time when stored food is scarce and often must also be purchased.

In both villages, many producers claim to treat seeds of food crops with *Thioral*. The crops include sorghum (48% at Thiougou and 88% at Donsin), millet (52% at Thiougou and 80% at Donsin) and cowpea (24% at Thiougou and 52% at Donsin).

A test of *Apron Plus* as a seed treatment for mildew on millet was conducted in 1993. Farmers perceived that treated parcels had lower levels of mildew. At both Thiougou (85%) and Donsin (55%) the majority of sampled producers expressed interest in using *Apron Plus* again next year.

Intercropping. Sorghum and cowpea were intercropped in association in 1990 and 1992 tests. In 1990 the *R.S.P.* protocol specified that one seed of each crop be planted in each hill. In 1992, producers were asked to sow parcels as they normally would. In Donsin, seeds of both crops were placed in a gourd and sown at random. In Thiougou, generally one seed of each crop was placed in the same hole. The main advantage of the association of the two crops, according to producers, is that they can harvest something (cowpea) even if sorghum fails.

Donsin producers sowed relatively high densities of cowpea and sorghum in 1992. In the mixed plots, cowpea densities were very high and sorghum densities were very low. The village-based technician believed that they were trying to maximize production of the high-yielding seed and spray given by *R.S.P.*

Producer satisfaction with crop performance in intercropped parcels was relatively lower than for pure parcels. Cowpea was said to sometimes suffocate young sorghum plants.

Cultural Practices. Ten producers tested simple and tied ridges as measures for conserving water in 1990. They reported good water retention with tied ridges but found that the labor required by the technology could not easily be made available.

In 1991, researcher-managed tests included 10 *operations* which farmers' evaluated. The most important actions that can be taken to increase production, according to sampled farmers (in order of number of citations and cited by at least 50% of the sample), are: frequent weeding, fertilizer applications, tillage, earthing-up, and insecticide treatment.

Farmer appreciation of the impact of these actions on crop performance was one important factor in the design of the 1992 tests. In 1992, farmers managed test parcels themselves with "reminders" from *R.S.P.* technicians of the utility of frequent weeding, applying fertilizer, etc. Fertilizer applications on test parcels were few. Producers report fertilizing other parcels, however. More than one-half the Thiougou sample (67%) fertilize some of their sorghum and maize (60%). At Donsin, farmers use mulch and/or manure on some of their sorghum (92%) and maize (80%).

More than one-half (52%) the sample weeded test parcels twice; another 40% weeded them 3 times. This corresponds roughly with what producers report doing ordinarily. At Donsin, producers say that sorghum, maize, and millet are weeded twice; and cowpea and peanut once. At Thiougou, 50% of the sample claim to weed sorghum and maize 3 times; the others weed these crops twice. Cowpea is weeded twice by 56% and otherwise once. Peanut, which is largely a women's crop, is weeded once. This may indicate that women are otherwise too occupied with communal fields to devote more time to individual peanut fields.

An entire opinion survey was devoted to farmers' evaluations of zaï at Donsin in 1993. This traditional technology for recuperating degraded land for agricultural production was tried by over 70% of Donsin producers after *R.S.P.* organized a farmer-to-farmer field trip to Yatenga Province to view the technology as it is practiced there. *R.S.P.* selected 42 producers at random to interview regarding the zaï technology.

Zaï creates a favorable environment for plants on poor land. It retains moisture and fertilizes plants. *Zaï* increases germination rates, survival rates, and production. The construction of zaï is demanding of labor and organic matter and thus has important implications for other village agricultural activities.

The graphs below expresses the positive impact on villagers of the zaï technology. Yields are greater using *zaï*, according to producers. Consequently, an increased number of producers intend to try *zaï* next year.

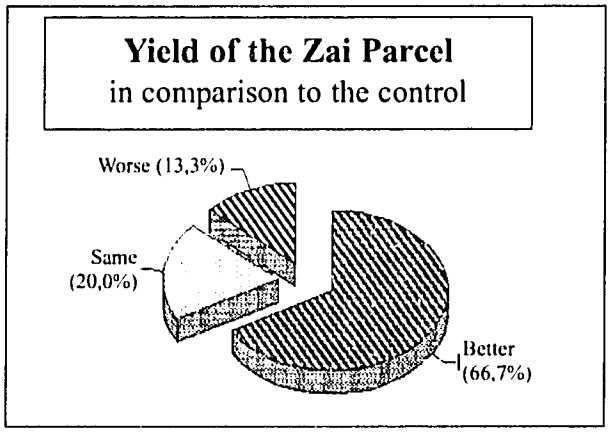

Figure .1.

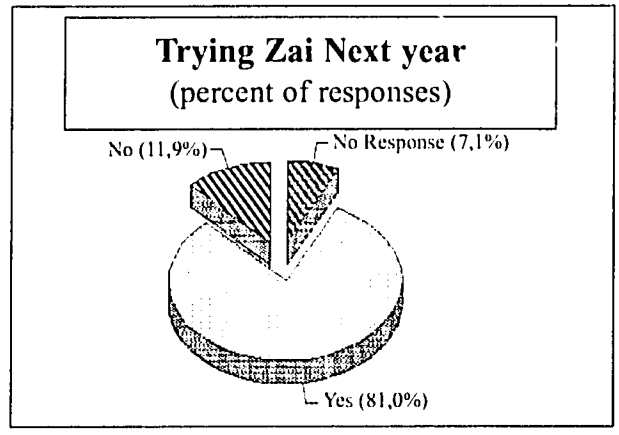

Figure 2.

While the availability of organic fertilizer, labor, and correct equipment (strong pick-axes) are factors which may limit the spread of *zaï* in Donsin, at this time producers are favorably disposed to trying it. Interestingly, 17% of the sample indicated that *R.S.P.* could be of further help by instructing farmers in how to construct zaï correctly. *R.S.P.* thus arranged another farmer-to-farmer visit in March, 1994, this time bringing Yatenga producers to Donsin to demonstrate how to make *zaï*. *R.S.P.* has also arranged for the testing of pick axe models from Yatenga.

Secondary Crop Characteristics. In 1990, producers were asked about characteristics, aside from productivity and early maturity, which they look for in a variety.

For sorghum and millet, the most important secondary quality is storability. Stover is also important, as is the taste of the grain.

Taste predominates in maize, followed by storability.

For peanut, commercial qualities are most important, and the production of plant biomass for fodder.

For cowpea, the production of plant biomass and a second grain harvest are equally important, followed by the grain's commercial qualities.

Interest in Adopting Tested Innovations. This fundamental question is asked each year, although the formulation of the question has changed with time and experience.

Typically, few producers if any are ready to adopt a tested innovation after one or even two years. Questions about *trying* an innovation again the following year are likely to be answered positively if *R.S.P.* is furnishing seed and materials. In 1992 and 1993, producers were asked if they would replace a local variety or practice with a tested innovation. A positive response to this question indicates a readiness to adopt. A negative response may mean an innovation is not appreciated or, instead, that the producer wants to test it again along with his usual practice. If

a tested variety produces better than a local variety, for example, the farmer may wish to test it again before committing himself to adopting it.

In 1990, an open question was asked regarding interest in "adopting" a tested theme. Seventy-five percent of the sample responded positively to participating again in a test.

In 1991, 91 of 92 partners expressed interest in continuing to work with *R.S.P.* That year they had witnessed the productivity of researcher-managed tests and were impressed with the importance of frequent weeding and fertilizer applications. However, these same farmers subsequently revealed that they were not ready to adopt these practices themselves.

In 1992 there was considerable interest in Thiougou in the dual purpose cowpea variety. Some 76% of the sample was in favor of testing it again. The figure for Donsin was 24%. Tested sorghum was of interest to 40% of the producers at Thiougou but none at Donsin. The intercrop was of interest to 30% of Donsin producers, perhaps because they saw another opportunity to obtain valuable cowpea seed. Only one producer at Thiougou expressed interest in intercropping cowpea and sorghum.

Producers at Donsin overwhelmingly (88%) favor a variety of cowpea which can be harvested repeatedly. At Thiougou, 40% showed interest in a cowpea variety which can be harvested for fodder after one grain yield. A relatively large proportion of producers at Thiougou, 44%, expressed interest in devoting a parcel to cowpea exclusively for fodder There was essentially no interest in doing this at Donsin. Again, this interest in forage cultivation appears to be linked to the presence or absence of draft animals and equipment in the production unit.

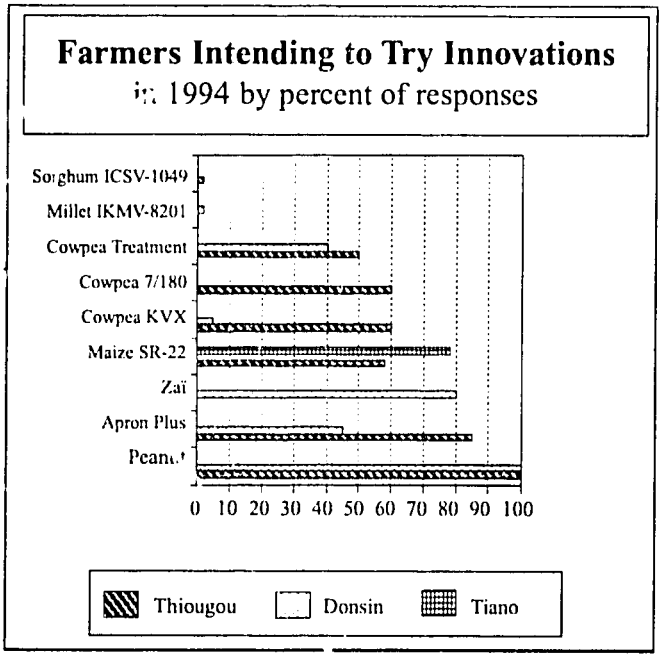

Figure 3.

Both cowpea varieties (the high-yielding KVX 396-4-4 and the dual purpose 7/180-4-5) performed well in 1993. Some 60% of the sample at Thiougou reported to be ready to replace the local variety by a tested variety. At Donsin, interest in testing the improved varieties again was strong even if villagers were not yet ready to replace the local variety by the improved one (KVX 396-4-4). Interest in treating cowp . was also strong, over 40% at both sites.

Producers in neither village were prepared to replace local sorghum and millet with tested varieties. Interest in adopting new maize varieties was high, however, at Tiano (75%) and Thiougou (58%).

Interest in using *Apron Plus* was high: 85% at Thiougou and 55% at Donsin. Discussions with producers at Donsin more recently suggest that they may not yet be willing to purchase and use *Apron Plus.*

Tested peanut varieties were preferred to local varieties by 89% of sampled women producers.

Figure 3 summarizes the "adoptability" of tested innovations in 1993.

Response Differences by Village. Producers' responses to tested innovations vary according to village. This is not surprising, given that villages research sites have been selected largely on the basis of differences in their agro-ecological conditions (Table 3).

Table 3. Average and annual rainfall at r.s.p. village research sites

SITE	ZONE	AVERAGE ANNUAL RAINFALL 1970-1990	Rainfall			
			1990	1991	1992	1993
Donsin	Sudano-sahelian	647 mm	537	766	631	646
Kamsi	North Sudanian	741 mm	571	1070	940	732
Thiougou	South Sudanian	732 mm	577	1054	904	686
Tiano	Sudano-Guinean	848 mm	n/a	n/a	n/a	668

General questions in 1990 on farmers' appreciation of on-farm tests and their interest in continuing to collaborate further with R.S.P. were not revealing of differences at the village level. Positive responses were obtained for Kamsi (69%), Donsin (73%), and Thiougou (79%).

In 1991, the nature of the tests — farmer managed versus researcher managed — and the closed-ended format used in the opinion survey revealed important differences between villages. For example, whether or not a farmer uses animal traction influences his evaluation of a technology. This single characteristic served to distinguish Thiougou in 1991 and helped to explain why farmers' responses there differed markedly from villages with little animal traction.

Thiougou producers expressed greater readiness to adopt more intensive practices than producers in the two other villages. Acceptance rates for intensive operations (on at least one field), such as tillage, fertilizer applications, and frequent weeding ranged from 65% to 100% of sampled household heads at Thiougou. Rates in the other villages were much lower, between 7% and 57%. *R.S.P.* used this information for planning the 1992 campaign and to assess the results of that year's campaign.

Differences between Thiougou and Donsin were clearly evident in 1992 (tests were not conducted at Kamsi that year). Crop performance was better at Thiougou and producer responses to survey questions were consistently more positive at Thiougou. Interest in sowing tested varieties, for example, was at 40% for sorghum and 76% for cowpea at Thiougou. Corresponding figures at Donsin were zero and 24% respectively.

As reported earlier, Donsin producers expressed no interest in investing in insecticide for cowpea, while 80% of Thiougou producers were interested in 1992.

Researchers concluded that the forage/grain cowpea variety was of greater interest at Thiougou than at Donsin because of the importance of animal traction in Thiougou village (a reason cited frequently by farmers). At Donsin, farmers emphasized the importance of grain production for human consumption. These explanations are supported by survey results from the 1993 campaign. A high-yielding grain cowpea variety, KVX 396-4-4, was tested at Donsin. It was reported to out-perform the local variety by 65% of the sample. Some 40% of the sample now indicated a willingness to invest in insecticide treatment. This contrasts sharply with results from the previous year's opinion survey, suggesting that Donsin producers will pay for inputs if they improve food security.

Cereal performance and farmer interest in tested cereals also exhibits important variation by village. Millet (IKMV 8201) at Donsin was least appreciated. Sorghum at Thiougou performed relatively better. The strongest performance of a cereal crop was maize at Tiano.

Interest in *Apron Plus* also varied between Thiougou and Donsin. Some 85% of the sample at Thiougou is ready to use it next year compared to 55% at Donsin. Mildew on millet is judged to be more of a problem at Thiougou than at Donsin.

The test of *zaï*, as discussed earlier, was also a response to producers' interests in a specific village (Donsin). Soil degradation in Donsin and decreasing levels of production are conditions motivating farmers to take actions to recuperate degraded land.

<u>Response Differences by Farmer Status.</u> Statistically significant differences appear on the 1992 survey according to a producer's status, that is, whether a new or continuing partner.

Continuing partners generally respond more favorably to tests and employ more intensive agricultural methods. Thus, continuing partners treat cowpea, fertilize fields, fertilize test parcels, stock stover, and are interested in substituting tested seed for local seed all at significantly higher rates than for new partners.

This suggests that there is a tendency for first time partners to be somewhat skeptical about *R.S.P.* research. This skepticism abates with time and exposure to and involvement in research. This evolution is encouraging for research and development and supports the notion that farmers gradually open up to innovation that is worth their while through regular and continued contact with *R.S.P.*.

Producers' Assessments of the State of Village Natural Resources. With increasing frequency since 1990 villagers have informed R.S.P. of their concern about diminishing and deteriorating natural resources: rainfall, soils, forests, and pasture. It has become apparent that without actions to address the resource base, R.S.P.'s efforts to introduce improved and sustainable agricultural practices will not succeed. It is thus that in the 1992 opinion survey, at Donsin and Thiougou, questions were asked to elicit producers' perceptions of the current state and evolution of natural resources in comparison to the past. A complete inventory of producers' responses is found in the opinion survey report (May 1993). Summarized below are the most frequent responses.

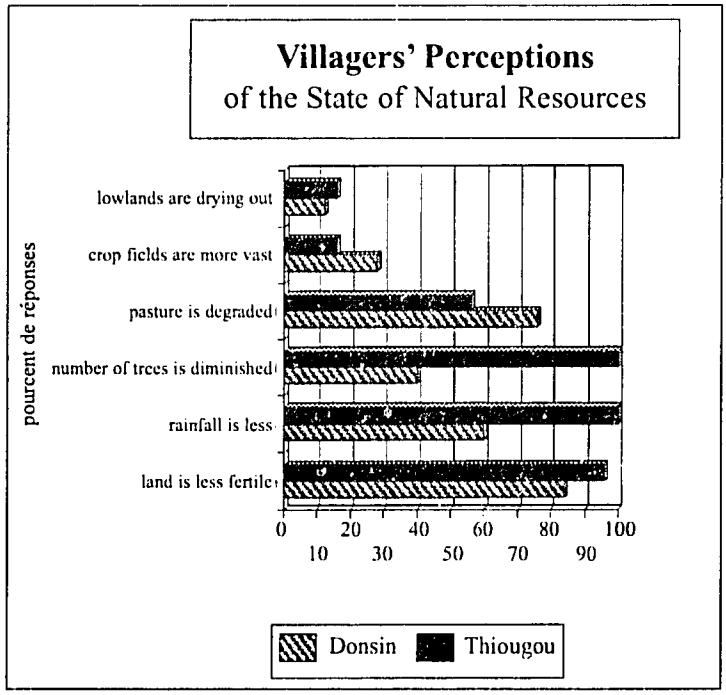

Figure 4.

R.S.P.. has responded to this situation with village research programs targeted more on both additional diagnostic activities and possible interventions for arresting or reversing resource degradation. The introduction of zaï and revegetation of rock bunds in Donsin, as well as the regeneration of degraded bush land and severely eroded land, at Thiougou and Donsin respectively, are examples of regenerative land management activities.

The 1993 opinion survey inventoried actions producers take to address resource degradation. Producers' responses for Donsin and Thiougou villages are shown in the graphs below. *Natural*

regeneration and *transplanting* describe efforts to increase tree cover. Obstruction is a technique for slowing water run-off and erosion.

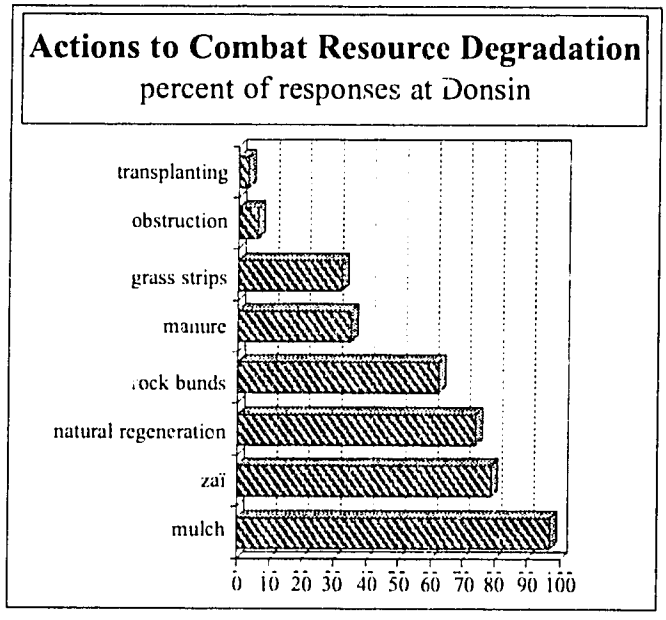

Figure 5.

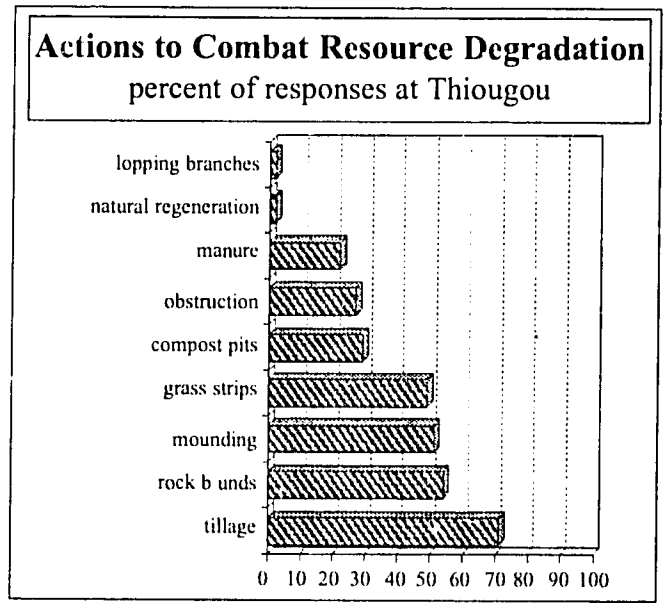

Figure 6.

Villagers have given *R.S.P.* a clear mandate for the future to address issues of resource degradation. At Tiano, too, over 70% of sampled farmers are using grass strips to reduce erosion and permitting trees to regenerate naturally. *R.S.P.* research actions which respond to farmers' concerns about natural resource degradation, in addition to varietal and other on-farm tests, will assure that village partners remain interested in the *R.S.P.* program.

IV. CONCLUSIONS

Villagers at *R.S.P.* research sites have consistently exhibited interest in collaborating with *R.S.P.* since 1990. High rates of volunteerism for on-farm tests plus opinion survey results substantiate this. The changing orientation of villagers and *R.S.P.* toward education and increased know-how in addition to the provision of inputs (such as seeds, fertilizers, and insecticides) is another indicator of progress.

While overall farmer response to participating in *R.S.P.* tests was good in 1990, with 66% of the sample indicating their interest in doing so again in 1991, it wasn't until 1991 that partners were asked about the kind of test which interested them.

In the graphs below the changing interests of farmers are indicated. When farmers were asked in 1991 about the kind of activity they would like to undertake with *R.S.P.* in 1992, responses were limited to varietal tests: sorghum, millet, or grain legumes (Figure 7). *R.S.P.* brought new seeds to the village and, it is apparent from four years of work, farmers are always interested in trying new varieties. The villagers' perception of *R.S.P.* at that time was as a provider of new varieties only.

The same question asked on the 1993 survey elicited the responses in Figure 8. While interest in seed (*inputs*) is still strong, interest in agricultural equipment, animal health, and, notably, training and awareness demonstrate that *R.S.P.* is changing the way it works with villagers. Its coverage is broader and it serves to instruct and influence villagers' awareness of problems and possible solutions to them.

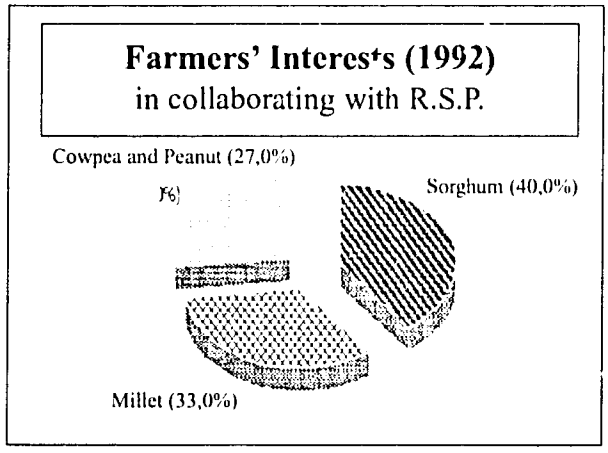

Figure 7.

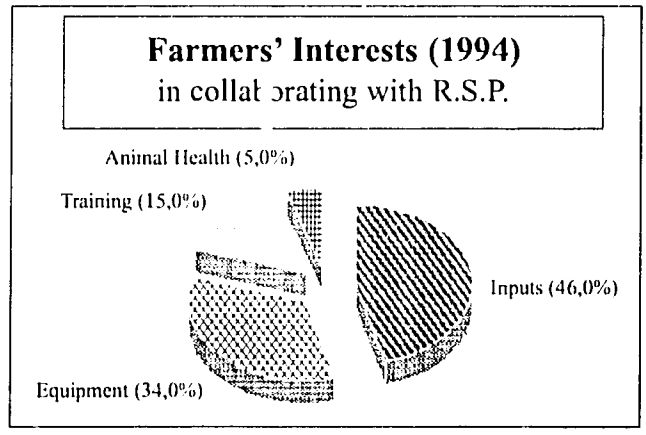

Figure 8.

By continuing to improve dialogue with villagers *R.S.P.* is certain to respond to their interests and needs. By branching out and including women producers and unmarried males as partners, *R.S.P.* will demonstrate its interest in village agricultural development. *The Farmer Opinion Survey* has been one tool by which *R.S.P.* has identified the concerns of villagers and assessed their responses to R.S.P.'s efforts to address those concerns. This survey must continue to be an integral part of the annual research program if it is to continue to serve these important ends.

Women's Agricultural Strategies in the Central Plateau, Burkina Faso

M.-C. Sorgho and E. Robins

ABSTRACT

A major effort has been devoted to incorporating women's issues into the consciousness of development over the past two decades. Gender analysis and a focus on the household as central decision-making unit have helped to elucidate the differences in women's and men's roles, and the interplay of social, economic, and technical factors in agriculture and natural resource management. Yet it is only occasionally noted that all women are not alike. It is necessary but not sufficient to perform gender analysis. It is equally necessary to analyze social and economic variation among women. This paper reports on the first phase of a research project designed to reveal women's agricultural strategies in the Central Plateau, Burkina Faso. The results of research on a sample of 227 women show that women's agricultural and economic activities have changed in important ways in the course of a generation. Younger women have their own fields from which they produce marketable products. The income they derive is used to satisfy cash needs, such as for school supplies, clothing, and health care for children. Women's market activities and associated travel render them more independent than women of the past. Constraints to women's development still exist, however. Literacy is nearly totally absent, investment in livestock and equipment is low, and individual parcels are on poor soils.

I. INTRODUCTION

More than twenty years have passed since Boserup's seminal work called into question the assumption that women, equally with men, would benefit from the development of third world economies (*Women's Role in Economic Development*, 1970). That uncertainty generated two decades of activities directed at increasing our understanding of women's circumstances and roles in order to improve their social and economic welfare. While it is still evident that social inequities exist -- women have less access to land, capital, credit, technology, and training, for example -- an extensive literature is testimony to the resources which have been devoted to incorporating *women's issues* into the consciousness of development (Droy 1990).

The facts which justify this orientation are now well known: the majority of the world's food producers are women; 70% of all agricultural labor in Africa is performed by women; women are producers, processors, and sellers of agricultural products; women manage crops, livestock, fuel, and water; up to 30% of all African rural households may be headed by women (Blumberg 1992; Spring 1986; Guyer 1984). The development of women, it is evident, is essential to the development of agriculture.

Gender analysis has proven to be an effective way of understanding women's (and men's) roles and the interplay of social, economic, and technical factors in agriculture and natural resource management. The focus on the household as central decision-making unit has helped to portray women as agents of change. Data disaggregation by gender reveals women's activities and the economic consequences of

their efforts. Studies in Burkina Faso (McMillan 1986) have shown that women grow on their own parcels alone 13% of the food grains, 16% of the rice, 66% of the beans and peanuts, and 100% of the vegetables produced by the household. Women re not given equivalent attention from agriculture research and extension (Brux 1991).

It is only occasionally noted that all women are not alike (Thomas-Slayter 1992, Spring 1986). Attention to the gender category, which can reveal the differential impact of development and, accordingly, the conditions which constrain women, may nonetheless disguise differences among women of different circumstances. This is to say that rural women are not a homogeneous group, and that it is necessary but not sufficient to perform gender analysis. It is equally necessary to analyze social and economic variation among women to ascertain, according to their different circumstances, their different interests and different needs.

This paper reports on the first phase of a research project on women's agricultural and economic strategies in the Central Plateau, Burkina Faso. The conceptual framework and methodology are described first, after which follows a discussion of research results based on a sample of 227 women from the village of Donsin.[1]

II. CONCEPTUAL FRAMEWORK AND METHODOLOGY

The research employs quantitative and qualitative analysis to compare and contrast women's circumstances within and among three villages. Differences, if any, in agricultural and economic pursuits may be associated with other differences in women's situations (for example, number and age of children or size of production unit). Different strategies may be inferred from different sets of significantly associated variables. Differences which vary at the level of the village may result from different agro-climatic conditions and proximity to major commercial and development centers.

Each of the three villages selected for study -- Donsin, Kamsaonghin, and Thiougou -- is located in a different sub-zone of the Central Plateau. Donsin is in the north Sudanean zone where annual rainfall is generally between 650 - 750 mm. There has been considerable degradation of soils at Donsin. It is also the most isolated of the three villages, being 20 km on bush track from the provincial capital, Boulsa. Kamsaonghin is found in the center sub-zone where average annual rainfall is higher, 750 - 850 mm. It is 15 km from Pouytenga, a major commercial center for regional West Africa. Thiougou is located in the southeast of the plateau; annual rainfall is 800 - 900 mm. Thiougou is 17 km from Manga, an important commercial and development center.

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[1] Donsin is 235 km from Ouagadougou. It consists of 7 *quartiers* each headed by a chief. They are all appointed by the chief of the village. The name *Donsin* means *many néré* (*Parkia biglobosa*).

This study is limited to villages of the Central Plateau, the research zone covered by the Central Team of the Production Systems Program (RSP) of the Institute of Agricultural Research and Studies (IN.E.R.A). One of the authors speaks *Mooré*, the language of the predominant ethnic group of the region (the Mossi), and conducted interviews at the research sites.

In May, 1991 the authors began interviewing women to clarify research themes and test questions. A sample of 227 women, or 67% of the adult female population of Donsin, was selected for study. Forty of these women were interviewed in detail.

The study focuses on two sets of variables: observable and measurable elements of *agricultural behavior* (i.e., *dependent variables*) and the socio-cultural factors which potentially are determinants of them (i.e., *independent variables*).

Agricultural behavior is defined by:

- number of common fields, which women cultivate under the management of the household head and which may indicate the size and composition of the production unit;
- number of individual fields, which women cultivate and manage themselves and which may vary according to family situation (e.g., presence of co-wives, number of children, etc.);
- choice of crops cultivated, which is a function of the family's food consumption habits, soils, location of parcel (e.g., near the homestead or in the bush), and other factors;
- products transformed, which indicates family needs, market demand, product availability, cash availability, individual know-how, and other factors;
- livestock raised, which indicates a certain level of wealth;
- equipment owned, which may be of importance in some villages but, in the case of Donsin, is not (i.e. women do not own equipment in Donsin); and
- commercial transactions, which may be an important source of personal income (monetary and otherwise).

The socio-cultural factors which may determine agricultural behavior are:

- customs and ethnicity, which may condition agricultural and economic options;
- village of origin, which may define of agricultural behavior and access to production resources;
- age, which may define agricultural activity;
- number and age of children, which may define production and income requirements;
- number of co-wives, which may define production requirements and access to resources;
- size of household labor force, which may define production requirements and access to resources;
- age of husband, which may be an indicator of household wealth, number of wives, and size of labor force; and
- household wealth, which may define access to resources.

The hypotheses exposed by the definition of *agricultural behavior* and the socio-cultural variables which are potential determinants of it focus on 1) differences in women's current social and economic circumstances, 2) differences in women's age, and 3) village of current residence.

III. RESEARCH RESULTS

Based on the data collected in the survey of 227 village women, the following results are noted.

Age, Agricultural Activity, and Family Dynamics. Eighty percent of older women surveyed report that women today are considerably more commercially active than when they were young. This is a major research finding. They attribute this to 1) reduced rainfall and the need to work harder to produce the same amount, 2) the consequent increased dependency of men upon women as agricultural partners, 3) men allocating women personal fields to supplement production from communal fields, and 4) the sale of products from personal fields to meet increasing cash needs. Women have more of their own cash than ever before.

Agricultural Activities. Younger women, and thus those with school age children or younger, cultivate more parcels, both common and individual, than older women. Regression analysis yields a value of F = 58 10 which is significant at the .00 level. For each increase in age of 1 year, a women will cultivate .089 fewer common parcels. The number of individual parcels cultivated also declines with age but the relationship is somewhat less strong.

The younger one-half of the sample is cultivating 60% of the common fields (Table 1). They cultivate 52 % of the individual fields in the sample. It is noted that young women, just after marriage, work for at least two seasons on common fields before they are given fields of their own.

Table 1. Total Number of Parcels Cultivated by Women of Different Ages

Parcels by Woman's Age	Age 17 - 31 (N = 114)	Age 32 - 90 (N = 109)	Total
Communal	732.60	481.40	12131.00
Individual	507.52	459.48	9661.00
Total	1239.57	940.43	21791.00

Women who are members of larger production units also cultivate a greater number of parcels, both individual and communal. They are cultivating 59% of the total number of parcels and 63% of the communal fields (Table 2).

Nearly one-half the women sampled report that they alone, or they in collaboration with their husbands, decide which crops to plant in communal fields. The decision about which crop to raise in individual fields is theirs alone. These decisions are based on the needs of themselves and their children, as well as on the physical condition of the field.

Table 2. Total Number of Parcels Cultivated by Women of Different Prod. Units

Parcels By Size of Production Unit	Prod. Unit 1-8 Members (N = 111)	Prod. Unit 9-32 Members (N = 112)	Total
Communal	454 .37	759 .63	1213 1.00
Individual	437 .45	529 .55	966 1.00
Total	891 .41	1288 .59	2179 1.00

Younger women (approximately one-half the sample, between the ages of 17 and 31) are members of larger households (Table 3). They cultivate a greater number of fields and are more commercially active than older women.

Table 3. Size of the Production Unit to Which a Woman Belongs

Age by Size of Production Unit	Age 17 - 31 (n = 114)	Age 32 - 90 (n = 109)	Total
Total Number of Persons in Production Units	1343	884	2227
Average per Production Unit	11.8	8.1	10.0

Transformation and Commercialization. Approximately 85% of the sampled women market products. Younger women are more commercially active. Of the three products most often marketed by Donsin women -- cowpea fritters (*beignet*), sorghum or millet biscuits (*galette*), and shea nut butter (*beurre de karité*) -- only the *karité* is marketed equally by older and younger women. The sellers of *beignet* and *galette* are more often younger women. Women necessarily market products to satisfy cash needs for children's clothing, health care, and school supplies. Home consumption by children of fried *beignet* and *galette* is another reason why these foods are prepared by younger women.

Animal Husbandry. There is no interdiction against women raising livestock at Donsin, although such prohibitions operate in other villages. Women are reticent to reveal the *number* of livestock owned, however, for fear of bringing calamity on them. About one-half the sample raises chickens, and about one-third raises goats.

Cultural Factors: Religion. Women say that religion opens the door to new ideas and practices and can make women more independent. About one-half the sampled women are animist; most of the remainder (37%) are Moslem. A small percentage are Catholic or Protestant. The relationship between religion and agricultural behavior will be a theme of a future investigation.

Cultural Factors: Ethnicity. The question of ethnic "sub-group" affiliation was not sufficiently pursued by enumerators. Thus, for only 9% of the sample was a sub-group affiliation obtained. This will be addressed again in future research.

Matrimonial Status. Nearly all village women are married or remarried. Given that the general practice is still for a husband to be chosen for a woman, divorce is one means for a woman to rid herself of a man she has not selected. A woman, thus, may leave her village of origin, or return to it, after divorce. In either case, her agricultural practices may change. Thirteen percent of the sample in the informal survey was divorced. This will be pursued further in future research.

Literacy. Two women (one Catholic and the other Protestant) of the sample of 227 are literate. Literacy may prove to be a factor in determining women's agricultural behavior in the other villages.

Village of Origin. The women sampled in the formal survey come from 60 different villages. No clear relationship was established between village of origin and agricultural behavior.

Family Wealth. Socio-economic profiles of village production units recently have been prepared by RSP. The next sample of women will be stratified according to relative wealth.

IV. CONCLUSIONS AND PERSPECTIVES ON FUTURE RESEARCH

The research conducted in Donsin reveals several processes which demonstrate women's greater agricultural autonomy and financial independence, and decentralization of household decision-making. Fundamental constraints to their further development still exist, however.

- Women's agricultural and economic activities have changed in important ways in the course of a generation. Younger women have their own fields from which they produce marketable products. Thus, they have cash to satisfy their own cash needs and those of their children.

- Cash needs are greater for women with children, for whom they purchase school supplies, clothing, and health care.

- Women's market activities and associated travel render them more independent than women of the past.

- Schools, Islam and Christianity, and development projects also contribute to opening a woman's world.

- Reduced rainfall and degraded soils have made agriculture more difficult than in the past. Women have more responsibility for agricultural production than before. Men are more dependent upon women to meet production goals. For these reasons, men are more "respectful" of women today.

- Literacy, which is known to be a fundamental factor in raising the well-being of women and their families, is essentially absent at Donsin and represents a major constraint to women's development.

- Women own livestock, especially chickens and goats, but in small numbers. Women probably have not yet accumulated sufficient cash to purchase more and other types of livestock.

- No women in Donsin own agricultural equipment (few producers in Donsin use animal traction). It is not likely that they possess the capital to make such investments.

- Women's individual fields are of poor quality. Their decision about which crops to grow is in part a function of need (for food and cash, for example) and in part a function of their access to land of good quality.

Given that the research was also a test of methodology, some results are informative of methodological issues and may serve as a guide to improving future research.

- We believe it is important for a woman researcher or enumerator to collect data from village women. For open questions and interviews, especially, this is essential for obtaining reliable information.

- Determining the *age* of women or children is problematical. A woman generally possesses an identity card which includes a date of birth. It sometimes appears unlikely that a particular woman is of a particular age. A discussion of important events the woman remembers from her youth can help to pinpoint the time of her birth. Mostly, the date on the card was generally the best information we had.

- The date of a child's birth often is unknown. We established classes: *nursing*, *weaned*, and *of school age*. Older or married children were generally classed as *absent*. We now believe it is necessary to know where the older children are. A married son living nearby, for example, has a wife who may work with the woman respondent (that is, the woman's daughter-in-law works with her mother-in-law).

- Questions about whether a crop is consumed by the family or marketed must refer to the previous year's agricultural campaign. Most of the harvest for cereals is stored and may be consumed or sold depending on other circumstances. Questions about the allocation of a recent harvest are not likely to be fruitful.

- In villages which are closer to commercial centers and more developed than Donsin women may have greater social and economic opportunities.

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Performance of Several Sorghum Lines Under *Striga hermonthica* Infestation: Preliminary Results from Kawara, Burkina Faso

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ABSTRACT

Sorghum (*Sorghum bicolor* L. -Moench), a major crop in terms of surface area cultivated and production in West Africa, significantly suffers from infestation by a parasitic plant known as *Striga hermonthica*. This reduces yields and eventually requires fields to be fallowed. Among control alternatives for this parasite, sowing varieties which discourage *Striga* emergence may be the most feasible and least expensive practice for farmers. The objective of this study was to test improved, *Striga*-resistant germplasm and to assess their productivity and level of resistance in a *Striga* infested environment. Six sorghum lines originating from the International Sorghum and Millet Collaborative Research Support Program (numbered 173, 191, 203, 215, 239, 269) at Purdue University were tested with a local variety control. Treatments were laid out in four randomized complete blocks in a village of southwestern Burkina Faso, West Africa. Tests were conducted on sandy soils in a field formerly abandoned by the farmer because of its high level of *Striga* infestation. Compared with the local variety, the introduced germplasm displayed compact grain heads, short and stout stems, and grain of larger size and of pearly-white color (instead of the white of the local control). Two to six *Striga* plants/m^2 were observed in plots sown with the new lines as opposed to an average of 31 plants/m^2 in plots sown with the local variety. Considered together, the new lines produced 242% of the grain yield of the local variety and 164% of the gross economic yield (gross value of stover and grain). These preliminary results show a high potential for *Striga* control through the use of adapted, *Striga*-resistant varieties.

Key words: *Striga hermonthica*, plant resistance, integrated pest management, parasitic plants, weeds, West Africa.

I. INTRODUCTION

Among the staple crops of Burkina, sorghum ranks first in surface area cultivated and total production. It is the basis of the diet of the majority of the country. In general, population increase has resulted in rapid expansion of cultivated area, and in order to satisfy food security requirements farmers must cultivate these lands virtually continuously

One of the most virulent parasites in the area is *Striga hermonthica*, a parasitic weed of several annual grasses. The lack of rotation may have encouraged the gradual buildup and infestation of *Striga*. *Striga* seed germination is stimulated by germinating sorghum, millet or maize seeds in the soil. Striga roots grow toward the sorghum roots, penetrate them, and establish haustoria. Through this mechanism, *Striga* plants feed themselves by drawing on sorghum sap, and emerged

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plants then multiply by producing large numbers of tiny seeds. The impact of high infestation levels on host yields can be dramatic. Therefore, *Striga* is often cited as one of the main agricultural production problems in Burkina Faso (RSP Zone Ouest, 1993).

Traditional control of *Striga* is limited to hoeing and pulling of *Striga* plants, as well as soil fertilization and rotation with non-host crops or fallow. However, damage to the host starts before *Striga* emergence. In addition, weeding does not destroy the whole plant; *Striga* can, thus, grow again and produce seeds. Pulling of *Striga* has the disadvantage of uprooting host plants or breaking host roots, which reduces yields. These two methods are labor-intensive.

Research in the region confirms the effectiveness of soil fertilization with chemical or organic fertilizers to reduce *Striga* infestation level. As far as weed control is concerned, chemical weed control with 2,4-D is advised. Unfortunately, obtaining fertilizer in sufficient quantity for the treatment of all fields which need it is not easy for farmers. Also, few farmers can afford the purchase and manage the application of 2,4-D. The remaining practicable solutions for farmers are the possibility of *Striga*-resistant or *Striga*-tolerant varieties. The objective of this study was to test sorghum germplasm reported to be *Striga*-resistant and to assess its yield potential and level of attack in a highly infested environment.

II. METHODOLOGY

Area selection was based on observations during the 1992-93 campaign, which revealed a high *Striga* infestation level on many farmers'fields in the Southwestern part of Burkina Faso, where soils are dominantly sandy. Tests were conducted in the village of Kawara, located in this region. Field selection was guided by farmer's identification of exhausted, *Striga*-infested land that had been fallowed, as well as observations of the field by researchers during 1992-93. The six lines tested were numbered 173, 191, 203, 215, 239, 269, and originate from the International Sorghum and Millet Collaborative Research Support Program's sorghum breeding program. The most widely planted local white sorghum variety from Kawara was used as control. These lines and the variety were laid out in 4 randomized complete blocks. A dose of 100 kg/ha of fertilizer (14-23-14-2-1, N-P_2O_5-K_2O-B-S) was applied and incorporated at the onset of the season. In-row spacing of hills (thinned to 2 plants per hill) was 50 cm and rows were 80 cm apart from each other, creating a density of about 50,000 plants/ha.

The main measurements were as follows:

- Count of *Striga* plants (in quadrats of 50 cm × 50 cm for heavily infested plots and in whole plots of 2.4 × 10 m for slightly infested ones).
- Mean plant-height measurement at harvest time.
- Harvesting and weighing of stover and grain.

Economic yield was calculated on the basis of market prices at harvest time. Statistical analysis was analysis of variance including orthogonal comparisons. These comparisons determine the significance of the difference between tested lines (taken together) and the local control, (noted as "Local vs. lines" in Table 1), and among the various lines (appearing as "Among lines" in Table 1).

III. RESULTS

In general, the tested lines are all of the same plant type, which is different from the guinea-type sorghum variety in the village. All resistant lines are of the caudatum type, with compact heads and relatively early maturity. Grains of these lines are pearly-white, while those of the local variety are white and smaller in size. Table 1 presents the results of the test. Stalks of the lines are relatively short (on average 41% of the local variety's height) and stout (stover biomass weighs 132% of the local variety's biomass, in spite of greater stalk height).

The number of *Striga* plants in plots confirmed the vulnerability of the local sorghum variety to *Striga* infestation. *Striga* density averaged 31 plants/m^2, while the average was 4 plants/m^2 for all lines taken together, and 2 plants/m^2 for line 203 (the least attacked) alone. This suggests that these lines do not stimulate *Striga* germination as much as the local variety. They contribute to the reduction of *Striga* reproductive (seed production) potential, and so decrease the infestation level for the following season. Additionally, the inhibition of parasitism increases sorghum yield potential.

This increase was noted in grain production of the various lines (average of 564 kg/ha), which was 242% of the yield of the local variety (233 kg/ha). The generally low yield level should be regarded within the local context of infertile, sandy soils that are common on the older fields of the area. It is likely that the applied fertilizer did not fully alleviate fertility constraints.

Table 1. Means of principal variables:

Variety/ Line	Striga	Sorghum Height	Stover biomass	Grain yield	Economic yield[1]
	(No./m^2)	(m)	(kg/ha)	(kg/ha)	(F CFA)
173	2.7	0.96	2624	593	61123
191	4.1	1.34	4354	625	83500
203	1.8	1.02	3056	457	59540
215	3.4	1.13	2797	624	64761
239	5.7	0.80	2406	504	54084
269	6.3	1.48	3907	582	76002
Local	30.9	2.72	2417	233	40667

Mean Lines	4.0	1.1	3191	564	66502
General mean	7.8	1.35	3080	517	62811
Lines as percent of local	13%	41%	132%	242%	164%
Effect	Probability of a larger F value				
Local vs. Lines	<0.001	<0.01	0.011	0.007	<0.001
Among lines	0.025	0.004	<0.01	0.8	0.027

[1] Economic yield = (grain yield × 50) + (stover biomass × 12)

Economic yield is calculated from the value of grain and stover produced in the various treatments and is based on market prices at harvest time. The local variety produced a value of 40,500 F CFA/ha. In contrast, the various lines ranged from 54,000 to 83,500 F CFA/ha, with an average of 66,500 F CFA/ha (164% of the local variety). This represents a clear advantage to farmers.

IV. CONCLUSION

The performance of tested sorghum lines in a *Striga*-infested field was superior to the local control. This suggests the possibility of reducing future infestations while offering higher production than a local sorghum variety. However, the compact form of grain heads may result in susceptibility to head rots. Also, the performance of these lines should be evaluated in the local farming system. Finally, the culinary acceptability of lines has yet to be confirmed among Burkinabè consumers.

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Analysis of the Production System and Farming of Rice by Women in Southwestern Burkina Faso: The Case of Kawara Women in the Comoé

A. Sidibé

I. THE PROBLEM

Rice is a cereal which plays an important role in the agricultural economy of Burkina Faso. In fact, one notes a very large disparity between levels of domestic production and consumption. In 1989/90 the production of paddy rice was estimated at 40,000 tons, whereas consumption was about 80,000 tons. From these figures, it is clear that the country cannot meet more than half of the rice requirement of its consumers. In 1988 the value of rice imports was about 10 billion Fcfa. This represents about one third of the total value of imported agricultural products.

Faced with this balance of payments deficit, the State of Burkina Faso has undertaken to promote rice production within the context of its comprehensive policy to reorient agriculture toward natural resource management. This policy of promoting rice farming came up against the problem of making the local rice competitive with imported rice. The cost of imported rice was in fact inferior to the production cost of domestic rice, which was being subsidized to encourage domestic production. Today rice production has been favorably affected by the monetary policy of devaluing the CFA franc. It is thus important to strengthen knowledge about production systems with a view to formulating a policy to intensify rice farming.

Furthermore, in several regions, rice farming has been the prerogative of women. Unfortunately, the role of women in agricultural production is generally little known. However, it has been shown that this role is appreciable. Wesphal (1988) has, for example, shown that 80% of Liberian rice was produced by women. Hertz (1989) explained that the difference in the average agricultural productivity of women as compared with men was less than about 5%. In Burkina Faso, women also play an important role in rice farming, especially on the improved, irrigated perimeters of the Western Plains. Even so, studies on production systems have attached little importance to women. Indeed, because of this omission, one may well wonder about the efficiency of their production system and the real significance of their contribution to agricultural knowledge. To rectify this, the present study aims to contribute to the knowledge of rice production systems used by women in the lowlands (bas-fonds).

II. THE SITE

Kawara is a village in the Southwestern Burkina Faso. It is situated on the Banfora-Baguéra highway, which divides the village in two, for a two-kilometer stretch. It is in the Sindou department(7 kilometers from Sindou) in Comoé province. It is bordered by the villages of Sindou-Koroné to the North, Timba to the West, Konadougou and N'Pogona to the South, and Sindou, the regional capital, to the East. *(Refer to map marking the sites).*

The 1990 census, undertaken by the Farming Systems Program (RSP) of the INERA (Agricultural Research and Study Institute) records a population of 1186 for Kawara, a figure which breaks down into the following ethnic groups: 34% Dioulas, 30% Senoufos, 20% Natioros, 10% Samoghos and 2% Peuhls (INERA/RSP 1991).

The climate of Comoé province is tropical, of the Sudanese-Guinean type. The average annual temperature is 27.2°. The rainy season starts in March/April and ends in October/November. Kawara's rainfall, as measured by the RSP Program (1990-93), records a quarterly average of 1026.9mm, for 76.5 days of rain.

Farmland in Kawara is on mainly sandy-clay soil. This is due to the fact that the village is situated in a basin, encircled from North to East by a chain of hills and on the South to the West by lowlands, thereby causing a toposequence which favors the build-up of sand, especially over marshy zones.

From a socio-economic point of view, the organization of the village of Kawara includes five independent groups:

- The Village Group (GV) - a male-only group, including 182 members, 92 of whom are young men. The principal activities of this group are farming corn, millet, sorghum and sunflowers on the collective fields; communal reforestation; the management of a cereal bank; and the organization of a self-managed cotton market.

- The women's village group (GVF), includes approximately 100 members, and was founded in 1985. Their activities are shared between communal reforestation, farming of a collective rice paddy for Natioros and Sénoufo women, the communal preparation of dolo[1] by Samogho women, a collective pottery for Dioula women (who are *griots*[2]), and also a jointly managed mill.

- The GJA - the Group of Young Farmers, is a mixed group, with 30 members. Its main activities include collective reforestation, collective farming of a sorghum and a rice field, the management of a cooperative savings and loan (Coopec). The United Rice-farmers Group (UGR), is an offshoot of the Rice-Farmers Group (GR), which brings together farmers from three villages on the Badini plain, i.e.: from Sindou, Kawara and Konadougou. This group includes 77 members and is led by a board of 7 members. Their activities include the marketing of rice, with the support of the Operation Rice Project; they also organize meetings and credit management. The Rice-farmers Group (GR) comprises 3 UGR farmers from the Kawara plain. These three UGR members have the same activities as the independent UGR. The GR is in charge of coordinating activities with the Project.

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[1] "millet" beer, made from red sorghum

[2] griots = a West African cast who are poets, musicians and witchdoctors

III. OBJECTIVES, HYPOTHESES AND ANTICIPATED RESULTS

Objectives:

- Global objective:
  - Evaluate the contribution made by women and by rice production to the overall agricultural production of the farmer.

- Specific Objectives:
  - Study the system of rice production
  - Analyze the way women manage rice stores

Hypothesis:
- the yield and management of stores vary according to the age groups of the women involved.

Anticipated results:
- to make a data base available to users (decision-makers, developers, researchers) that will document the contribution of rice-farming and of women to agricultural production and farming.
- to make a constructive contribution to the creation of agricultural policies by formulating recommendations.

IV. METHODOLOGY

Choice of site. Our choice was guided by the presence of INERA/RSP on the sites. Kawara was chosen to represent the sub zone where food is cultivated for home consumption, the land still worked with very little agricultural equipment, and where there is rice-farming in the lowlands (both crop-ready, laid out with bunds etc. as well as unprepared land) which is farmed by women. The presence of INERA researchers since 1990 helped keep the costs of this study to a minimum.

Samples and analytical tools. Our survey was based on the list of farms registered on the 1990 census of RSP. We also used the list of rice-farmers from the Comoé "Operation rice" project. We worked on a sample of 21 farms, representing 20% of the farming population.

The principal criterion of selection was that rice be farmed by women. As a first stage, we considered the sample of farms which INERA had focused on, but then broadened this relatively small number of farmers, by supplementing further farmers chosen randomly. A description of the production system and rice-farming of the women was made, based on material gathered through questionnaires, interviews and secondary material.

Data was collected to include: the global census of the population, the surface areas allocated to each woman, details of the current state of the land on the Plains, and of the types of land management, crop rotation, agricultural equipment, time taken for labor, the cultural techniques, use of inputs, production and finally, the crop yields.

V. RESULTS

The Production system. In this village, as in many other villages in the area, rice is grown in the lowlands during the rainy season, whether on land prepared with bunds etc. or on left unprepared. Rice-farming is mainly worked by women, with a small group of men who do not cultivate cotton going over to rice. Technical support for the cultivated plains (Badini and Kawara), is provided by the Comoé Operation Rice Project, through the intermediary of four extension agents who are based in Kawara and Konadougou. The individual plots farmed by each female farmer measure, on average, 0.25 hectare on the Badini plains, and 0.10 to 0.20 hectare on Kawara plains. As well as these two plains, there are also undeveloped or semi-developed plains which are farmed. For the village of Kawara, 77 inhabitants farm the Badini plain and 324 farm the Kawara plain.

Soil Management. Part of the land is allocated to each family* by the land Chief, who is trusts its management to the family patriarch*. The remainder remains the responsibility of the land Chief who may decide on reallocation as needed.

In the lowlands, the actual farming is mostly done by women. Land left unprepared with bunds etc. remains under the management of the land chief, who takes charge of sharing it out in return for a payment in kind of one or two tines of rice per parcel of land, and per season.

Cultural practices. Firstly, the nursery areas are prepared. This preparation involves spading and creating raised seed rows using *daba* weeding hoes. We did not know the precise surface areas of the nurseries, but most women use a tine of seed to sow them.

The seeds are sown before the first rains on ridges, or sown broadcast on a part of the parcel prepared accordingly. For those who use fertilizer, the quantity spread on nursery beds is estimated to be one plateful (+2.5kg.) of NPK (cotton fertilizer) per sowing*.

The land preparation on the prepared and laid out plains takes place at the same time as the establishing of the nursery beds. The work is done manually using *daba* weeding hoes with which the clods are broken up. The earth is then usually levelled with a board. On the unprepared plains, the land is worked before starting the nursery beds. After sowing the nursery beds, both prepared and unprepared plains are worked in the same manner, and according to the same farming schedule.

The planting out is generally done in staggered rows. This is the most demanding of all the tasks involved. It is begun only after the women have finished all sowing. Indeed, one observes large variations in time (between 20 and 40 days) between the sowing of nursery beds and the beginning of bedding out.

The spreading of fertilizer with NPK generally takes place at the same time as the planting out, but urea is applied only when panicles* have emerged.

Weeding, done manually, is done once. However, some parcels were observed which had not been weeded.

Harvesting begins at the end of November, and carries on until the beginning of January. Improved varieties are the earliest. Women use sickles or knives to cut the stalks. Threshing is done manually with a stick. It seems that attempts to mechanize this process made during the "Rice Project" have been in vain. According to the women, the pedal-driven beaters were slower. Winnowing is also done manually, with recourse to wind power.

Use of inputs.

Seed Use. Both domestic and improved varieties are used by women farmers. Local varieties used include: *malo-gouani, malo-soumani* and *malo-sourouni*. Improved varieties include FKR 24 (BR-51-319-9), FKR 14 (4418) and FKR 16 (4456). It appears that the improved varieties are not favored by the women, who find them more susceptible to flooding. On the other hand, they sell better.

Use of fertilizer and plant health /*phytosanitary products. The study showed that very few women took action against insects, in spite of the fact that insects cause considerable damage. From this point of view, the level of use of phytosanitary products is almost nil. On the other hand, almost half of the women used cotton fertilizer (NPK) as opposed to only 13% who used urea.

Use of manpower. Collective labor in the form of mutual cooperation is highly developed in Kawara. The grouping together of workers and types of work is according to gender. Therefore, the jobs of sowing and harvesting in communal fields are delegated to mutually cooperating groups of women and young girls. There are some farms, however, on which women do the thinning out of plants (2 days per week) and men help with the harvest. The members of the collective farms have one day per week to themselves, to work their own fields. Each farm member can belong to an association which exercises cooperative or profit-making activities (Traoré, 1992). The young boys invest the major part of their energy in working the collective fields, or they migrate into the Ivory Coast, to bring back cash (RSP, 1990).

Outside collective work, young girls divide their work between mutual cooperation activities and the their mothers farming. The "women's groups" which contribute their labor to harvesting are eligible to receive provisions which can amount to 2 to 5 tines per season.

Table 1 below, summarizes the average time spent by women on the various tasks involved in rice farming.

Table 1. Estimation of time spent on tasks/hectare

Activity	Hours worked
Nursery beds	8
Planting out	56
Spreading Fertilizer	4
Weeding	24
Watching for birds	60
Harvesting	48
Cutting, threshing and winnowing	
Total	200
Total (in hours)	1200

Source: Study survey.

This table shows that planting out and harvesting represent the most demanding tasks. They represent, respectively, 40% and 34% of the time taken for the whole operation, excluding the job of bird-watching, which is done by children.

Marketing. Farmers have three available ways of marketing to sell their products. These are:

- The *supervising structure** which can buy the women's product for the account of the *Caisse de Péréquation des Prix CGP* (Bank of Price Standardization) on condition that the variety cultivated be one of the recommended "improved" varieties.

- Village groups and local businesses also constitute an outlet, one which does not distinguish between which seed varieties.

- Thirdly, it is possible for the women to sell their products directly to consumers.

Surface area and yield. Table 2 gives the surface areas farmed and the corresponding rice yields, according to age group of the women involved.

Table 2. Areas cultivated and rice yields by age group (women)

Age (years)		Prepared land	Unprepared land	Prepared land	Unprepared land
15-29	17	0.19	.24	2088	1184
30-49	45	0.19	.28	2003	1026
50+	38	0.19	.28	1638	1207
Average		0.19	.25	1910	1139

As far as surface area is concerned, there are no significant differences between the different age groups of women farming, on the prepared or unprepared plains. It was concluded that the allocation of land does not factor in the number of the woman's children or dependents she has to feed.

In terms of yield, generally speaking the yields are low. In fact it would seem that rice yields in the lowlands at their worst amount to about 1600 kg per hectare.[3]

Our general estimates indicate that the highest yields are obtained from prepared parcels. The classification by age group in the table shows that the yields from prepared land farmed by young women are higher than those from similar land farmed by older women. On the other hand, the productivity of the latter is better than that of younger women when farming non-prepared land. Older women may have better mastery of the traditional system of farming, or perhaps they concentrate more on the non-prepared parcels than on those which have been prepared.

Management of grain stocks.

Management of communal grain store. The crops harvested in the collective fields are the collective property of the farm which is managed by its chief. These stores are generally made up of millet and corn. Its true consumption only begins 2 to 3 months after the harvest, but before this, each woman is given 2 to 3 tines full of each type of cereal. During periods of normal consumption, each woman receives 4 to 6 tines full, depending on the number of people she has to feed. The collective store is also used to supply* the seed grain needed for the fields and rice paddies.

The management of rice stores. The analysis of data in table 3 indicates in a global manner that, unlike other grains, part of the rice produced (half in fact) is grown to sell. Approximately 49% of the rice produced is eaten, of which 4% used on seed* and 45% per family.

For sales, one observes from table 3 that sales immediately after the harvest amount to 34% and later sales are used to cover payment of labor utilized to farm the rice fields.

Table 3. Management of Rice Stores by Kawara Women.

Age group (years)	yield (kg/ha)	Sales after harvest	Payment for labor	Share	Auto-consumption & seed
15-29	1400	29	12	4	51
30-49	1286	35	12	4	45
50+	1281	35	15	5	41
Average	1297	34	13	4	45

[3] Paper for the rice program of INERA (the Agricultural Study and Research Institute).

From Table 1, the analysis of the management of rice stores according to age group indicates that the younger the woman, the less she sells. Much more than half of her production is to provide for her own family.

Older women are the ones who sell the most, especially after harvest-time. One might conclude that the latter are more independent than the younger women.

One also remarks that it is the older women who use paid labor the most.

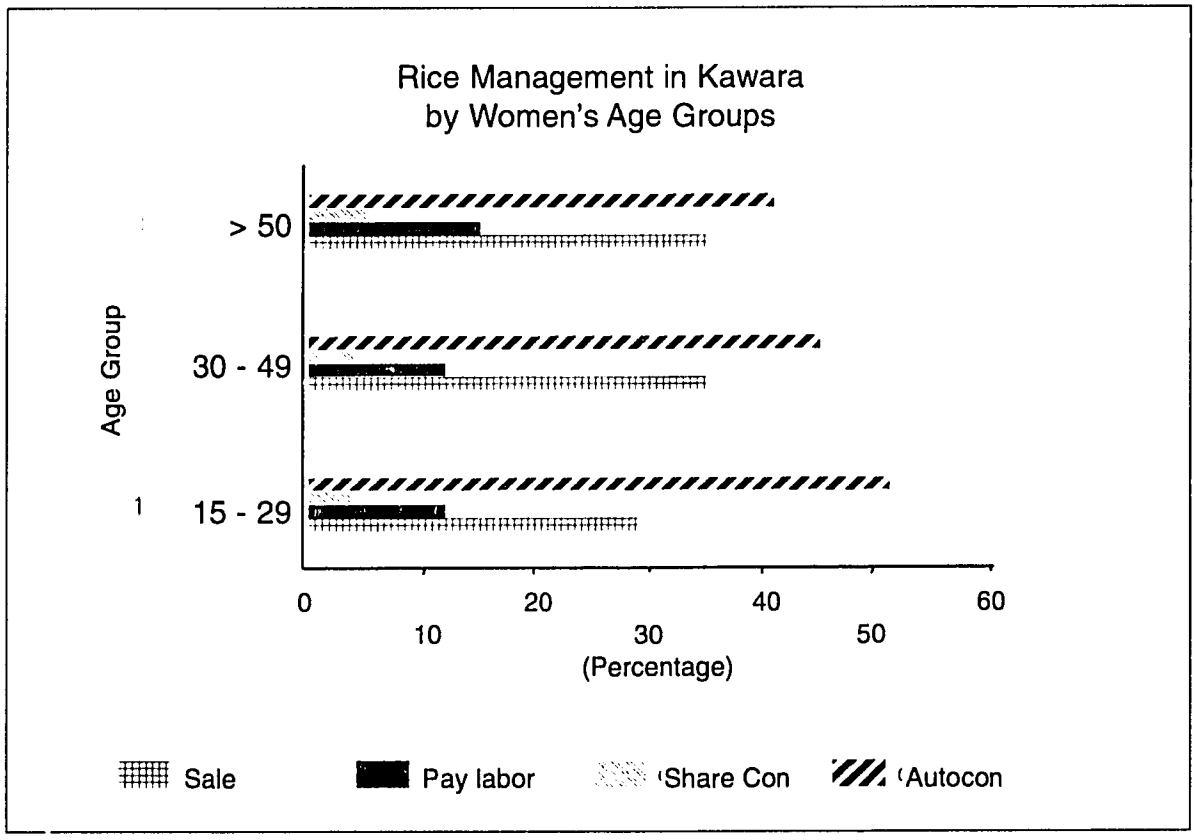

Figure 1.

Contribution of rice to satisfy the demand for cereal. In Kawara, the most commonly consumed cereals are maize, millet, rice and fonio. Figure 2 (below) shows the levels of consumption per farm of the different cereals. It is clear from this graph that more maize and millet are consumed than any other cereals, including rice, which is also eaten in significant quantitites. Rice accounts for 25.6% of consumption, as opposed to 37% and 35.4% for maize and millet respectively. Fonio is of less significance*, contributing about 2% to the total cereal consumption.

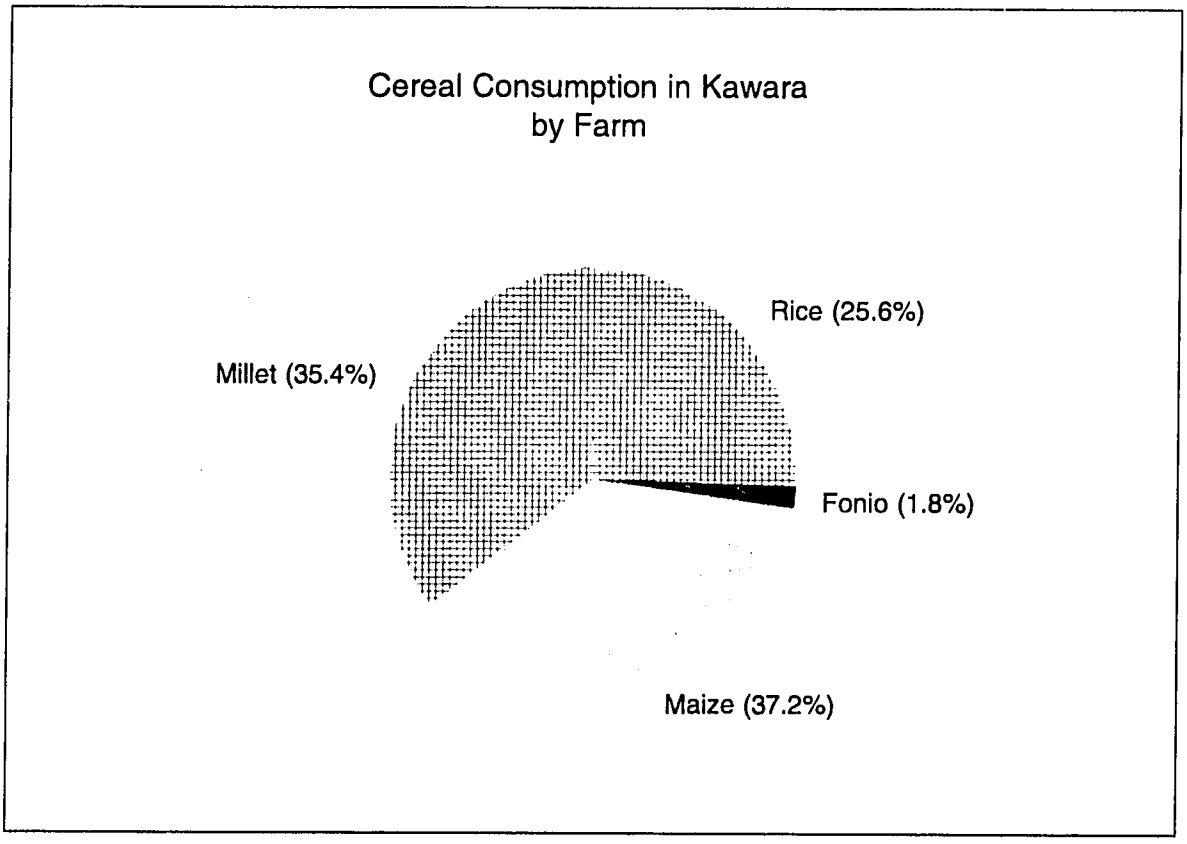

Figure 2.

One remarks that more than half of the rice produced by women supplies the needs of the farms, and this contribution satisfies about one third of the total cereal demands. Only one third of women's rice production constitutes a true source of income for their cash needs. This results in possibly negative consequences to the levels of incentives and investment of women, which are indispensable to the intensification of their rice production.

V. CONCLUSION

In Kawara, rice is mainly cultivated by women, who thereby contribute effectively to satisfying the demand for cereals. Unfortunately, as is often the case in Aftrica, this contribution has been unrecognized up until now. The object of this study was to describe the production system of rice and the farming methods used by women in Kawara.

This study has led to the following observations:

- Kawara women use more than half their rice production to feed members of the farm they belong to, and their contribution satisfies approximately one third of cereal needs;

- In spite of this remarkable contribution, these women cannot devote all their time to rice cultivation, but must also work in the farm's collective fields. This impacts on operations

such as the planting out in the rice field, which can only comment if sowing has first been done in the collective fields;

- As a consequence the women invest very little **to produce the low yields observed. One notes the particularly low levels of equipment and use of inputs (fertilizers, phytosanitary products* and paid labor);

- the study indicates, besides, that it is only after a certain age (50 years, plus) that women are in more control of their rice production, although at this age they are less motivated, and less effective producers.

It is important to reinforce the technical support made available to women and to facilitate their access to inputs so that they can increase rice production as a source of income as well as food supply for their own needs.

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On-farm Performance of Forage/Grain Varieties of Sorghum and Cowpea: Agronomic Evaluation by Researchers and Farmers

A. Sohoro, S. J.-B. Taonda, J. Dickey, and E. Robins

ABSTRACT

Farmers on the Mossi Plateau of Burkina Faso have identified the following need areas in their farming systems: (1) increased food, cash, and forage production potential, (2) acceptable levels of risk, and (3) low required cash investment. Varieties of sorghum (ICSV-1049) and cowpea (7/180-4-5) that produce grain and forage were tested by researchers, reviewed with farmers, and then tested by farmers. All tests included plots with pure and mixed stands of the two crops. Researcher managed trials in 1991 produced well and were received enthusiastically by local farmers. Approximately 50 farmers each in the villages of Donsin (650 mm mean annual rainfall) and Thiougou (910 mm mean annual rainfall) cooperated in farmer-managed tests of the varieties in pure and mixed stands in 1992. Agronomic performance and farmer reaction were monitored. Results in 1992 included (1) highly variable, generally poor performance of the sorghum variety during a short rainy season, (2) acceptable yield, stability, and income production by the pure stand cowpea, (3) strong farmer interest in two improved cowpea varieties in both villages, and (4) apparent willingness to invest some cash in cowpea pest management in Thiougou, but not in Donsin. Edaphic conditions at Donsin make production more risky and less vulnerable to insects. The improved cowpea varieties appear to offer good food, cash, and forage production potential in both villages, and the sorghum ICSV 1049 appears to be unacceptably risky for extensive cultivation in this region.

I. INTRODUCTION

Traditional systems of livestock management in the Sudan savanna zone of Burkina Faso are under stress, and farmers are looking for alternatives. Under the old system, specialist herdsmen would pasture the cultivators' cattle in return for their milk. This system depends on the existence of sufficient pasturage, but human and animal population pressure on drought-stricken land has diminished available pasture land area and quality. Farmers are seeking alternatives for nourishing their animals as the old system becomes unreliable. Supplement with cultivated forage is one possibility.

The Farming Systems Program (RSP) of INERA organized on-farm, joint researcher/farmer managed tests of forage/grain varieties of sorghum and cowpea in central Burkina Faso during 1990 and 1991 (RSP, 1991 and 1992b). Farmer interest in this technology was high (RSP, 1992a), reflecting their concurrent needs to resolve the problems of animal and human nourishment. Among tested varieties, farmers preferred the forage quality of varieties ICSV-1049 (sorghum) and 7/180-4-5 (cowpea).

Cowpeas are very marketable in the region, and therefore a potential source of cash as well. They are traditionally intercropped with cereals, but insecticide application needed for high levels of production is at once more necessary and more efficient in pure-stand cowpeas. The objectives of this study were to:

- Evaluate the forage and grain production potential and risk of forage/grain varieties of sorghum and cowpea as sole crops and intercrops under farmer management
- Identify the conditions under which such varieties would be adopted by farmers

II. METHODS

Tests were put in by 50 farmers in each of two villages, representing the northern (Donsin at 645 mm mean annual rainfall) and southern (Thiougou at 727 mm mean annual rainfall) portions of central Burkina Faso. Relative to Donsin, Thiougou is less prone to drought periods (Figures 1 and 2), and has generally lighter textured soils, as well as some younger soils (Table 1). Thiougou is also more intensively mechanized, where 82% of farmers are equipped with animal traction, versus 4% at Donsin. Mechanization, as well as superior, more reliable rainfall, and greater land availability allow Thiougou farmers to enjoy greater food security.

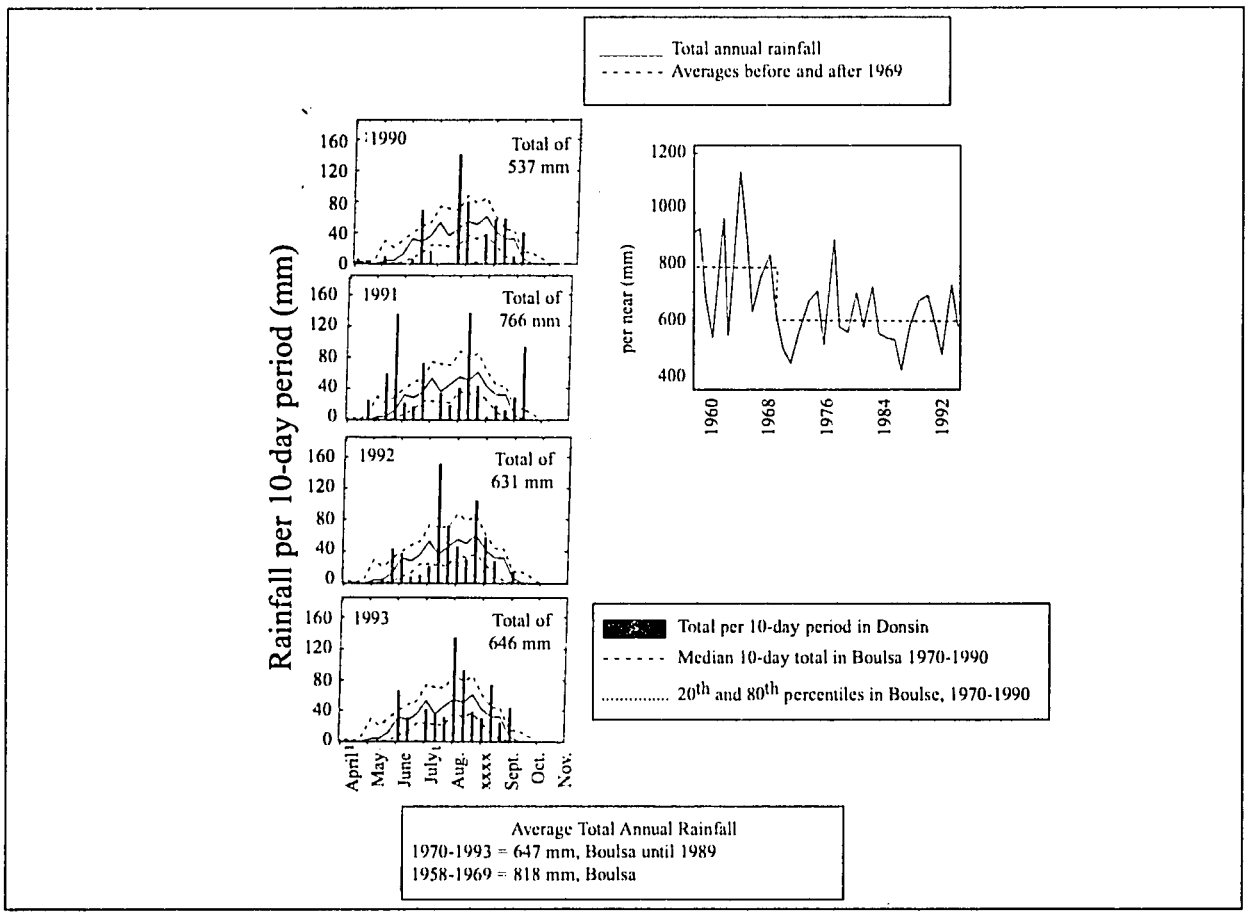

Figure 1. Donsin rainfall in 1992 relative to expected rainfall. Note that due to recent changes in the regional climate, post-1969 rainfall levels indicate expected rainfall better than pre-1970 rainfall levels.

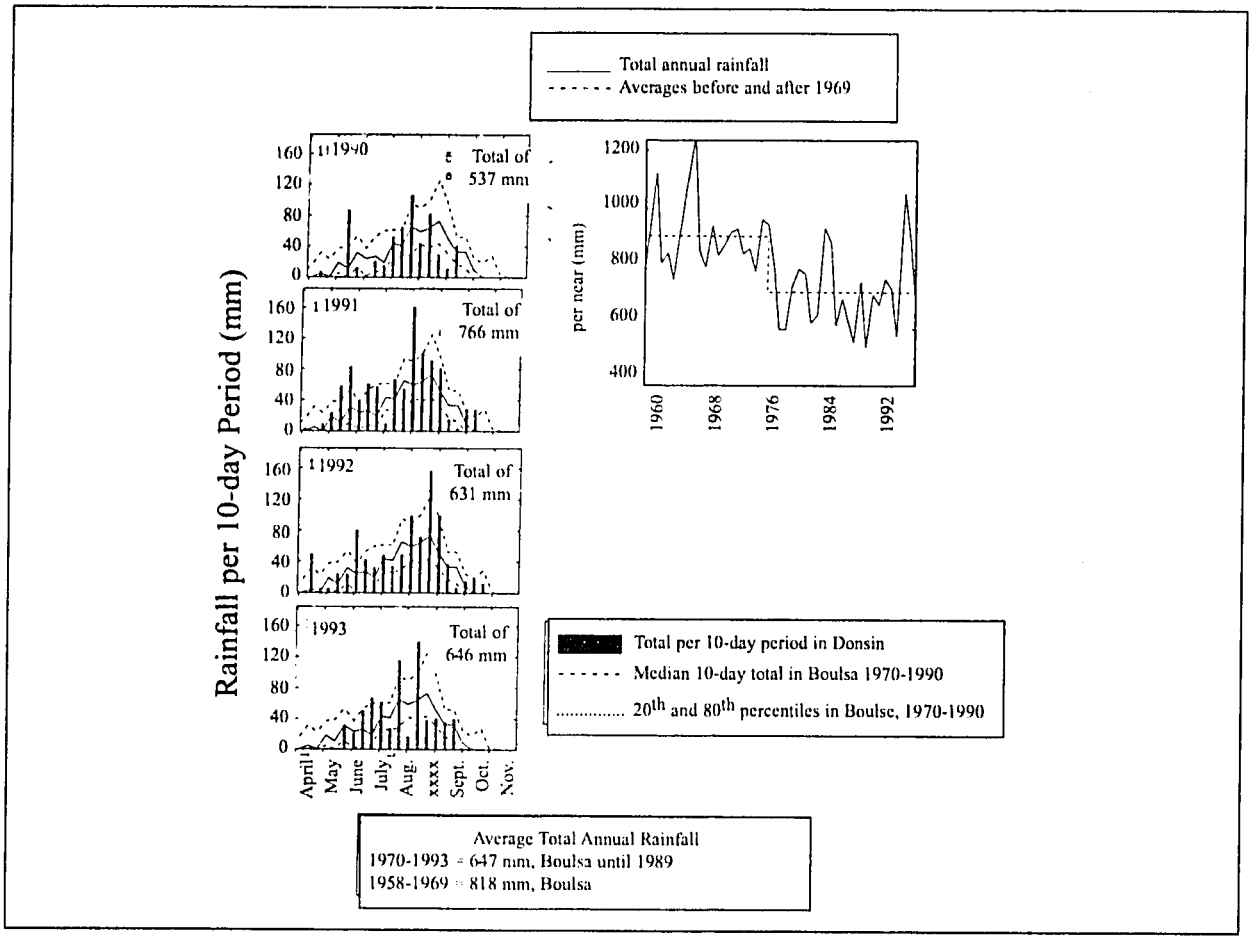

Figure 2. Thiougou rainfall in 1992 relative to expected rainfall. Note that due to recent changes in the regional climate, post-1969 rainfall levels indicate expected rainfall better than pre-1970 rainfall levels.

Table 1. Dominant soils at the two village sites (according to the French classification system).

Donsin	Thiougou
Ferruginous tropical soils, sandy/clayey to clayey/sandy texture	Ferruginous tropical soils, ferruginous modal soils, or ferruginous shallow soils with induration at depth, sandy to sandy/silty texture
Gravelly ferruginous soils, sandy/clayey to clayey sandy texture	Slightly evolved, eroded soils formed in colluvium, sandy to sandy/silty texture

The three treatments were pure-stand sorghum and cowpea, and a sorghum/cowpea intercrop. The varieties used were ICSV-1049 and 7/180-4-5. The cowpea grain variety KVX 61-1 replaced 7/180-4-5 at several sites in each village, due to a shortage of seed for 7/180-4-5. Farmers were provided seed, and plots were 20 m x 20 m for each of the three treatments.

Farmers had followed extension guidelines during the previous tests under joint management with researchers. In 1992, farmers prepared land, fertilized, sowed, weeded, and harvested according to their own discretion, and researchers monitored field management. Cowpea spraying was carried out by RSP, to enable production of good grain yields during the phase before farmer adoption of this practice.

Forage and grain production was evaluated on all plots. Farmers (25 per village) responded to structured questionnaires regarding their evaluation of production quantity and quality, and any perceived implications for their farming system.

III. RESULTS AND DISCUSSION

No farmers chose to purchase and apply fertilizer to test plots. Mineral (especially nitrogen) deficiency symptoms were evident on the sorghum in most plots. Weeding was often carried out late, so that weed competition often influenced crop productivity. Although aware of more ideal cultural practices, the combination of motivation and constraints affecting farmers seldom resulted in organic or mineral fertilization and timely weeding.

Plant densities practiced by farmers are very different from extension guidelines, and differ greatly between the villages (Table 2). At Donsin, the average densities for the two crops were from 50 to 80% of recommended densities. At Thiougou, they were from 150 to 350% of the same recommendations. The very high intercropped cowpea densities are probably due to a strong preference for cowpea relative to sorghum production in cooperative fields, especially since good cowpea production is possible when fields are treated with insecticide by cooperating researchers. Farmers explained that the recommended densities are generally less productive than their habitual densities under their field conditions. With the exception of the intercropped cowpea density at Thiougou, the deviations of observed from recommended densities are probably a farming system adaptation to prevailing rainfall and fertility conditions. This suggests that extension guidelines for these densities are not flexible enough to address the range of field conditions encountered by farmers.

Table 2. Observed hill density planted by farmers at Donsin and Thiougou, 1992.

Village	Crop	System	Mean observed hill density (hills/ha)	Percentage of recommended density
Donsin	Cowpea	Pure stand	24 000	77
		Intercropped	8 600	80
	Sorghum	Pure stand	19 800	63
		Intercropped	16 587	80
Thiougou	Cowpea	Pure stand	48 789	156
		Intercropped	36 245	345
	Sorghum	Pure stand	51 680	165
		Intercropped	35 203	169

Average yields were in general quite low (Table 3). Late commencement of rains (Figures 1 and 2) retarded sowing. Wandering ruminants so appreciated the forage quality of the ICSV-1049, which has somewhat sweet stems, that they often grazed it before grain was ripe. Late-season drought, delayed weeding, and animal damage caused major reductions in sorghum yield. Also, the caudatum-type heads of this variety suffered head rots to a much greater extent than local sorghum growing in adjacent fields.

Table 3. Mean and maximum yields observed relative to yield potential for each group.

Crop	System	Statistical Parameter	Donsin kg/ha	% pot'l	Thiougou kg/ha	% pot'l	Yield Potential kg/ha
Cowpea	Pure stand	Mean	384	21	168	9	1 800
		Max	869	48	780	43	
	Intercrop	Mean	130	13	126	13	
		Max	400	40	319	32	
Sorghum	Pure stand	Mean	42	1	201	7	
		Max	163	5	577	19	
	Intercrop	Mean	22	1	60	2	
		Max	225	9	214	9	

Although the stability curves for sorghum were relatively flatter than for the other systems (Figures 3 and 4), they produced lower economic yield than the other treatments in virtually all environments. Pure stand cowpea produced superior economic yields across all environments in Donsin, but intercropping offered some advantages in the less-productive environments at Thiougou. Average economic yields were in the order pure-stand cowpea > intercrop > pure-stand sorghum, except for when considering grain only at Thiougou, where there were no significant differences among treatments.

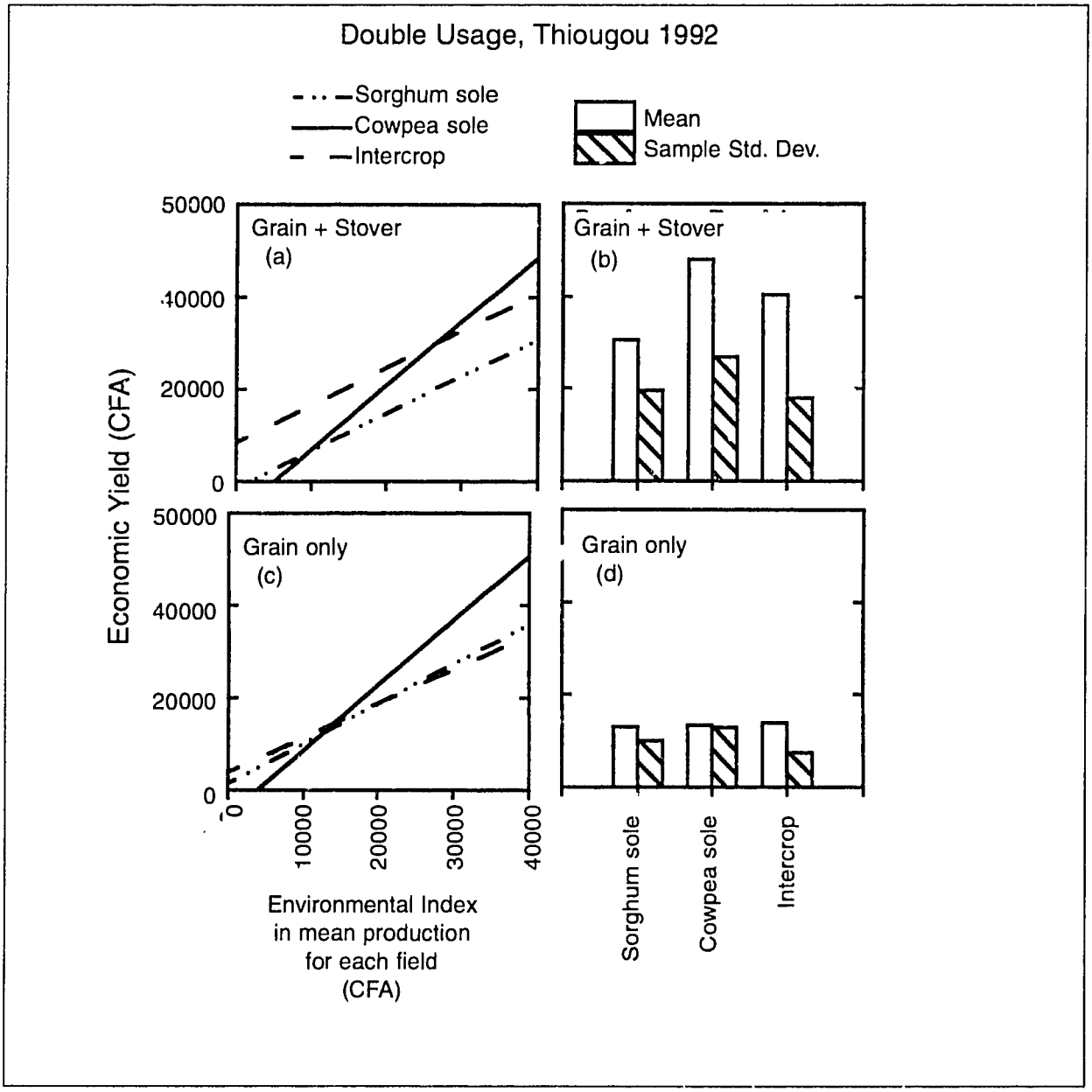
Double Usage, Thiougou 1992
Sorghum sole
Cowpea sole
Intercrop
Mean
Sample Std. Dev.
Economic Yield (CFA)
50000
40000
20000
0
Grain + Stover
(a)
Grain + Stover
(b)
Grain only
(c)
Grain only
(d)
0
10000
20000
30000
40000
Environmental Index
in mean production
for each field
(CFA)
Sorghum sole
Cowpea sole
Intercrop

Figure 3.

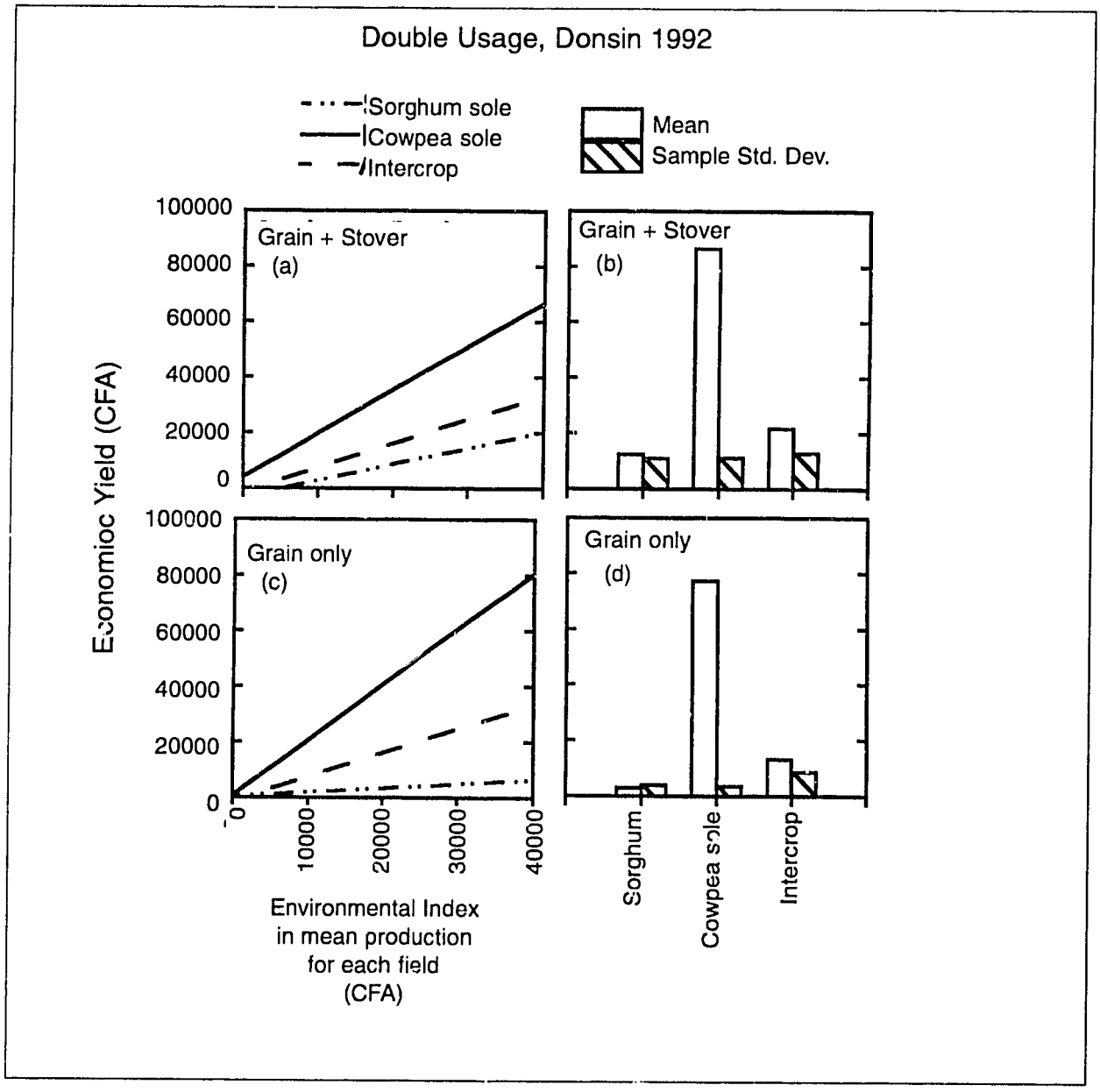

Figure 4.

The reactions of farmers to technologies appeared to be strongly influenced by the frequency of animal traction and level of food security, both of which were higher in Thiougou. Farmers in Donsin were clearly dissatisfied with ICSV-1049 production, however Thiougou farmers were largely satisfied with only slightly better production (Table 4). Forty percent of Thiougou farmers plan to plant some of this variety again, whereas no Donsin farmer plans to. Three factors contribute to these differences:

Table 4.

Question posed	Favorable Responses Donsin	Favorable Responses Thiougou
Have animal traction?	4%	82%
Harvested cowpeas once?	12%	40%
Satisfied with...		
production in...		
pure stand...		
sorghum?	4	61
cowpea?	68	68
intercropped...		
sorghum?	4	17
cowpea?	44	50
quality of...		
stover from...		
sorghum?	68	88
cowpea?	82	78
Plan to...		
plant...		
ICSV-1049?	0	40
7/180-4-5?	24	75
cowpea primarily as forage?	4	44
treat cowpea?	0	81

- The presence of draft animals in Thiougou, motivating farmers to produce supplemental feed
- The unwillingness to risk sacrifice any potential grain production at Donsin, where food security is low
- The slightly better production results in Thiougou

Farmers in both villages found cowpea production largely satisfactory, but Thiougou farmers are more interested in planting 7/180-5-4 as such (Table 4). Donsin farmers preferred grain varieties, which provide somewhat higher grain yields, but produce forage of lower quality. For best forage quality, cowpea plants should be cut after the first grain harvest (when leaves are still green), then dried and stored out of the sun. This implies some sacrifice in grain yield, since smaller, second and third harvests are eliminated. Farmers in Thiougou were more likely to limit their harvest to one (Table 4). Thiougou's interest in cowpea forage reflects greater food security and need for draft animal feeding.

With regard to paying for insecticide and spraying cowpeas, Donsin farmers were quite clear: no cash would be available for this kind of purchase during the treatment period, which coincides with the period of greatest food scarcity in the village. Nearly half of the Thiougou sample say they will treat cowpeas at their own expense.

IV. CONCLUSIONS

- Cultural conditions such as drought, fertility, and weed competition contribute to very low yields, especially of improved varieties. Improvement of these conditions should therefore be considered a precondition for the adoption of most improved varieties.

- ICSV-1049 is not adapted to prevailing field conditions. In spite of its excellent forage quality, ICSV-1049 should therefore be extended with caution.

- Adequate food security and animal traction are key motivating factors for the adoption of forage/grain varieties of cowpea and sorghum.

- Pure and intercropped, cowpea has potential to increase cash yield of the harvest, but production is less stable across environments.

- Adequate food security is a precondition for farmers to invest in inputs, especially pesticides that are used during the hungry season.

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Sorghum Variety-Fertilizer Interactions in the Village of Kamsi

A. Sohoro, S. Ouédraogo, and J. Dickey

I. INTRODUCTION

The Central Plateau of Burkina Faso has been identified as an overpopulated area with a density of 107 inhabitants/km^2 of arable land area (Sédogo, 1991; Prudencio, 1986; Sohoro, 1984; Dugué 1989). On one hand, population increase in villages has caused the discontinuation of fallowing practices. On the other hand, it has resulted in the cultivation of new, less fertile, or unproductive lands. Limited arable land availability and tenuous food self-sufficiency are such that farmers subject their lands to continuous (mostly sorghum) cropping. Resulting soil fertility is characterized by:

- low organic matter content
- low content of exchangeable bases and acidification during cropping season
- widespread phosphorus deficiency

The combined effects of land overuse in villages of the Central Plateau and the infrequent use of fertilizers have caused a decline in soil fertility and yields have decreased to approximately 500 kg/ha approximately (Sohoro, 1992).

Food security is a daily problem for local populations and prospects are not bright when elementary laws of nature are not respected in land use practices (Roose, 1981). These laws mainly include the physical protection of soil surface horizons which are most biologically active and the regular restitution of nutrients and organic matter which are indispensable to maintain soil fertility.

The test reported here was conducted to assess the efficiency of various fertilizer regimes recognized to be economically profitable (Hien et al., 1992) in combination with high yielding varieties.

II. METHODS

<u>The study environment.</u> The test was conducted in the village of Kamsi. This village was identified by the RSP program in 1986 as representative of conditions of the central part of the Central Plateau in Burkina Faso (RSP, 1986). Kamsi is located in the Sudan savanna, 7 km south-east of Koudougou, the administrative center of the Boulkiemdé Province. It is under the administrative authority of the Ramongho préfecture (located 10 km to the east of Koudougou). Kamsi's geographical coordinates of Kamsi are:

Latitude: 12 ° 13' to 12 ° 15' N
Longitude: 2 ° 15' to 2 ° 20'W

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The village includes five soil/landform units. The three most extensive units are:

- slopes 66.24%
- hills 25.22%
- lowlands 4.97%

Rainfall records from the last 20 years show an average of 720 mm. The 1992 rainfall of 969 mm (Figure1) was irregularly distributed during the season.

Soil analyses conducted on a sample of 32 fields in 1991 resulted in the means presented in Table 1. Overall, soil fertility is low.

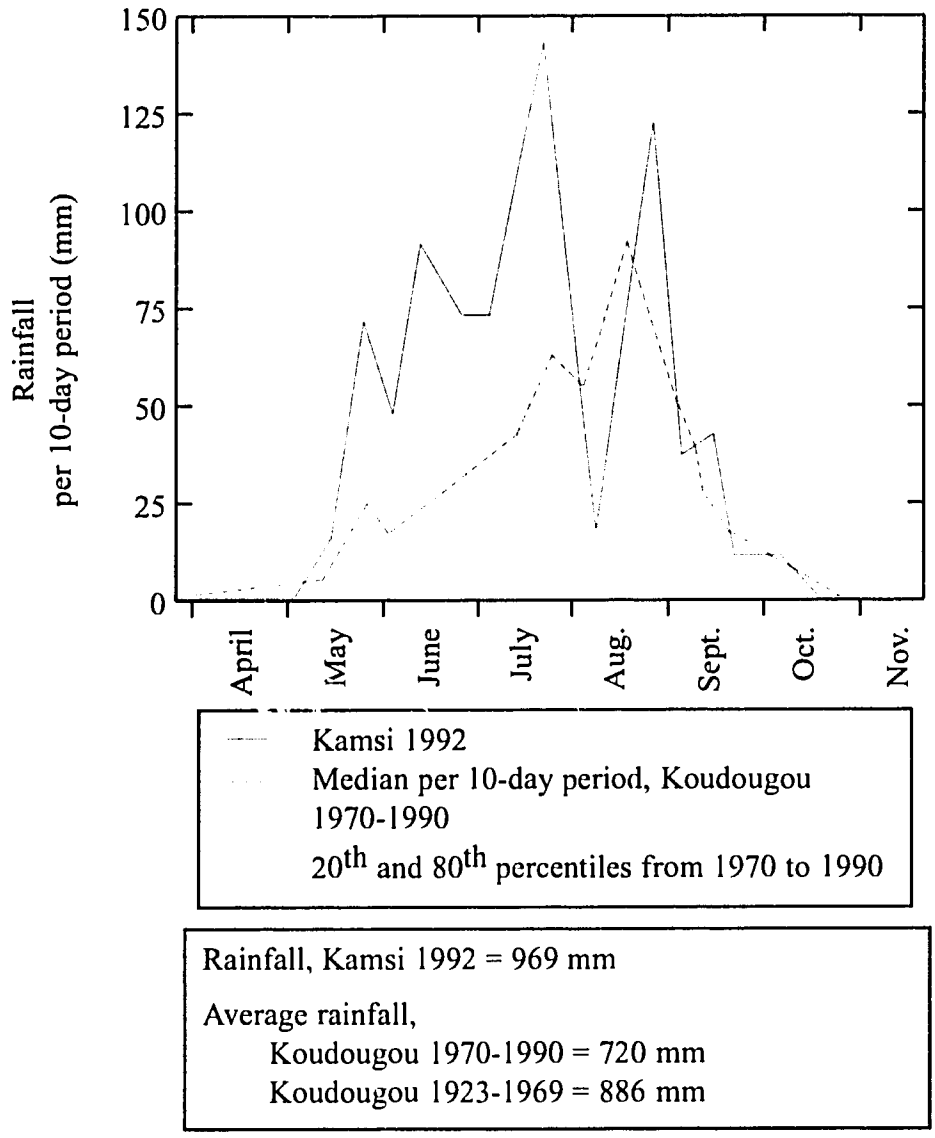


Figure 1. Rainfall in Kamsi.

Table 1. Results of soil chemical analyses in Kamsi.

Position on toposequence / Elements analysed	pH water	pH KCl	Total C (%)	Organic matter (%)	Total N (ppm)	C/N (%)	Available PB-II (ppm)	K (mg/100g)	Na (mg/100g)	Ca (mg/100g)	Mg (mg/100g)	Mg/Ca (mg/100g)	CEC (mg/100g)	Total bases (mg/100g)
Bottom land	6.91	5.94	5.12	8.83	392	13.07	166	0.55	0.36	2.69	1.11	0.42	6.82	5.64
Slope	6.9	5.99	5.51	11.17	463	13.96	116	0.31	0.28	3.64	1.19	0.40	7.46	6.57
Hilltop	6.89	5.93	6.76	11.88	494	13.86	216	0.92	0.32	2.47	1.29	0.47	6.55	5.21
Normal range in Kamsi*	6.91 to 6.99	5.93 to 5,76	5.12 to 6,76	8.83 to 11,66	392 to 494	13.07 to 13.96	116 to 216	0.31 to 0.36	1.38 to 1.47	3.64 to 2.69	1.11 to 1.29	0.40 to 0.47	6.55 to 7.46	5.21
Soil quality	Neutral	-	-	very low	very low	medium	very low	low to medium	high	-	-	medium	low	medium

* Reference (ASSA, 1991)
Source: Adama P. Sohoro (1992)

Table 2. Average yield by fertilizer treatment in Kamsi, 1992.

Fertilizer treatment	Local variety	ICSV 1049	Mean
BP + KCL	262	191	227
Control	269	171	220
Average	266 (a)*	181 (b)*	223
BP + MO	347	495	421
Control	291	474	383
Average	319	485	402
NPK	196	171	184 (a)*
Control	118	92	105 (b)*
Average	157	132	144
Average fertilizer	268	286	277
Average control	226	246	236
Grand average	247	266	256

* (a), (b) = significant difference between a and b

The village covers an area of 1570 ha; only 54.78% (860 ha) are fit for agriculture. Estimated land use percentages are the following:

- land unfit for agriculture 12.47%
- fallows 30.25%
- fields 54.78%
- watercourses 2.55%

According to the 1991 census, resident and migrant populations included 1561 and 1680 inhabitants, respectively. Population density is estimated to be 99.42 inhab/km^2.

Farmers grow sorghum in monoculture for subsistence purposes. They also raise small ruminants and poultry. Sorghum yields are 500 kg/ha on average (Sohoro, 1992).

Field plots. The study was conducted on 28 farms on the following locations on the toposequence:

- 9 farms in lowlands
- 10 farms on mid-slopes
- 9 farms on upper slopes

Sorghum varieties compared in the test included improved germplasm (ICSV 1049) and a local variety from Kamsi. The following 4 types of fertilizers were used in the test:

- Cotton fertilizer (14-23-14-6-1, N-P-K-B-S)
- Burkina Phosphate (0-9-0, N-P-K)

- Potassium chloride (0-0-53, N-P-K)
- Organic matter (manure or compost, in variable dosage)

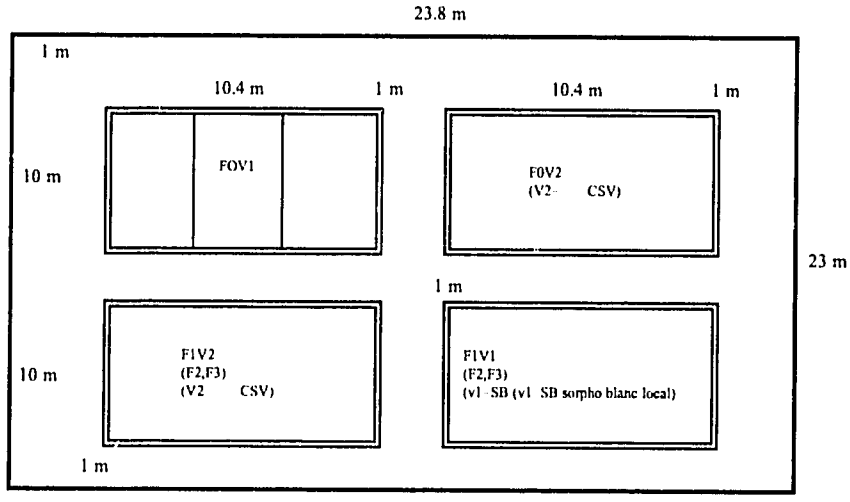
The various fertilizer combinations applied were:

- Burkina Phosphate (200 kg/ha) + potassium chloride (20 kg/ha) + urea (50 kg/ha) (23-18-53).
- Burkina Phosphate (200 kg/ha) + organic matter (5 Mg/ha) + urea (50 kg/ha) (23-18-0 + Organic matter)
- Fertilizer complex NPK (75 kg/ha) + urea (50 kg) (34-17-11-6-1).

Each fertilizer combination was compared to a control (no fertilizer) in both the local white sorghum variety and the ICSV 1049 variety. The design was replicated at least three times on each location on the toposequence for each type of fertilizer.

Four plots, one with each treatment combination were established at each participating farm (Figure 2). Individual farms were considered as replications. Unit surface area was 104 m^2 (10m x 10.4m).

Figure 2. Experimental design



FO = CONTROL (UNFERTILIZED)
F1 = BP + KCL (BP = 200KG/HA, KCL = 20KG/HA)
F2 = BP + M O (BP = 200KG/HA, MO = 5T/HA)
F3 = N P K (75KG/HA)

Dates of operations from sowing to harvest were recorded. Plant height measurements were made at the two weeding times and at harvest. Plant biomass and grain yields were weighed in all plots. Analyses of variance were conducted.

III. RESULTS AND DISCUSSION

The application of all fertilizers used stimulated plant growth. This effect was more pronounced for local varieties. Soil fertility variability was at times very pronounced, and control plots occasionally performed better than plots where fertilizer has been applied (Figures 3 and 4).

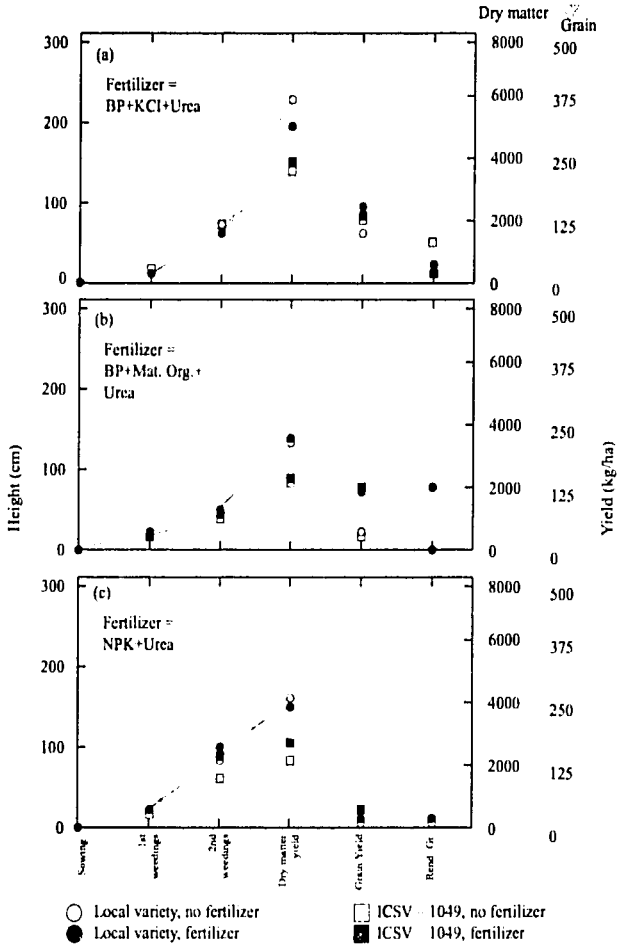


Figure 3. Plant height and grain and dry matter yields, forms on lowland sites.

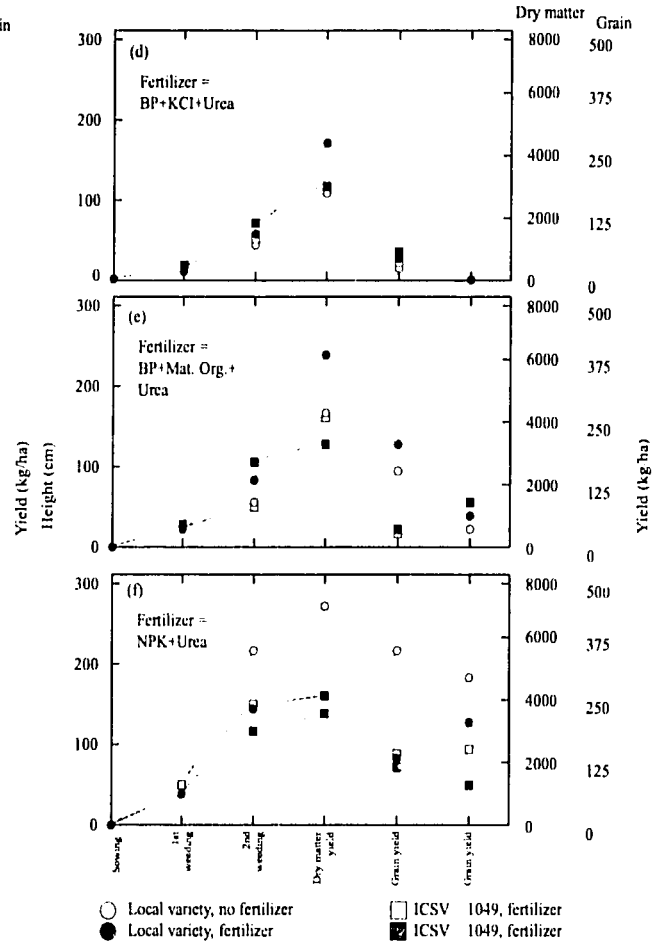


Figure 4. Plant height and grain and dry matter yields, forms on hilltop sites.

Mean yields in the tests were less than 500 kg/ha (Table 2). Yield differences between treatments were less than differences in vegetative plant growth. These facts can be attributed to the rainfall shortage during the first decade of the month of August and to the sudden stoppage of rains in early October.

Figures 5 and 6 indicate that the probability of total crop failure is higher in the lowlands than on mid-slopes. Yields in the 400 to 800 kg/ha range are frequent on mid-slope. Plateau positions gave the highest yields (1800 kg/ha), yet the frequency of total crop failure was also high there.

These findings concur with Sohoro (1992), where the irregular distribution of high total annual rainfall (900-1000 mm) resulted in lowland floods and drought periods during the vegetative growth and spikelet and/or grain initiation stages. In all of these cases, crop failure is likely since sorghum cannot withstand waterlogging and is somewhat sensitive to drought.

The combination of organic matter and Burkina Phosphate offers highest yields including:

- a lower crop failure probability
- a higher probability of yields over 400 kg/ha
- a possibility of very high yields of 1800 kg/ha

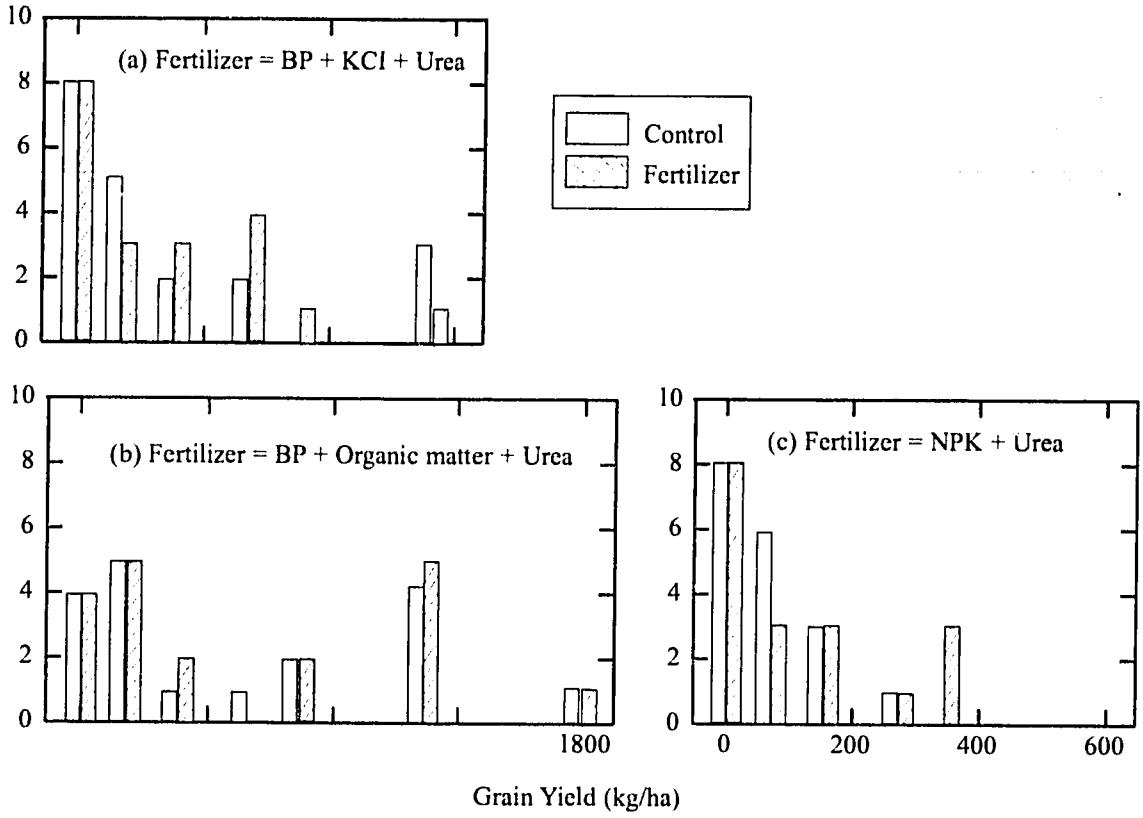


Figure 5. Frequency distribution of grain yields according to fertilizer treatment.

The yield difference between the complex fertilizer and the combination of Burkina Phosphate and potassium chloride is small.

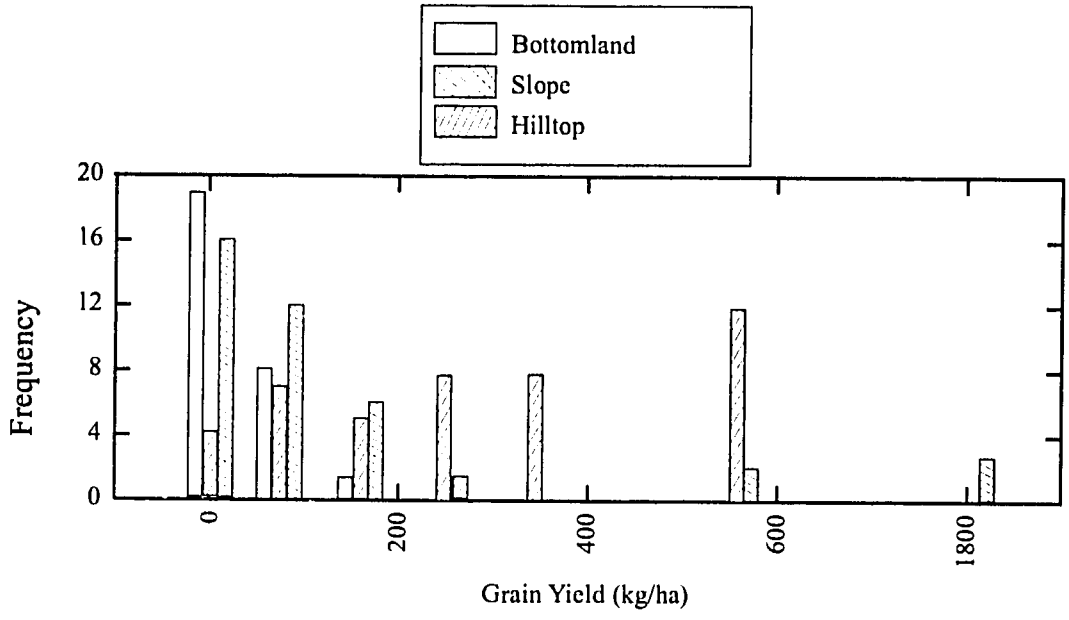


Figure 6. Frequency distribution of grain yields according to position on toposequence.

IV. CONCLUSIONS

The first year of the test gave the following significant results:

- Plant growth was improved by various fertilizer regimes, which confirms the inherently low local soil fertility.
- Low mean yields were at least partly due to erratic rainfall distribution. Research needs to address soil moisture constraints.
- Moderate yields can be expected on mid-slopes
- The combination of organic matter and Burkina Phosphate is promising since this treatment is the least expensive and resulted in no crop failure.

This test will be conducted again in 1993.

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The Riskiness of Alternative Phosphate Sources in Burkina Faso

V. Hien, D. Kaboré, S. Youl, and J. Lowenberg-DeBoer

I. INTRODUCTION

Extension specialists and agricultural policy decisionmakers need timely information on the risk characteristics of proposed agricultural innovations. Risk affects the potential for wide spread adoption of these technologies and may determine how an extension effort is implemented. The response of farmers to agricultural policy is heavily influenced by the riskiness of their production practices. The general objective of this article is to provide an example of stochastic dominance use as a tool in the risk analysis of on–farm–trial data.

The specific objective of this study is to determine the risk characteristics of the phosphate fertilization strategies tested by the Food Crops Fertilizer Project funded by the World Bank in Burkina Faso from 1989 to 1991. The overall goal of this project was to determine appropriate fertilizer rates and sources for millet, sorghum and maize crops in Burkina Faso. These cereals are the staple food crops in Burkina Faso. The potential for using local rock phosphate or partially aciduated rock phosphate was a special concern. Use of local phosphate instead of commercial fertilizer could save foreign exchange and create jobs.

The research tool for this risk analysis was stochastic dominance. In brief, this approach consists of comparing cumulative distributions of results according to certain rules of human risk behavior. These comparisons were done with a Quattro Pro spreadsheet developed at Purdue University (Lowenberg–DeBoer, et al., 1990).

Burkina Faso is a small, landlocked country in West Africa. It is bordered by the Cote d'Ivoire, Benin and Ghana on the south, by Niger on the east and by Mali on the west and north. It has a population of about 9.7 million, about 90% of which depend on agriculture for their livelihood.

The organization of this article is to provide in the second section a brief overview of stochastic dominance, in the third section a description of the agronomic data, in the fourth section the results of the stochastic dominance comparisons, and finally to draw conclusions for use of phosphate fertilizer in Burkina Faso and for use of stochastic dominance in analyzing on–farm–trial data. The on–farm–trial methodology has been described by Hien et al. (1990, 1991) and by Hien and Youl (1992). A step–by–step description of the analysis is available in Hien et al. (1993).

II. RESEARCH METHODS

Stochastic dominance is used to rank alternatives according to their risk characteristics. It identifies technologies that are dominated, those that might be acceptable to risk neutral

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decisionmakers and those that could be used by risk averse individuals. In this context, risk aversion is the preference shown by many humans to avoid alternatives with a substantial probability of low value results. It is not strictly an aversion to variability, because positive variability (that is in the direction of high value results) is desired by many individuals. The theoretical development of stochastic dominance is presented by Anderson.

Stochastic dominance is an non–parametric analysis. That is to say it does not focus on parameters (mean, variance, etc.), but on the distribution itself. As a consequence of this nonparametric approach, stochastic dominance takes into account information that is not easily summarized in statistical parameters.

The cumulative distribution is used for stochastic dominance analysis. For each level of the result, the cumulative distribution shows the probability of achieving that level or less. For example, if the cumulative distribution of yield for a sorghum trial is at 25% for 200 kg/ha that is interpreted to mean that there is a 25% probability that the yield will be 200 kg/ha or less. In some cases, the interpretation is facilitated by thinking of the inverse of the cumulative distribution. The inverse gives the probability of achieving a given level or more. In the example given above, the inverse would indicate a probability of 75% (1–0.25) that the yield would be at least 200 kg/ha. By definition the cumulative distribution is a monotonically increasing function between zero and 1.

Stochastic dominance rules – This study uses the first two rules of stochastic dominance to rank technologies. The first rule is based on observation that human beings usually prefer more to less of most goods. This observation is translated into statistical terms by the first degree stochastic dominance rule which states that if the cumulative probability of an alternative is greater than the cumulative probability for another alternative for all levels of outcome, the technology with the higher probabilities is dominated by the technology with the lower probabilities. The observation is put into graphical terms by saying that if one cumulative distribution is to the left of another cumulative distribution for all levels of outcome, the technology with the distribution at the left is dominated by the technology whose distribution is to the right. This type of dominance is called "first degree stochastic dominance."

The second stochastic dominance rule is based on observation that, in addition to preferring more to less, human beings usually prefer to avoid low value outcomes, that is to say they are risk averse. In statistical terms, the tendency for an alternative to have low value outcomes is indicated by the area under the cumulative distribution curve. The alternative with the greatest area under the curve at any given outcome level has the highest probability of low value results. Therefore, an option is dominated if the area under its cumulative probability curve is larger at every outcome level than that of the alternative. This type of dominance is called "second degree stochastic dominance". This rule is useful when the cumulative distribution curves of two options cross and the first degree rule can not rank them.

With the first two stochastic dominance rules alternative technologies can be classed into three groups:

1) dominated technologies,

2) technologies that could be acceptable to risk neutral individuals, and
3) technologies that could be used by risk averse decisionmakers.

The technologies that belong to the second category are not dominated by first degree stochastic dominance, but they are dominated if second degree stochastic dominance is applied. The technologies in the third category are not dominated by any other technology using either first or second degree stochastic dominance.

Estimation of cumulative distribution – In general researchers do not have exact distributions of outcomes. The distributions must be estimated. The estimation procedure of choice depends on the objective of the analysis, the type of information available and the number of observations (Lowenberg–DeBoer, 1992).

If the data come from on–farm–trials and if the goal is to determine the impact of general weather and/or price variability, sparse data techniques (Anderson, Dillon and Hardacker, 1977) with inter–annual data will be most appropriate. The observations will be the annual average outcome for a technology. In the Sahel the variability in annual averages depends largely on weather and price changes associated with weather driven supply variations. Variability in intra–annual data (farm level observations) reflects pest problems, soil differences, spatial variability of weather, management differences, and other factors.

Sparse data techniques are required when inter–annual data is used because of the small number of data points. On–farm–trials are seldom conducted for more than 3 or 4 seasons. Lowenberg–DeBoer et al. (1990) provide an example of sparse data estimation of cumulative distributions from on–farm–trial data.

If the focus is on the risk incurred by policymakers and extension in facilitating the adoption of a given technique, an "empirical" procedure may be used with cross– section time series on–farm–trial data (farm level observations). Policymakers and extension personnel are concern about all sources of risk that would cause an innovation fail. Their perspective is not limited to broad weather and price variability.

The empirical approach assigns probabilities to each observation, ranks the observations, and uses the sum of the probabilities up to and including the probability of a given outcome as an estimate of the cumulative probability. The cumulative probabilities are plotted and joined with straight line segments to form a cumulative distribution curve. Straight lines are commonly used to link plotted points because information on how the distribution acts between observations is lacking. As the number of observations becomes very large the estimated distribution approaches a smooth curve.

In the simplest case the empirical estimation assumes the observations are equally likely, that is the probabilities are 1/N (where N = the total number of observations). A common problem in using on–farm–trial data is that the number of farmers participating varies from year to year. In that case the equally likely observations assumption generates unequal weighting of crop seasons. For example, if 5 farmers participated the first year, 25 farmers the second year and 12 farmers the third year, the equally likely observations assumption would assign 11% (100

*S/(S + 25 + 12), of the probability to the first year, 60% (100 * 25/(S + 25 + 12)) to the second year, and 29% (100 * 12 12/(S + 25 + 12)) to the third year. If in fact, the first season had bad crop conditions, the second season had good conditions and the third season had in between conditions, and these three seasons were equally likely, the equally likely observations assumption would over represent good conditions.

A simple way to take into account the number of observations per year is to estimate the probability of an observations as the product of the probability of the season and the probability of the management situation. If the seasons are equally likely and the farmers are representative of the community, the probability of an observation is (1/t)*(1/nt), where t is the number of seasons and nt is the number of farmers participating in year t. The Lowenberg–DeBoer et al (1990) stochastic dominance spreadsheet was modified to incorporate equal weighting of crop seasons.

The advantages and disadvantages – Like all analyses stochastic dominance has its strong and weak points. The primary advantage of stochastic dominance is the lack of strong assumptions on the form of the utility function or the underlying distribution of results. Stochastic dominance rules use simple, intuitive observations on human behavior. It will work with any type of distribution, including those that are strongly skewed.

The principal disadvantage of stochastic dominance is that the comparisons must be made pairwise. For situations in which there are hundreds of possibilities (for example, stock portfolios) stochastic dominance is impractical. For on–farm–trial results this is not a major constraint because the number of treatments is usually limited to 3 or 4.

Stochastic dominance has also been criticized for failing to take into account errors in estimation of the cumulative distributions (see Cochran for a review of this criticism). Lowenberg–DeBoer et al. (1992) propose use of the Kolmogorov–Smirnov (K–S) test to determine if the distributions are statistically different. They suggest doing the stochastic dominance analysis for all comparisons, but to consider the results as only indicative when the K–S test is not significant at the 5% level.

In general the K–S test is used to determine if two distributions are significantly different (Steele and Torrie 1980). The alternative hypothesis is that the two distributions are in fact two estimators of the same underlying distribution that differ because of estimation error. The K–S test is "non–parametric". That is to say it is done at the level of the distribution as an entity and not on individual parameters, such as mean, variance, etc. The test statistic is applied to the maximum vertical distance between the distributions. If this distance exceeds the critical level for the chosen significance threshold (for instance alpha=5%), then it is said that the distributions are significantly different. The critical level depends on the number of observations. Like stochastic dominance, the K–S test is pairwise. This study uses a spreadsheet template to do the K–S test (Lowenberg–DeBoer, 1992).

Farmer objectives – A common assumption made by all types of risk analysis is that the decisionmaker's objective is known. A common criticism is that most farmers have several objectives and the weight placed on each objective is unknown. In Burkina Faso farmers want

to produce enough to feed their families and also enough to sell to provide a cash income. In this analysis, it is assumed that a technology with a strong chance of being accepted will be in the third category (acceptable for risk averse decisionmakers) for several objectives. The technologies were tested for the objectives of maximizing food self–sufficiency and monetary income.

For the food self–sufficiency objective the grain yield was used because the trials were of pure stands (not intercrops). Thus, any other nutritional index, such as calories or protein content, would be a linear transformation of the yield and would have the same stochastic dominance comparison.

The monetary objective was measured by the return to family resources measured as gross revenue minus purchased inputs. In economic theory, all revenue can be linked to resources used in production. In this case, family resources include land, labor, capital and management. This economic measure was chosen to make use of the available data: grain and stover yields, cereal prices, the price of fertilizers, and the labor for fertilizer spreading and incorporation. Labor times for planting, weeding and harvesting were not collected. Average labor times are available, but subtracting a fixed sum from each observation would not change the distribution or the stochastic dominance comparisons.

The estimation of returns used standard budgeting principles. The gross revenue is the yield multiplied by the average price of the product for that year. Cereals prices in local markets were used (see Hien et al, 1993 for details). The stover was valued at 14 FCFA/kg based on price data collected by the INERA livestock production program. In the trials, farmers followed their usual practices, except for the fertilizer on certain treatments. Burkinabe farmers use very few purchased inputs in cereals production, thus for the analysis it was assumed that the only cash outlay was for fertilizer, including the cost of spreading and incorporation. The fertilizer cost were: NPK, 105 FCFA/kg; urea, 96 FCFA/kg; potash, 88 FCFA/kg; Burkina rock phosphate, 35 FCFA/kg; and partially acidulated rock phosphate, 41 FCFA/kg (Hien et Youl, 1992). The hourly rate for labor used in spreading and incorporating fertilizer was the minimum wage (SMIG) of 120 FCFA/h.

III. AGRONOMIC DATA

The agronomic data included grain and stover yields for millet, sorghum, and maize in three areas of Burkina Faso. The four treatments were designed to test the efficacy of three potential phosphate sources.

T1 – Control, no fertilizer
T2 – Burkina rock phosphate, plus urea and potash
T3 – Partially acidulated Burkina rock phosphate, plus urea and potash
T4 – NPK (cotton fertilizer) plus urea

Exact amounts of fertilizer varied by zone in accord with extension recommendations (Hien et al. 1990). The amount of urea and potash were chosen to provide the same nitrogen and

potassium for treatments T2, T3 and T4. The crop and seed variety were chosen by the farmer. The experimental design was a randomized complete block. Each farmer constituted a block in the design.

The areas were defined by average annual rainfall: Zone A, less than 600 mm; Zone B, between 600 mm and 800 mm, et Zone C, more than 800 mm. Hien et al. (1991) and Hien et Youl (1992) provide a list of sites.

IV. RESULTS

In this section the stochastic dominance results are organized by farmer objective, and within objective by area and crop. Sorghum yields and returns in zone B are presented in graphical form as an example. A detailed presentation of the results, including graphical presentation of all estimated distributions, descriptive statistics and K–S test statistics, is given by Hien et al. (1993).

Grain Yields – Grain yields show positive fertilizer effects at all yield levels. The cumulative distributions of fertilizer treatments (T2, T3, T4) are generally to the right of the no–fertilizer control. In the example of sorghum in the medium rainfall zone (zone B), the cumulative distributions of the fertilizer treatments are to the right of the control distribution for all yield levels (Figure 1). This means that the fertilizer treatments increase the probability of higher yields under low yield conditions as well as in high yield situations.

Figure 1. Cumulative Distributions
of Sorghum Yields, Zone B 1989-91

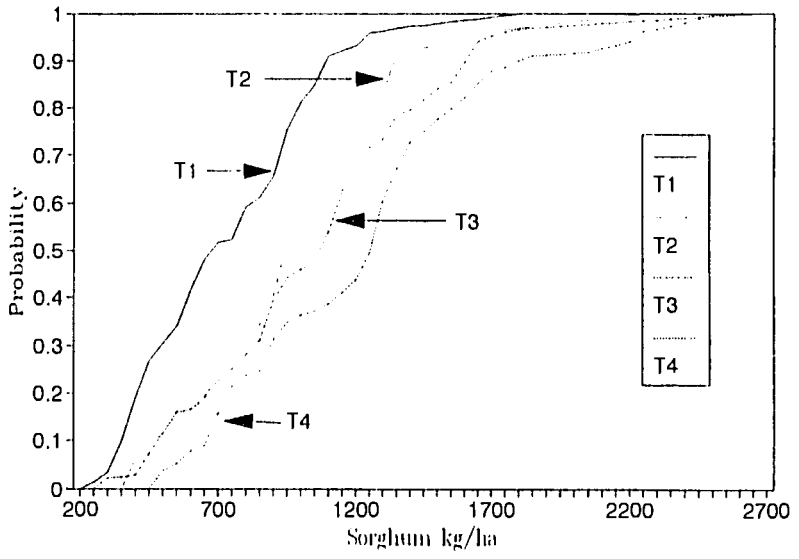


Figure 1 indicates that the control has a 50% chance of achieving 675 kg/ha or more, while the commercial fertilizer treatment (T4) has the same probability of achieving 1250 kg/ha or more. T4 achieves 869 kg/ha or more about 75% of the time. T1 has a 75% chance of producing 426 kg/ha or more.

Table 1. Risk categories for the food self–sufficiency objective for technologies tested by the Food Crops Fertilizer Project, Burkina Faso, 1989–91, by crop and agro–ecological zone.

Zone and crop	T1	T2	T3	T4
Zone A, Millet	dominated*	dominated	dominated	risk** averse
Zone A, Sorghum	dominated	risk averse	risk averse	risk averse
Zone B, Millet	dominated*	dominated	risk** averse	risk** averse
Zone B, Sorghum	dominated*	dominated	risk neutral	risk** averse
Zone B, Maize	dominated*	risk averse	dominated	risk** averse
Zone C, Millet	dominated	dominated	risk neutral	risk averse
Zone C, Sorghum	dominated*	dominated	risk neutral	risk** averse
Zoned C, Maize	dominated*	risk** averse	risk** averse	risk** averse

* Treatment dominated in a comparison between distributions that are statistically different at the 5% level using the Kolmogorov–Smirnov test.

** Treatment undominated in all comparisons and dominates in the first degree in at least in one case in a comparison between distributions that are statistically different at the 5% level using the Kolmogorov–Smirnov test.

In terms of grain yield the control is dominated in all zones and for all three crops studied (Table 1). In 6 of the 8 cases, the no–fertilizer treatment is dominated in a comparison between distributions that are statistically different according to the K–S test at the 5% level.

The treatments using rock phosphate (T2, T3) show more risk than those using commercial fertilizer (T4). In Figure 1, the T2 distribution is about halfway between the T1 and T4 curves. T2 has a 50% chance of producing about 923 kg/ha or more, and a 75% chance of producing about 692 kg/ha or more.

For the food self–sufficiency objective, the rock phosphate treatment (T2) is dominated for millet in all zones (Table 1).

For sorghum, rock phosphate is dominated in zones B and C, but in zone A it can not be excluded from the risk averse category. In Figure 1, the T2 curve for sorghum in zone B is always to the left of T4, and thus it is dominated by first degree stochastic dominance. For maize the rock phosphate treatment is in the risk averse category for zone B and C.

The rock phosphate treatment is undominated in comparisons between statistically different distributions only for maize in the high rainfall zone. The distribution of T2 is statistically

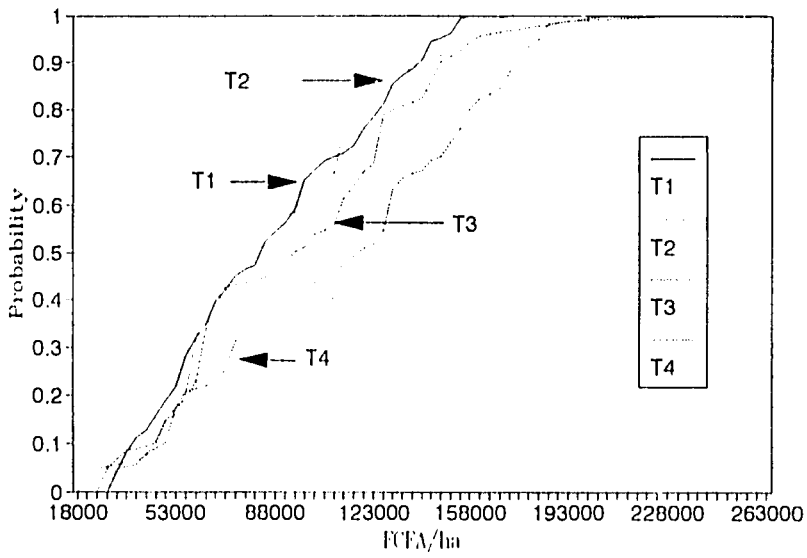
different from that of the no fertilizer treatment only for sorghum in zones B and C, and for maize in zone C. In general, the rock phosphate results must be considered indicative because the T2 distributions are often not clearly different from that of the control.

The treatment using partially acidulated rock phosphate (T3) shows less risk than the non-acidulated rock phosphate (T2). In the example of sorghum in zone B (Figure 1), T3 has a 50% chance of yields at or above 1087 kg/ha and a 75% chance of yields over 744 kg/ha. The T3 advantage is primarily seen under higher yield conditions. In Figure 1, the T3 distribution is generally to the right of the T2 distribution above 900 kg/ha. Under low yield conditions the two curves intertwine and are virtually indistinguishable. The T3 distribution starts to the left at a lower minimum yield than T2.

For millet T3 is dominated in zones A and C, but it is not excluded from the risk averse category for zone B (Table 1). For sorghum, T3 is in the risk neutral category for zones B and C, and in the risk averse category for zone A. T3 is not completely dominated by T4 for sorghum in zone B because T3 is the right most distribution for very high yield conditions (Figure 1). For maize, T3 is dominated in zone B and in the risk aversion category in zone C. T3 is undominated in comparisons involving statistically different distributions only for millet in zone B and maize in zone C. The T3 distribution differs statistically from the control distribution in 5 of the 8 cases. Because of the higher solubility of its phosphate, T3 provides a more reliable crop response and its yield distribution is more clearly distinguished from the no fertilizer treatment than in the rock phosphate (T2) case.

Cash return – The effect of fertilizer on cash returns is less clear than the effect on yield. The

Figure 2. Cumulative Distribution
of Sorghum Returns, Zone B 1989-91



cumulative distribution curves for all treatments intersect frequently, especially under low yield conditions (see Figure 2 for an example). The stochastic dominance comparisons show that the commercial fertilizer treatment is in the risk averse category for all three crops in all zones

(Table 2), but only 3 of the 8 cases are the result of statistically different distributions. Unlike the grain yield comparisons, the cash return analysis does not place the control in the dominated category in every case. T1 is in the risk averse category for sorghum in zone B because it's minimum value is larger than the minimums for the fertilizer treatments. In Figure

Table 2. Risk categories for the monetary return objective for technologies tested by the Food Crops Fertilizer Project, Burkina Faso, 1989–91, by crop and agro–ecological zone.

Zone and crop	T1	T2	T3	T4
Zone A, Millet	risk neutral	dominated	dominated	risk averse
Zone A, Sorghum	dominated	risk averse	risk neutral	risk averse
Zone B, Millet	dominated*	dominated	risk** averse	risk** averse
Zone B, Sorghum	risk averse	risk neutral	risk averse	risk averse
Zone B, Maize	dominated*	risk averse	dominated	risk** averse
Zone C, Millet	risk neutral	dominated	risk neutral	risk averse
Zone C, Sorghum	dominated*	dominated*	risk neutral	risk** averse
Zone C, Maize	risk neutral	risk neutral	risk averse	risk averse

* Treatment dominated in a comparison between distributions that are statistically different at the 5% level using the Kolmogorov–Smirnov test.

** Treatment undominated in all comparisons and dominates in the first degree in at least in one case in a comparison between distributions that are statistically different at the 5% level using the Kolmogorov–Smirnov test.

2 this is shown by the fact that T1 intersects the horizontal axis to the right of the other distributions. In a stochastic dominance comparison the distribution with the largest minimum can not be dominated. T1 is in the risk neutral category for millet in zones A and C, and for maize in zone C.

For the cash return distributions, the advantage of the no fertilizer treatment shows up in low yield seasons. The fertilizer must be applied before the season's rainfall and other characteristics are known. As a consequence, cost are incurred, even if the lack of rainfall or other constraints limit fertilizer response. If yields are limited by weather, the fertilizer yield response is small, but the cash returns for the fertilizer treatments are less than that of the control because of the fertilizer cost.

The case of returns to the rock phosphate treatments (T2, T3) is more complex than that of the

commercial fertilizer (T4). The rock phosphate treatment (T2) is dominated for millet in all zones and for sorghum in zone C. Only in the case of sorghum in zone C is this domination the result of a comparison between statistically significant distributions. T2 is in the risk averse category for sorghum in zone A and maize in zone B. T2 is in the risk neutral category for sorghum in zone B and maize in zone C. T2 is not dominated by the first stochastic dominance rule for sorghum in zone B because the T2, T3 and T4 distributions intertwine at about 53,000 FCFA.

In the analysis of monetary returns, the partially acidulated rock phosphate (T3) is dominated for millet in zone A and maize in zone B. T3 is in the risk averse category for millet and sorghum in zone B and maize in zone C. T3 is in the risk neutral category for sorghum in zone A and C, as well as for millet in zone C.

For the monetary income objective, the benefits of commercial fertilizer are relatively clear. T4 is always potentially acceptable to risk aversion decisionmakers. The rock phosphate results are less clear. The distributions of T2 and T3 intersection frequently with the T1 distribution. For example, for sorghum in zone B, the T1 and T2 curves cross four times and even at relatively high income levels, they are not well separated (Figure 2). The T1 and T3 curves for sorghum in zone B cross three times, but beyond 71,000 FCFA/ha the T3 distribution is to the right.

V. CONCLUSIONS

The stochastic dominance shows that among the four treatments tested, commercial NPK fertilizer has the most desirable risk characteristics. The commercial fertilizer (T4) is in the risk averse category for the food self–sufficiency criteria and for the monetary returns objective for all three crops considered and for all climatic zones. The K–S test indicates that the comparison of the commercial fertilizer treatment and the no fertilizer control is relatively robust.

The no–fertilizer control is largely dominated by the fertilizer treatments. For the food self–sufficency objective the control is dominated in every comparison. For the cash return comparisons, the control has the advantage of limiting costs in cases when yields are constrained by weather. In that case, the yield response is small, but the fertilizer treatments have higher costs and hence lower net returns.

The rock phosphate treatments (T2, T3) have better yields and in certain cases higher returns than the control, but those benefits are less sure than for the soluble commercial fertilizer. From a cash return point of view, the rock phosphate treatments offer few advantages. The distributions of cash returns to the rock phosphate treatments are rarely significantly different from those of the control. The T2 and T3 distributions intersect each other frequently, as well as crossing the T1 curve. The rock phosphate treatments never dominate the commercial fertilizer treatment.

It should be noted that this analysis compares the risk characteristics of three fertilizer application strategies with the no fertilizer option. The risk of fertilizer application on cereals relative to the risk inherent in the farmer's other activities (livestock raising, commerce, etc.)

Upland Rice: An Alternative for Cash Crop Diversification to Stabilize Farm Incomes in Western Burkina Faso

E. Sankara, A. Sidibé, and J. Dickey

ABSTRACT

In Western Burkina Faso, cotton is traditionally grown as a cash crop. Declining cotton yields and prices have encouraged farmers to consider alternatives to cotton. Rice is a marketable crop that is well adapted to clayey or hydromorphic soils in this region. Upland rice was tested under researcher and farmer management, to better define the conditions of possible adoption. Two villages were chosen based on the availability of animal traction equipment. Two rice varieties were tested with farmer cooperators: FKR-5 and FKR-33. Traditional cultural practices were used, including moldboard plowing, hand-sowing, and hand-weeding. Upland rice planted after a fallow period produced a higher yield than that planted after other crops. The variety FKR-5 was the earliest and most tolerant of periods of drought. Well timed and executed land preparation contributed to good plant development and higher yields. The major constraints were the large amount of labor needed, mostly during sowing and weeding. Highest yields were 3000 kg/ha. Follow-up tests will attempt to mitigate the labor constraint during weeding through the use of herbicides, cover crops, and mechanized weeding.

I. INTRODUCTION

Rice culture is widespread in western Burkina Faso, found mostly in lowland and irrigated situations. The potential for upland rice cultivation has increased with the availability of adapted, early varieties. The zone of adaptation is defined by total seasonal rainfall and soil type, and is concentrated in the western part of the country (Figure 1).

The Farming Systems Program (RSP) of INERA is charged with the identification of key constraints to adequate agricultural production and natural resources management in this region. Crop, tree, land, and animal management practices that help relieve these constraints are tested, and results are communicated to extension entities. This is accomplished through collaborative discussion, planning, testing, and evaluation among farmers and researchers.

In western Burkina, cotton is traditionally grown as a cash crop. It was introduced during the colonial period, and still is a key means of earning foreign exchange for Burkina. Declining cotton yields and prices have recently encouraged farmers to consider alternatives to cotton. Rice is another marketable crop that can be grown on fine textured, upland soils in this region, a substantial land area (Figure 1). Rice is widely consumed in villages on special occasions, (baptisms, weddings, funerals), and in the cities as a staple; (Burkina Faso consistently runs a rice trade deficit). Seed of upland rice varieties developed by breeding programs in national and international institutes is increasingly available in Burkina Faso. The objectives of this study were to:

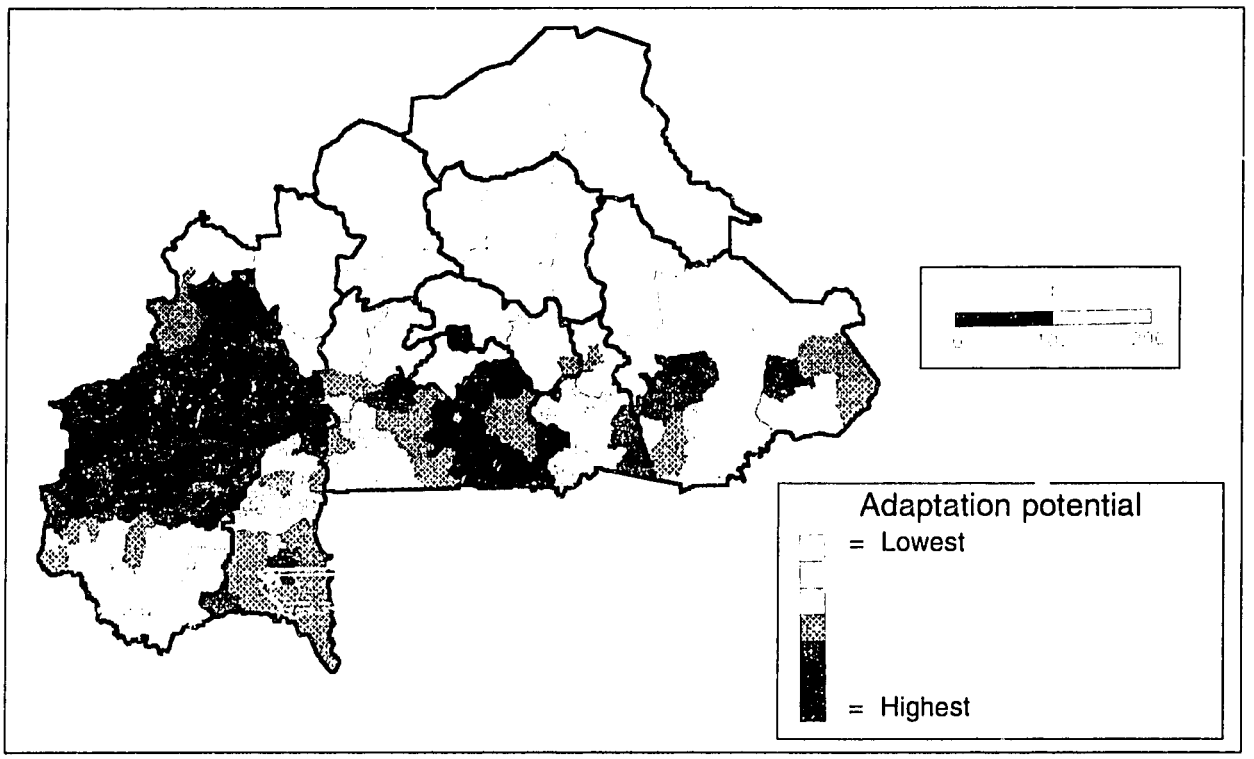


Figure 1. Distribution of adapted agroecological zones for upland rice, Burkina Faso (*Djaby et al.*, 1994).

- Determine the conditions of adaptation of upland rice farming in two agroecological sub-zones in western Burkina Faso
- Evaluate the ability of upland rice to convert land, labor, and capital inputs into food and cash, relative to cotton and maize (the major alternative cash crops)
- Evaluate two available upland rice varieties

II. METHODS

Upland rice was tested under joint researcher/farmer management to better define the crop's potential. Two villages, Kayao and Yasso (Figure 1) were chosen based on the presence of appropriate rainfall and soil conditions for upland rice, and on the availability of animal traction equipment, deemed necessary for land preparation in medium- to large-scale upland rice fields. The tests extended over the 1991 (13 farms), 1992 (11 farms), and 1993 seasons, however the 1993 results are not reported here. Two rice varieties were tested on each farm in each year: FKR-5 and FKR-33 (a product of IRRI).

Plots were 20 m x 20 m in size. Traditional cultural practices were used, including moldboard plowing, hand-sowing, and hand-weeding. Fertilization was with 200 kg/ha complex fertilizer (14-23-14-6-2, N-P-K-S-B) incorporated at planting, and 100 kg/ha urea (46-0-0) incorporated at the first cultivation (11 to 30 days after planting — DAP), for a total 74-46-28-12-4.

For statistical analysis, farms were taken as blocks, and years as a random subplot factor. Analyses for each of 4 location x year combinations (1-way, randomized complete block — RBCD) were supplemented by combined analyses across years (RBCD, years as split plots), across villages (2-way RBCD), and across years and villages (2-way RBCD, years as split plots, Steel and Torrie, 1980).

Economic viability of the system was compared with cotton and maize in simple, partial budgets, based on data from tests of each crop. Sensitivity of the rice budget to proposed, but untested changes in rice weed management practices was explored by modifying the real rice budget. Net benefit and coefficient of income variation, which are respectively indexes of earning potential and risk, were calculated as parts of these budgets.

Farmer reaction was gauged during ongoing, formal and informal dialog between researchers and farmers.

III. RESULTS AND DISCUSSION

Rainfall in both villages during both years exceeded mean total seasonal levels for the post-1970 period (Figures 2 and 3). Decades during the rice growing period with total rainfall less than the 20th percentile level are referred to here as mid-season droughts, and occurred in Yasso during 1991 and in Kayao during 1992.

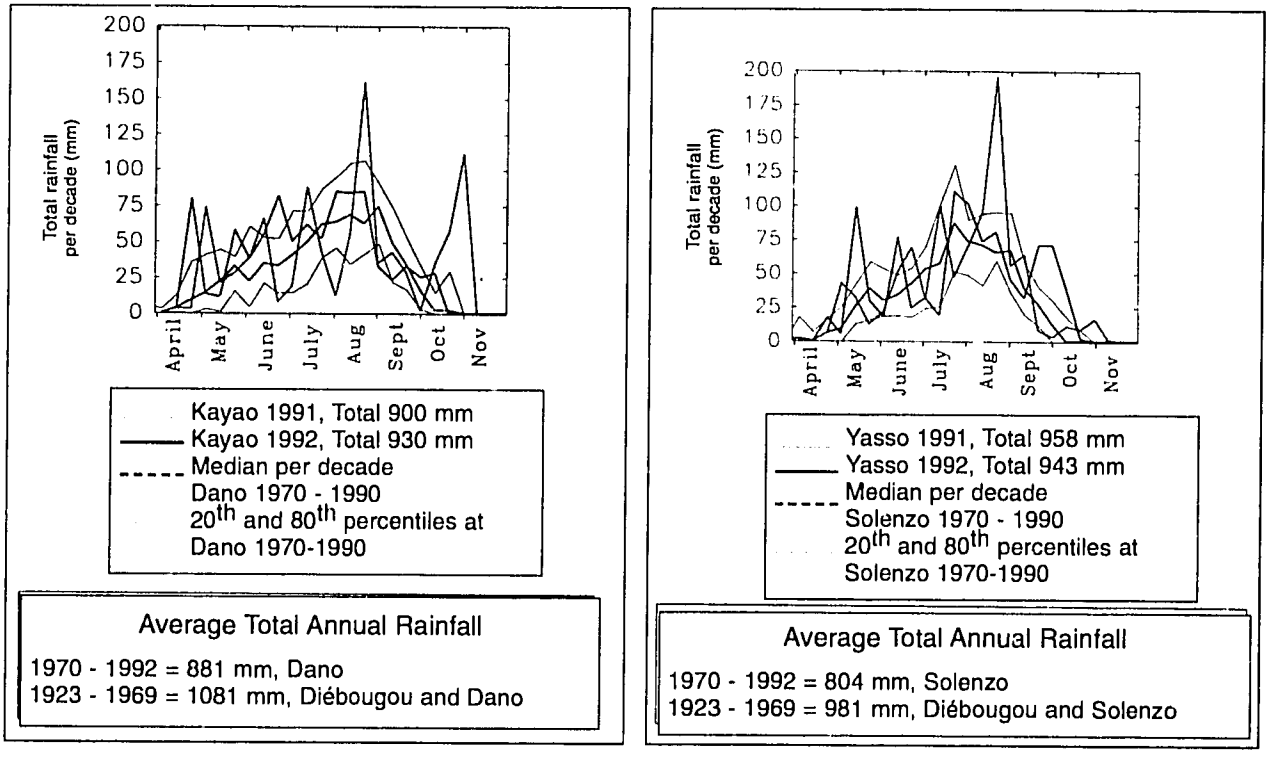


Figure 2 and 3. Kayao and Yasso rainfall in 1991 and 1992 relative to expected rainfall. Note that due to recent changes in the regional climate, post-1969 rainfall levels indicate expected rainfall better than pre-1970 rainfall levels.

Mean yields of upland rice were generally lower when subjected to mid-season drought (Figure 4). There were no significant differences between the two variety means in any of the analyses (Table 1). Yields of FKR-5 were generally lower than for FKR-33 when subjected to mid-season drought. In the absence of such drought, however, this difference was reversed. Although insignificant in the analyses of variance, the interaction of the varieties with climate is further suggested by frequency distributions of grain yields (Figure 5) and stability analysis (Figure 6). Plots in the highest and lowest yield classes were mostly FKR-5, with plots of FKR-33 most common between these extremes. These distributions are summarized in a steeper curve for FKR-5 in the stability analysis, and we conclude that FKR-5 is a less stable variety under the tested conditions.

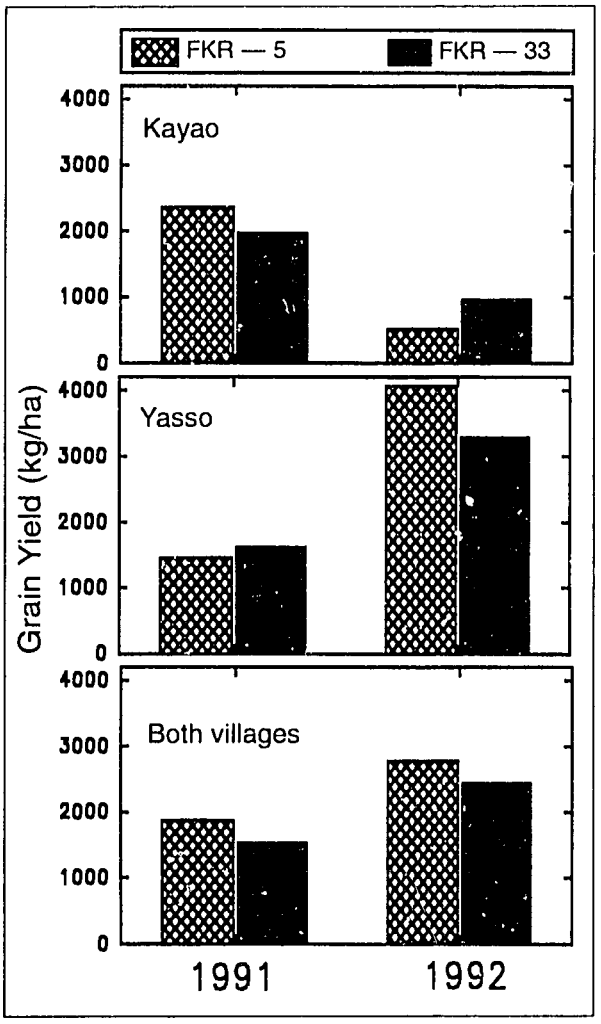


Figure 4. Upland rice grain yield means for Yasso and Kayao, 1991 and 1992 seasons.

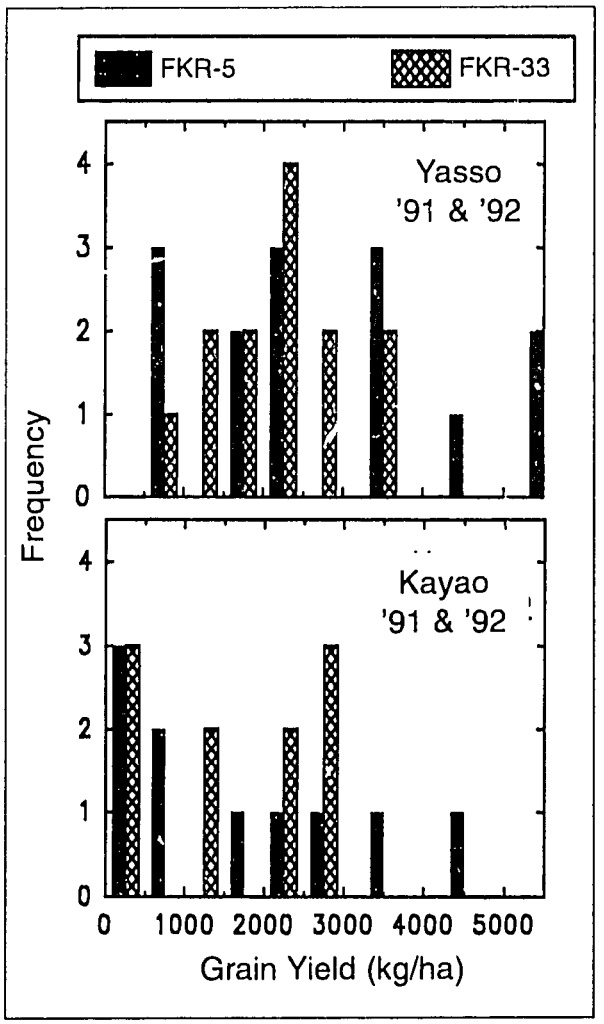


Figure 5. Frequency distributions of rice grain yield in Kayao and Yasso, 1991 and 1992.

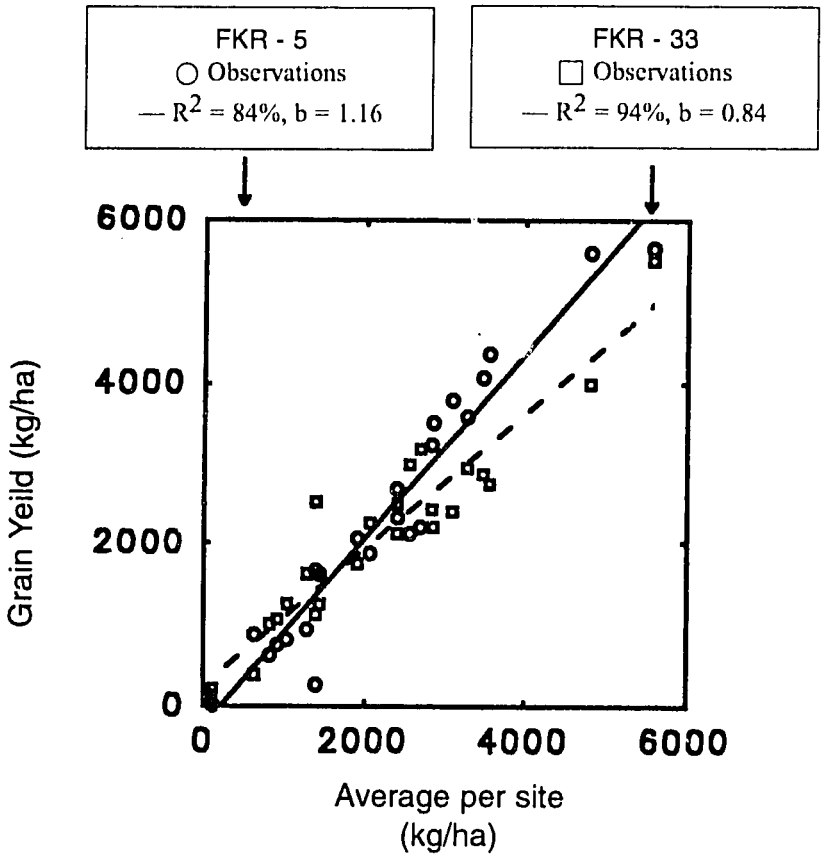


Figure 6. Stability analysis for grain yield for FKR-5 and FKR-33, Kayao and Yasso, 1991 and 1992.

Table 1. Summary of analyses of variance, upland rice tests at Kayao and Yasso, 1991 and 1992.

Combined Analyses:

Effect	Kayao	Yasso	1991	1992	All years and villages
	---------- Probability of no effect ----------				
Village (Zone)			- - †	0.001	0.09
Variety	- -	- -	- -	- -	- -
Village x Variety			- -	0.09	- -

Individual Analyses:

Effect	Kayao 1991	Kayao 1992	Yasso 1991	Yasso 1992
	---------- Probability of no effect ----------			
Variety	- -	- -	- -	0.07

†Values greater than 0.1 are represented by - -.

The apparent drought tolerance of FKR-33 is at least partly escape: this variety flowered at an average of 68 DAP, seven days earlier than FKR-5. Although mid-season drought is a factor, early- and late-season droughts are more common in the region.

Two management factors appeared have a practically significant influence on grain yield. The rice trials followed a variety of crops in the rotation, and the distributions of grain yields for each type of preceding crop are distinct (Figure 7a). Although these data must be considered very preliminary due to the lack of control to test this factor, the data suggest an advantage to planting upland rice after a fallow period, or after an intensively cultivated (and fertilized) crop like melons. Also, the date of the first weeding, when used as a covariate, was always highly significant. (It was not included in the presented analyses, since it was highly correlated with the village effect). The optimal date of first weeding is 15 DAP, yet many farmers did not succeed in weeding at this time (Figure 7b).

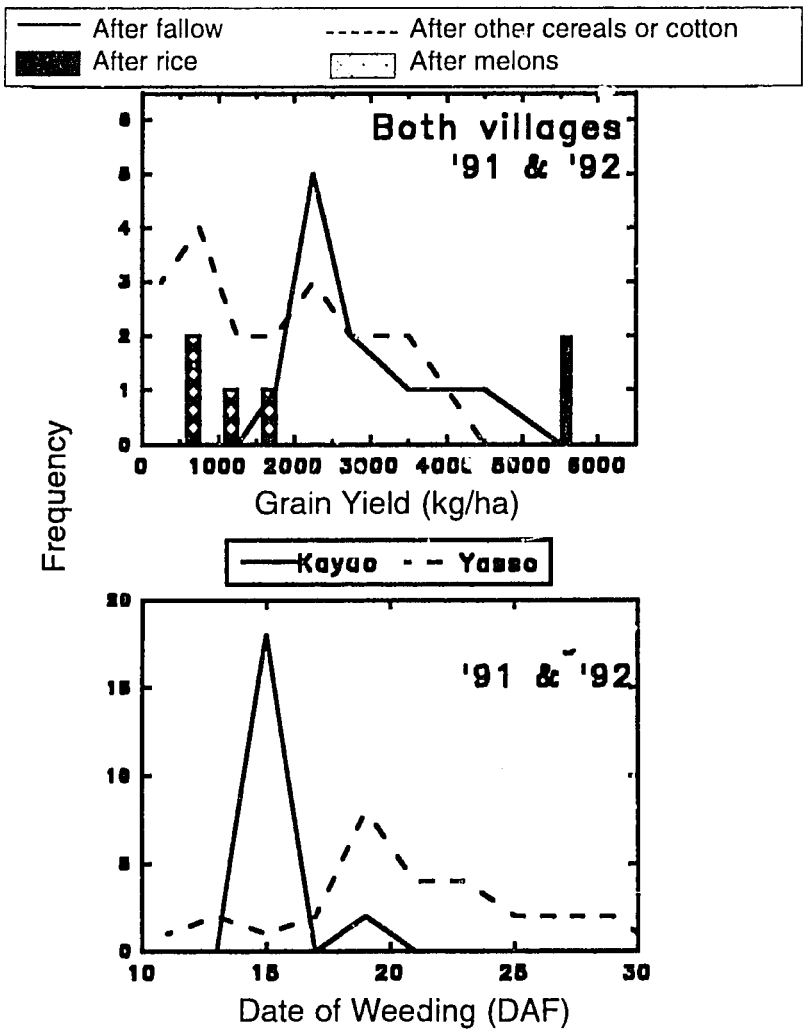


Figure 7a (top). Frequency distributions of rice grain yield for each class of preceding crop. Figure 7b (bottom). Frequency distribution of the timing of the first weeding in Kayao and Yasso.

The economic viability of upland rice is promising. Average yields under favorable conditions were in the 2000 to 4000 kg/ha range, with a maximum plot yield of 5600 kg/ha. Based on these trials and others for cotton and corn, the average net returns from upland rice compare very favorably with the alternatives (Table 2). However, production costs and the variability of net returns are highest for upland rice. It should be also be noted that the tests were conducted in years of greater than average annual rainfall, so that the stability of production during drier seasons may not be reflected.

Table 2. Partial budgets comparing upland rice crops with maize and cotton, the major cash crops in western Burkina Faso. Data from on-farm trials.

Item	*Cotton*	*Maize*	*Rice*	*Rice with chemical weeding*
	*(CFA/ha)**	*(CFA/ha)*	*(CFA/ha)*	*(CFA/ha)*
Gross revenue	70 550	122 500	187 000	187 000
Variable costs	111 978	70 800	121 800	95 600
Labor	88 000	55 000	97 800	47 600
Inputs	23 978	15 800	24 000	48 000
Net revenue	(41 428)	51 700	65 200	91 400
In dollars/ha:	($148)	$185	$233	$326
Coefficient of variation	41%	39%	60%	?
Assumptions:				
Number of Cases (No.)	10	6	14	0
Unit price of commodity	85	50	85	85
Commodity yield (kg/ha)	830	2450	2200	2200

* $1 = 280F CFA

Labor for the first hand weeding makes up 55% of upland rice production costs. Chemical weed control, widely used just to the south in northern Côte d'Ivoire, would hypothetically reduce production costs by 22%, and increase net returns by 40%. Chemical and manual weed control are being compared in the 1993 trials, and preliminary results are very favorable.

IV. CONCLUSIONS

The conditions of adaptation of upland rice include:

- The ability of farmers, through access to credit or other means, to support at least a level of upland rice production costs equal to that demanded by cotton
- The presence of fine-textured soil and at least 800 mm average (post-1969) annual rainfall
- The ability of the farmer to weed on a timely basis, (chemical weed control may help provide a practical means to satisfy this requirement)

- The availability of fallow or garden cropped land for planting with rice (preferred, not required)

If these conditions are met, and if drought periods do not damage the crop, net returns from upland rice compare very favorably with cotton and maize.

Both of the upland varieties tested appear to be acceptable, with FKR-5 having more yield potential under moist conditions, and FKR-33 holding out best under occasional drought.

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Steel, R.G.D., and J.H. Torrie. 1980. Principles and Procedures of Statistics. McGraw Hill, Inc. New York. pp. 398-399.

Dynamic Recommendation Domains in Burkina Faso: A Geographic Information System as a Tool for Facilitating the FSR-Extension Connection

M. Bertelsen, S. Ouédraogo, J. Dickey,
S. J.-B. Taonda, E. Robins, and D. Kaboré

I. INTRODUCTION

The flow of information between FSR researchers and extension agents is often problematic. The identification of recommendation domains (RDs) is the traditional means of generalizing research results to specific zones as well as a means of overcoming the researcher-extension communication problem. Within a given RD, the interests of researchers and extension agents coincide and should reinforce each other. Nevertheless, many times RDs are never formally defined. Even when they are there is a tendency for them to become static and rigid over time, along with the researcher-extension relationship.

Dynamic RDs are one means of addressing these problems. Dynamic RDs are RDs whose frontiers change in response to different technologies or adoption criteria. Different criteria may result from additional data or from an evolving understanding of the technology based on dialogue among farmers, researchers, and extension agents. A new technology may have characteristics which make it suitable for adoption in systems far from where it was tested. Efficiency demands that all such areas be identified: a geographic information system (GIS) is very useful tool for accomplishing this.

Dynamic RDs are illustrated here by defining and overlaying different data criteria "layers" to indicate zones of probable adoption for upland rice. Upland rice is a relatively new crop in Burkina Faso and is seen by many as a substitute in some farmers' systems for cotton. The terms of trade have turned against cotton in Burkina Faso in recent years and farmers are searching for alternatives. Upland rice is one such possibility. RSP teams have found encouraging production results and enthusiasm for upland rice among farmers. Upland rice is judged to be ready for broader extension among Burkinabè farmers.

II. METHODS

A GIS module including computers, peripheral equipment and software was installed in the RSP unit of INERA for the expressed purpose of assisting the RSP team in developing national recommendation domains[1]. The ATLAS GIS and IDRISI software chosen for the module had already become the defacto standard for project-level GIS systems throughout Burkina. This compatibility along with the general willingness on the part of others working with GIS systems in country to share basic GIS and database files have permitted the module to advance rapidly[2].

[1]This effort is a component of the ARTS Project (Agricultural Research and Training Support), a USAID-financed project in Burkina Faso.

[2]In this example we have benefitted from data and assistance given to us by USAID's FEWS (Famine Early Warning) Project, and the Ministries of Agriculture and Water.

The GIS is used to rapidly re-assess changing socio-economic and even physical forces which may constrain adoption outside of a given RD. The GIS accomplishes this by overlaying adoption criteria layers on a digital map, weighting them according to their importance, and producing new maps of RDs for consideration. The interactive nature of the GIS encourages the involvement of all interested parties, thereby improving communication and results. If data is sufficiently detailed, the GIS may be able to pin-point areas within a RD where the probability of adoption is the highest. This is especially useful when targeting limited research and extension resources.

III. RESULTS AND DISCUSSION

From a GIS perspective a RD is defined by overlaying various levels of data which affect the adoption of a given technology. This process is illustrated by the series of numbered figures which follows (referred to by the numbers in parentheses).

The potential adoption of upland rice is perceived to depend upon two main (physical) criteria: rainfall and soils. Consequently, the delimitation of the RD begins by identifying the areas of rainfall greater than 800 mm per year, the accepted minimum (1). Departments with sufficient areas of soils identified by RSP agronomists and soil scientists as appropriate for upland rice become an additional data layer (2). Overlaying these two layers of data yields a first approximation of the RD (3). This preliminary RD is more appropriate for targeting potential small-scale or subsistence producers than commercial producers since only physical criteria are used. By adding additional layers of data, an RD more focused on commercial producers can be achieved.

Because bovine animal traction has been identified in RSP villages as an especially important indicator for commercial adoption, we delimit the areas where oxen are important and very important (4). Also important is access to markets (primary and secondary road system) (5). Finally, production experience with cotton is considered important since these commercial farmers have experience with purchased inputs and are searching for alternatives (6).

Combining these criteria with the previous map yields a much more refined and focused RD (7) which can be blown-up for even further refinement (8). We add village locations (9) and focus on the northernmost area of highest adoption probability (10).

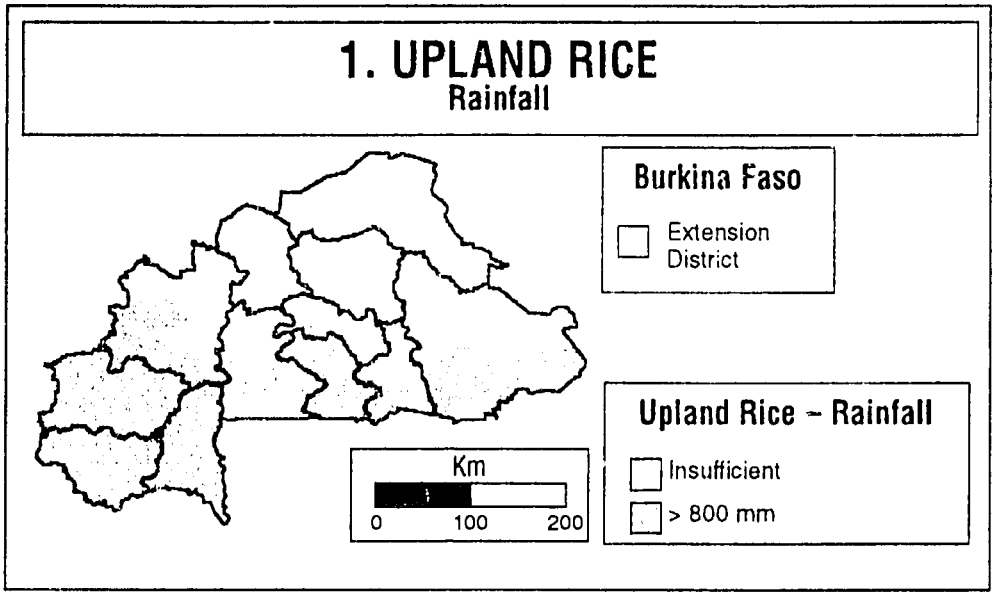
Since soils are particularly crucial to upland rice we return to delimit at the national level (11) and the extension district level (12) the highest potential soils. Overlaying these soils with the previous RD map allows us to identify very specific areas and villages within an already high probability zone for adoption (13).

Finally, the facilities of the software allow us to call-up and identify (for example) the largest high potential villages within the area as well as whatever other data which may be available concerning these sites in the village database (14).

IV. SUMMARY AND CONCLUSIONS

Dynamic RDs are one solution to the FSR/extension communications problem and a GIS can be a very useful tool in developing them. Dynamic RDs focus attention on high adoption probability areas and thereby increase the likelihood that the high potential benefits from investments in FSR research and extension will be achieved.

Using a GIS, dynamic RDs are easily modified. Additional layers can always be added, subtracted or weighted differently to produce a new map. The dynamic RD which results is as good as the database and the knowledge of the group doing the analysis. The process encourages the development and refinement of databases to meet the future needs of FSR research and extension.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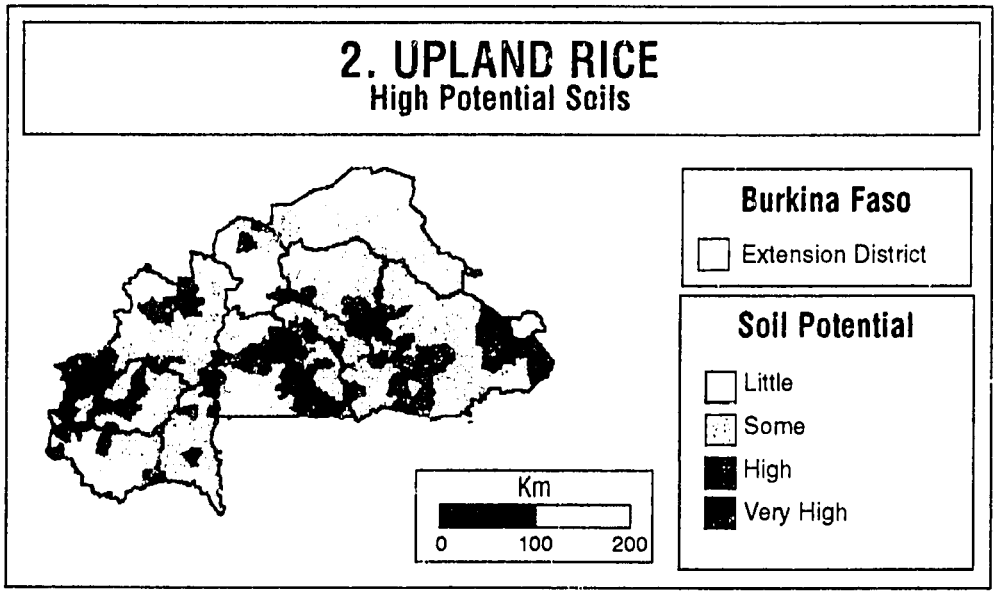
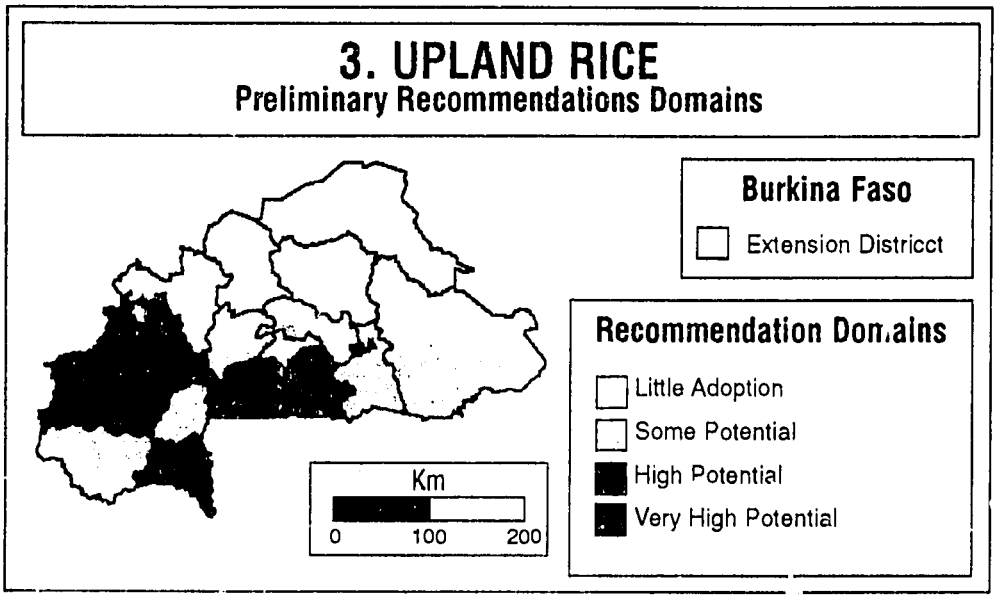
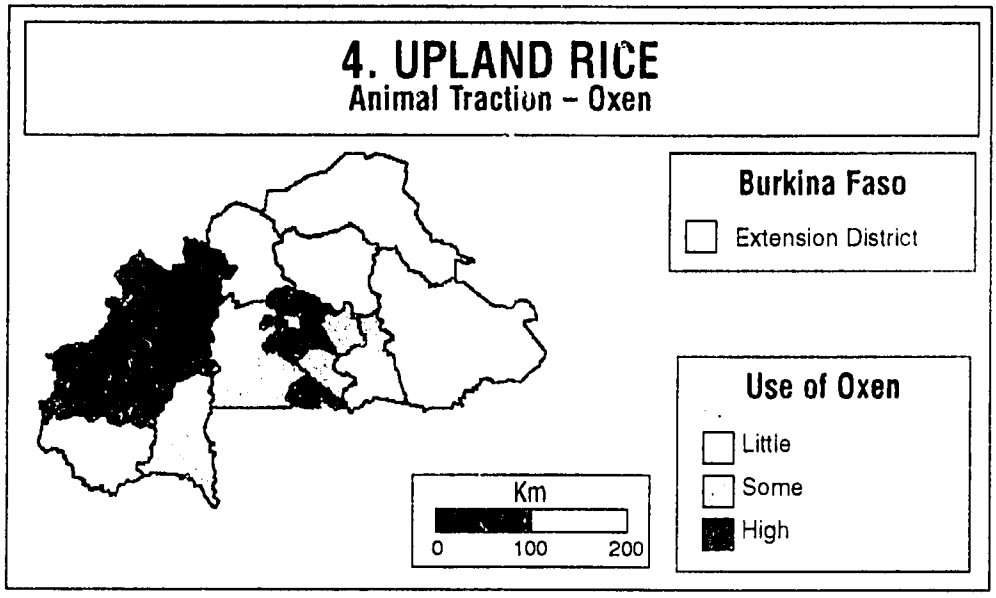
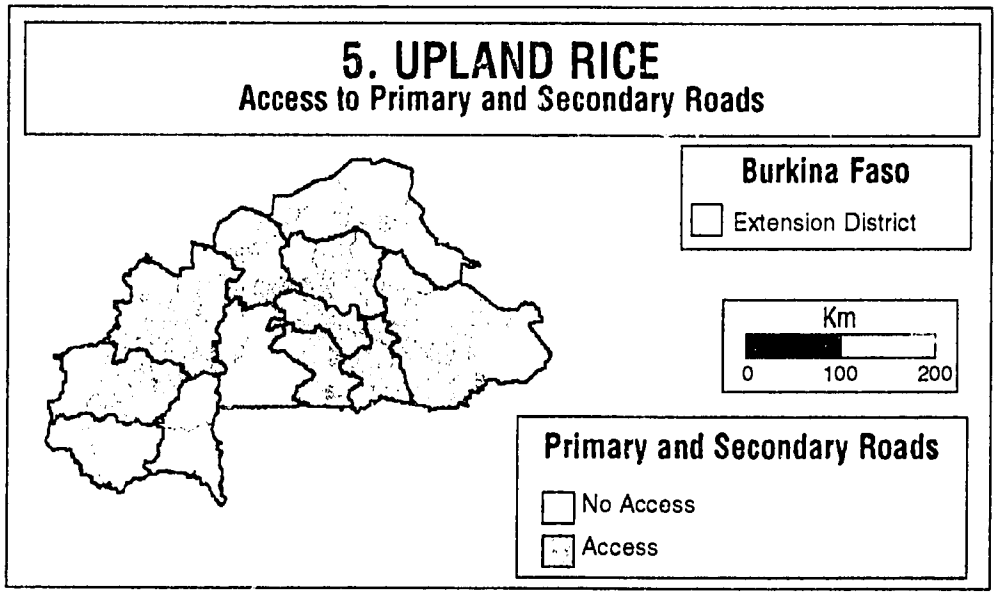
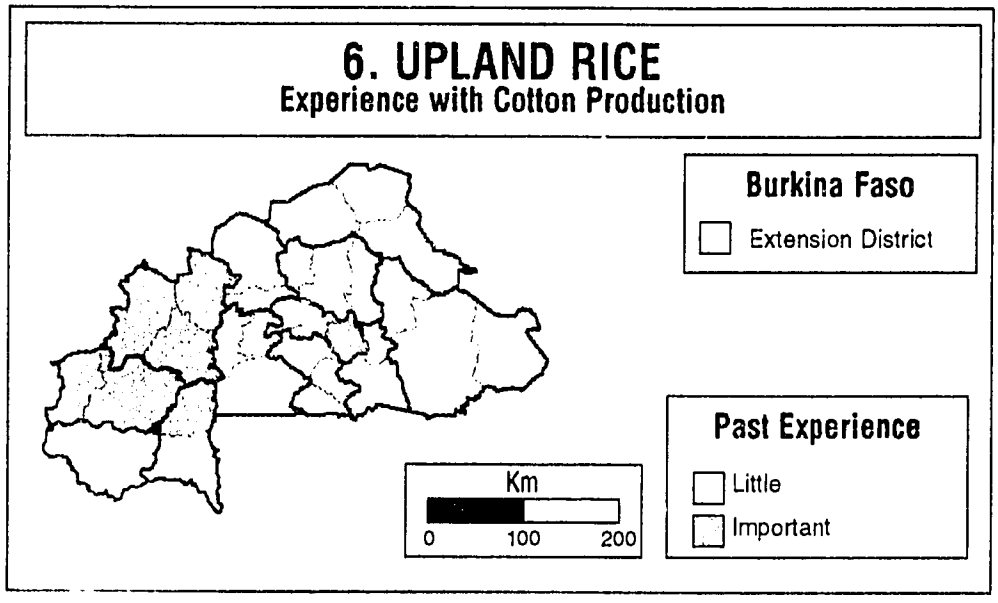
Rainfall
Burkina Faso
Extension District
Upland Rice - Rainfall
Insufficient
> 800 mm
Km
0
100
200

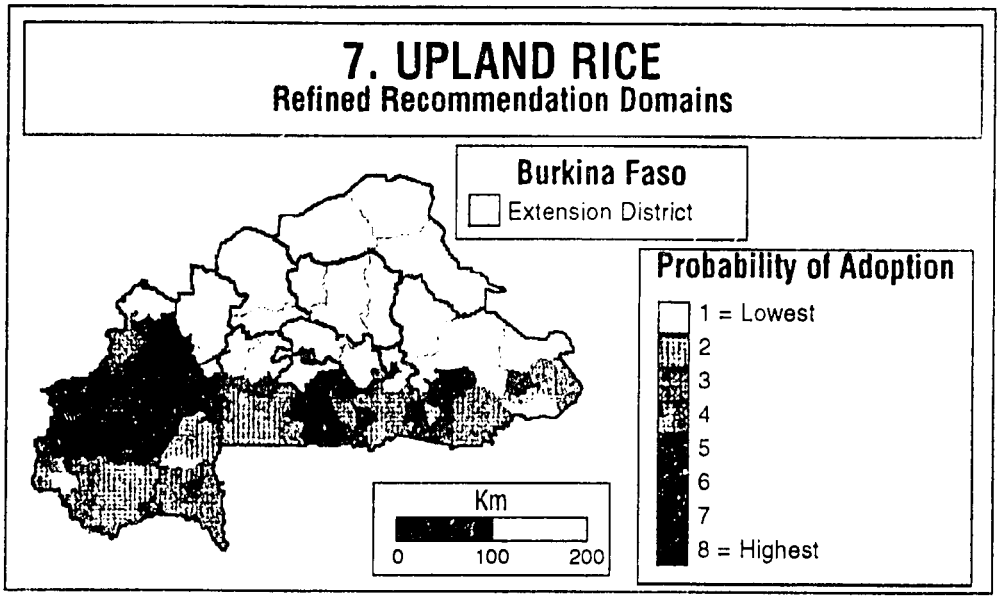

2. UPLAND RICE
High Potential Soils
Burkina Faso
Extension District
Soil Potential
Little
Some
High
Very High
Km
0
100
200

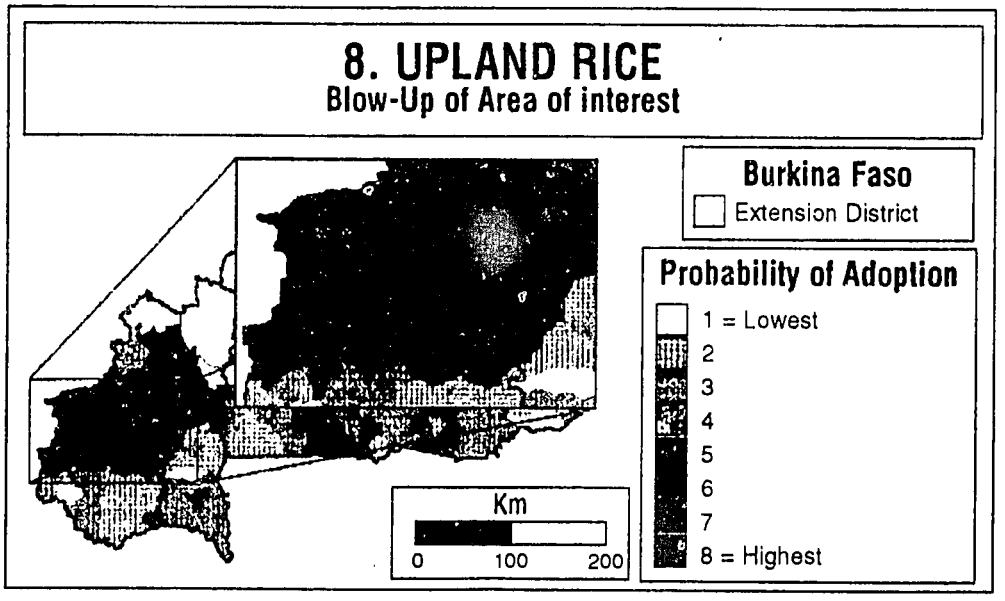

3. UPLAND RICE
Preliminary Recommendations Domains
Burkina Faso
Extension Districct
Recommendation Domains
Little Adoption
Some Potential
High Potential
Very High Potential
Km
0
100
200

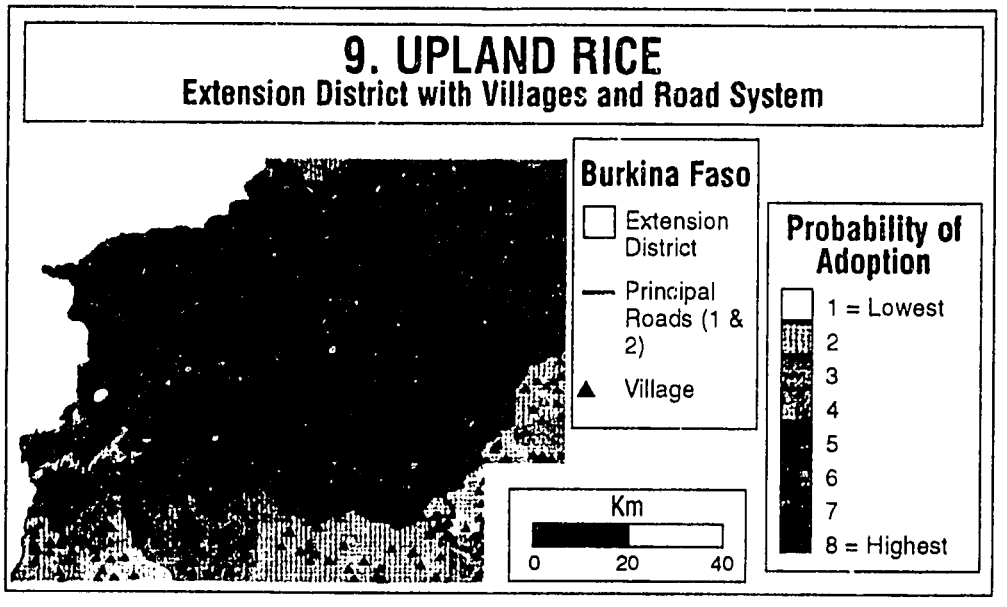

4. UPLAND RICE
Animal Traction - Oxen
Burkina Faso
Extension District
Use of Oxen
Little
Some
High
Km
0
100
200

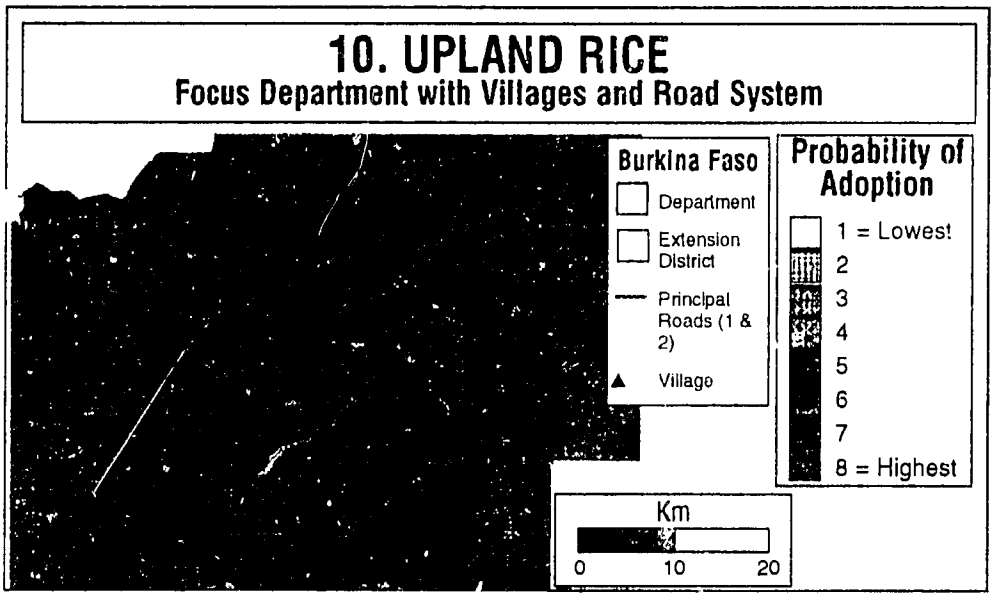

5. UPLAND RICE
Access to Primary and Secondary Roads
Burkina Faso
Extension District
Km
0
100
200
Primary and Secondary Roads
No Access
Access

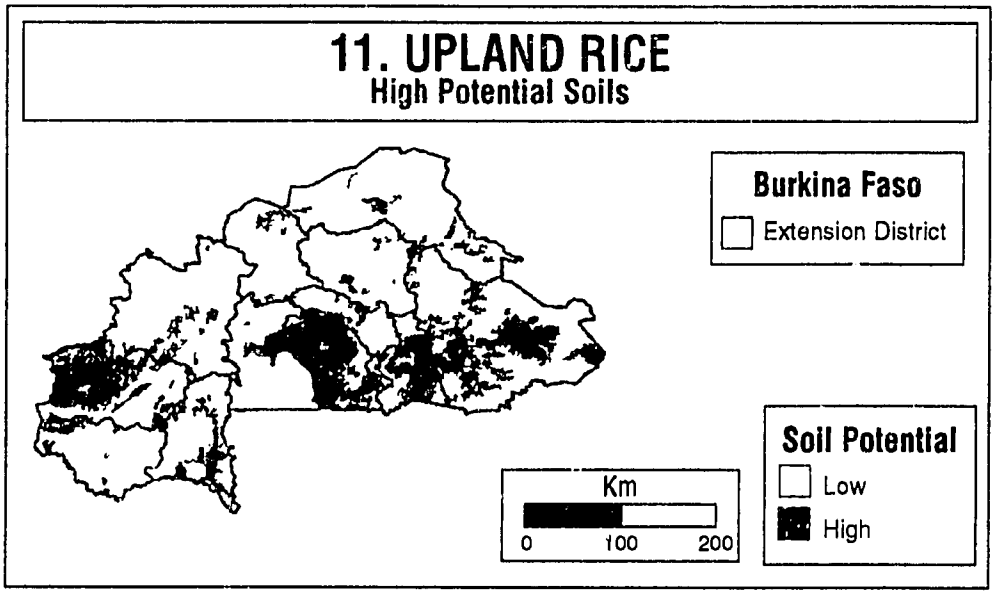

6. UPLAND RICE
Experience with Cotton Production
Burkina Faso
Extension District
Past Experience
Little
Important
Km
0
100
200

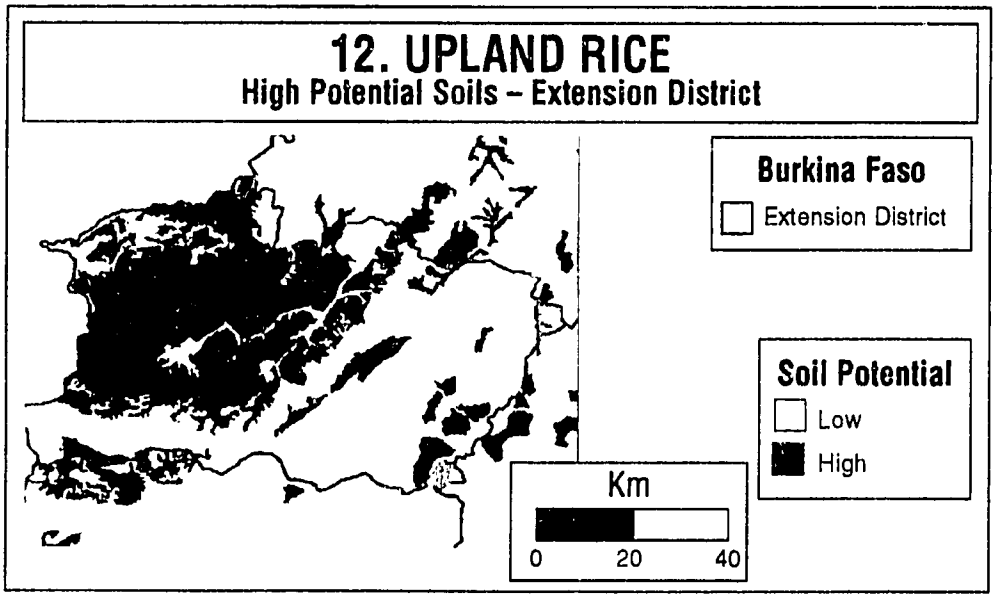

7. UPLAND RICE
Refined Recommendation Domains
Burkina Faso
Extension District
Probability of Adoption
1 = Lowest
2
3
4
5
6
7
8 = Highest
Km
0
100
200

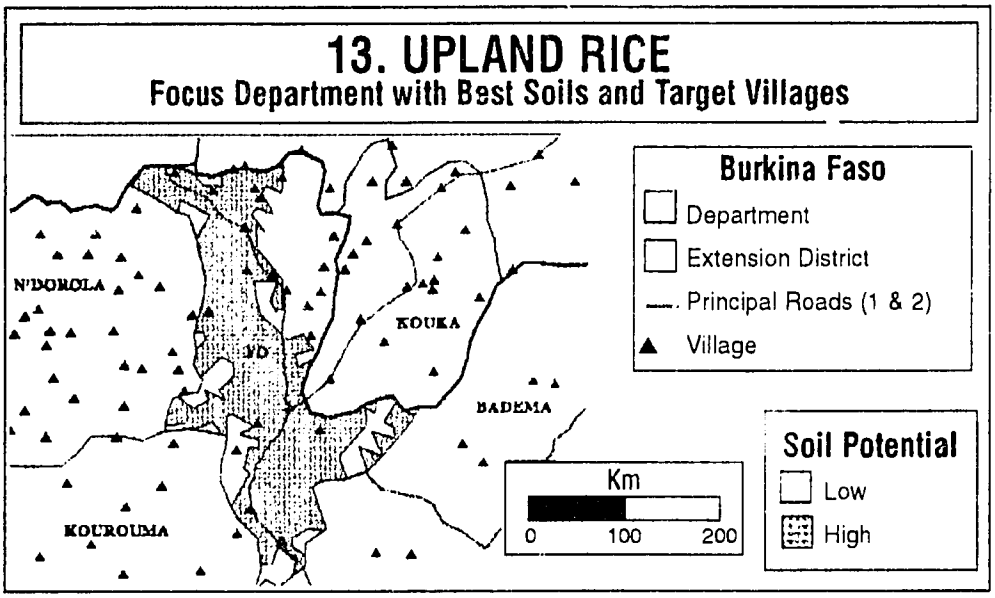

8. UPLAND RICE
Blow-Up of Area of interest
Burkina Faso
Extension District
Probability of Adoption
1 = Lowest
2
3
4
5
6
7
8 = Highest
Km
0
100
200

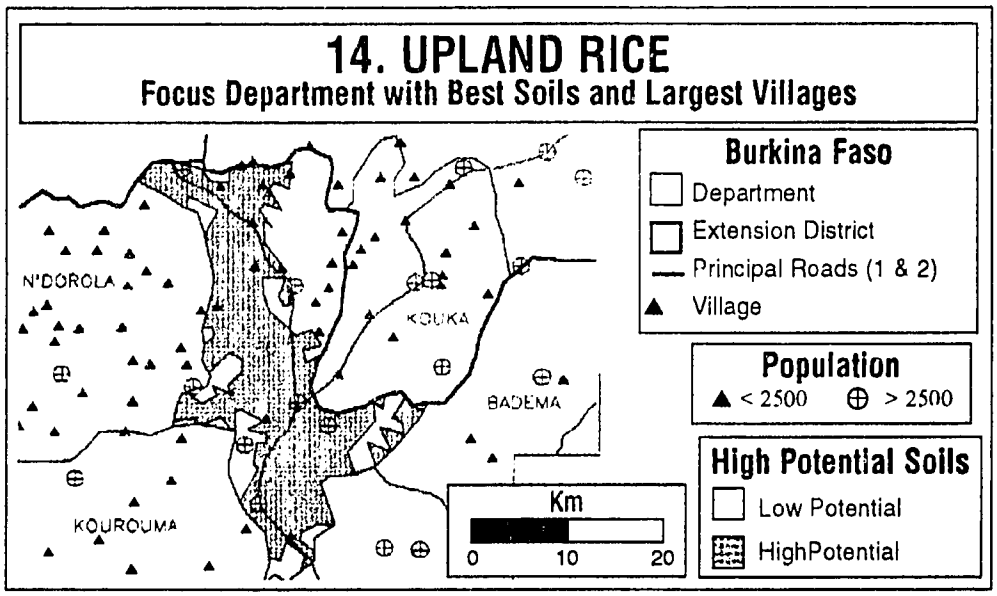

9. UPLAND RICE
Extension District with Villages and Road System
Burkina Faso
Extension District
Principal Roads (1 & 2)
Village
Probability of Adoption
1 = Lowest
2
3
4
5
6
7
8 = Highest
Km
0
20
40


10. UPLAND RICE
Focus Department with Villages and Road System
Burkina Faso
Department
Extension District
Principal Roads (1 & 2)
Village
Probability of Adoption
1 = Lowest
2
3
4
5
6
7
8 = Highest
Km
0
10
20


11. UPLAND RICE
High Potential Soils
Burkina Faso
Extension District
Soil Potential
Low
High
Km
0
100
200


12. UPLAND RICE
High Potential Soils – Extension District
Burkina Faso
Extension District
Soil Potential
Low
High
Km
0
20
40


13. UPLAND RICE
Focus Department with Best Soils and Target Villages
N'DOROLA
KOUKA
BADEMA
KOUROUMA
Burkina Faso
Department
Extension District
Principal Roads (1 & 2)
Village
Km
0
100
200
Soil Potential
Low
High


14. UPLAND RICE
Focus Department with Best Soils and Largest Villages
N'DOROLA
KOUKA
BADEMA
KOUROUMA
Burkina Faso
Department
Extension District
Principal Roads (1 & 2)
Village
Population
< 2500
> 2500
Km
0
10
20
High Potential Soils
Low Potential
HighPotential

Section III
Integration of Livestock and Crop Production

1900

Supplementary Feeding of Milking Cows with Cottonseed Meal for Improved Dry Season Productivity in Western Burkina Faso

A. Lalba and J. Dickey

ABSTRACT

In Burkina Faso, range feed availability during the dry season is limited, yet supplementary feeding of livestock is seldom practiced. This study demonstrates the potential of modest supplementary feeding of milking cows, to augment milk and meat production during the dry season on mixed farms in western Burkina Faso. Feeding 1 kg of cottonseed meal/cow/day doubled milk production in the cool, dry season (from the beginning of November to the end of February), and multiplied by 5 in the hot, dry season (from the beginning of March to the end of May). Production for supplemented and non-supplemented groups was less satisfactory during the hot, dry than during the cool, dry season, due to inadequate range feed availability. This led farmers in the control group to stop milking on 10 March, unlike farmers who supplemented feed, who were able to continue milking and collecting revenue at market throughout the dry season. The effectiveness of feed supplements could be improved, however, notably by the addition of fermentable carbohydrates in the form of crop residues and forage legumes. These results suggest that policies encouraging local availability of agricultural by-products for feeding would encourage intensification and improve the profitability of livestock production systems.

Keywords: Range, feed supplements, cottonseed meal, milking cows, farming system

I. INTRODUCTION

Farming systems in the cotton-producing zone of Burkina Faso are experiencing a progressive degradation of natural resources. The area is subject to very high human and animal pressure due to the in-migration of pastoralists from the eastern and northern parts of the country seeking arable lands and better quality grazing lands, respectively. A consequence of natural-resource degradation is the shortage of range feed for cattle during the dry season. The cotton zone, which was until recently a host area for transhumant pastoralists, is currently a zone of out-migration of these pastoralists who travel further southwest in search of grazing lands

Diagnostic studies conducted by the farming systems research (RSP) program of INERA have helped define this feed constraint for cattle during the dry season and its impact on animal productivity in relation to primary needs of pastoralist families. Pastoralists rely a great deal on cow's milk production for home consumption as well as for income from its sale, which is managed by women. During the dry season, because range feed is scarce, family nutritional needs compete with survival of calves before weaning. Pastoralists tend to favor survival of calves by discontinuing milking, thus doubly depriving their families during the whole dry season, which lasts for 7 to 8 months.

The objective of this study was to assess the effectiveness of modest supplementary feeding of lactating cows on milk production and on cattle and calf weight increase during the dry season.

II. METHODOLOGY

Study site: The study was conducted in Yasso, a village located in the center of the cotton-producing zone, which receives an average of 802 mm rainfall/year (1970-1993 period). This village was selected as a research site by the Western RSP team to represent the farming systems of the sub-zone characterized by cotton production and heavy use of animal traction. The village was also chosen due to the importance of the problem of cattle feeding during the dry season, which is widespread and of economic importance.

Pastoralist and animal selection: The experimental design was defined in agreement with Fulani pastoralists after several consultations. Pastoralist practices such as range feeding and milking techniques, marketing and home consumption of milk, etc. were taken into account. The sample included 57 milking cows mostly of the méré breed (mostly zebu-taurin crosses with some gounkan Fulani zebu). However, no consideration was given to the cow's breed or number of previous lactations the latter ranging from 1 to 4. Lactating cows, which were regularly milked and which had calved in 1992, were systematically selected for the study. Cows were put into 8 herds belonging to 8 sedentary pastoralists of the village. Practically speaking, it is very difficult to reliably implement a variety of feeding treatments within a single herd. For this reason, the treatments were assigned at the level of the herd. The 8 herds were separated into two homogeneous groups based on their average initial weight including 3 control (unsupplemented) herds (Group 1) and 5 supplemented herds (Group 2) with an approximately equal number of cows in each herd.

Supplementary feeding: A single feeding ration and a control were preferred for reasons of simplicity, sample size, and to make the comparison evident to farmers. This ration consisted of 1 kg of cottonseed meal, at a cost of 30 F CFA, per cow per day. This amount was recommended by thematic research as a minimum production supplement affordable to the average pastoralist. According to the results of feed content analyses conducted by the Institut d'Etudes et de Médecine Vétérinaire des Pays Tropicaux (personal communication) based on standards of the Institut National de Recherche Agronomique, this amount corresponds to 0.93 feed units for milk production, 0.86 feed units for meat production, and 376 g of digestible nitrogen compounds.

The following feeding treatments were applied:

- Group 1: Usual pastoralist practices for feeding cattle during the dry season, mostly based on the use of rangeland and feeding of locust bean (Parkia biglobosa) powder and cooking salt diluted in water.
- Group 2: In addition to local standard pastoralist practices, every cow was given 1 kg of cottonseed meal every evening upon its return from a day of open grazing.

Both groups were watered at the well once a day around 11:00 AM, the usual practice of the pastoralists. The whole herd was protected against animal trypanosomosis, bovine pasteurelosis, and internal parasitosis by trypamidium, pastovax, and panacur treatments respectively.

Measurements: Data was collected on:

- Milk quantity produced. Measurements were conducted in the corral every three days during daily morning milking. After a brief suckling by calves which triggered milk letdown, cows were milked manually by women and men. Measurements were taken for each cow once milking was over. Transparent, 2-liter cups graduated in 10 cl increments were used for volume measurements. Total milk production (including calf milk intake) could not be estimated since calf milk intake is difficult to assess. In fact, the various assessment methods for milk intake by calves are insufficiently accurate (Nicholson, 1984). A weekly injection of ocytocin, which appears to be more accurate as it triggers total milk letdown, would be counter to pastoralist practices, which deliberately favor a milk diet for calves during this period of high nutritional stress. Monstma's (1962) conversion factors, which estimate milk quantity ingested by calves according to their age and growth rate, would also be inappropriate in this experiment, where no restriction was placed on calf age. Therefore, the analysis merely concerns milk drawn by pastoralists, with no correction for that consumed by calves.

- Cow weight increase. The perimeter of each cow's chest was measured at the beginning of the study, at the end of the cool, dry season and at the end of the hot, dry season each time with a zoometric tape. Later on, chest perimeter was used to estimate live weight by employing Berekmoes' measurements (1991) corrected by Bosma and Diakité (1991), both, as cited in Bosma (1992).

- Calf weight increase. This was measured monthly with a 100 kg scale. The "two bicycle tires" method, a widely known field technique in West Africa, was used. Calves are suspended by the two tires, which are fastened to the lower hook of a spring balance scale which is tied to a tree branch by the top hook.

- Economic parameters. These included the milk quantities marketed and consumed at home, as well as market prices.

Apart from these variables, additional information was recorded, such as mortality, time of drying up after a successful mating, etc. The test started on 20 January 1993 and measurements were taken until 30 May 1993, taking in parts of the dry cool season and the whole dry hot season.

Data analysis: Milk production, as well as calf and cow growth were compared between unsupplemented and supplemented groups (Groups 1 and 2, respectively) and between periods (the dry, cool and dry, hot seasons) in an analysis of variance. The initial weight of the cow was taken as a covariate in the analysis of cow growth and milk production; and that of the calf

for analysis of the calves growth. Frequency distributions were also developed in order to define the distribution of treatment effect , given the relatively diverse experimental on-farm conditions.

Variable costs only include the cost of 1 kg of cottonseed meal supplement which is 30 F CFA/day (factory price plus value added tax and transportation). Gross milk production was calculated on the basis of the liter price of milk and from income data. This price is not subject to change during the dry season. The sale unit is the ladle-full, which is generally negotiated between the vendor and the client and results in an average, stable price of 25 F CFA during the whole dry season. On average, milk is sold for 125 F CFA per liter. Gross meat production was estimated from the selling price of a tropical cattle unit, a unit of 250 kg of live weight. At the dry season cattle market in Yasso, such an animal would cost about 40,000 F CFA, or 160 F CFA per kg on the hoof.

III. RESULTS

Effect of supplementary feeding on milk production: Milk quantities produced are shown in Figure 1a. There was a significant difference ($P<0.001$) between the means of the two groups over the two periods and the initial weight of the cow was a significant ($p=0.06$) covariate. However, the period and the group interaction with period were not significant ($p>0.1$). Milk production of the non-supplemented group declined by a third from the cool, dry to the hot, dry phases of the dry season, whereas production by supplemented animals was relatively constant. On average, supplementary feeding multiplied cool, dry season production by 2 and hot, dry season production by 5. The treatment resulted in a tripling of milk production over the whole dry season.

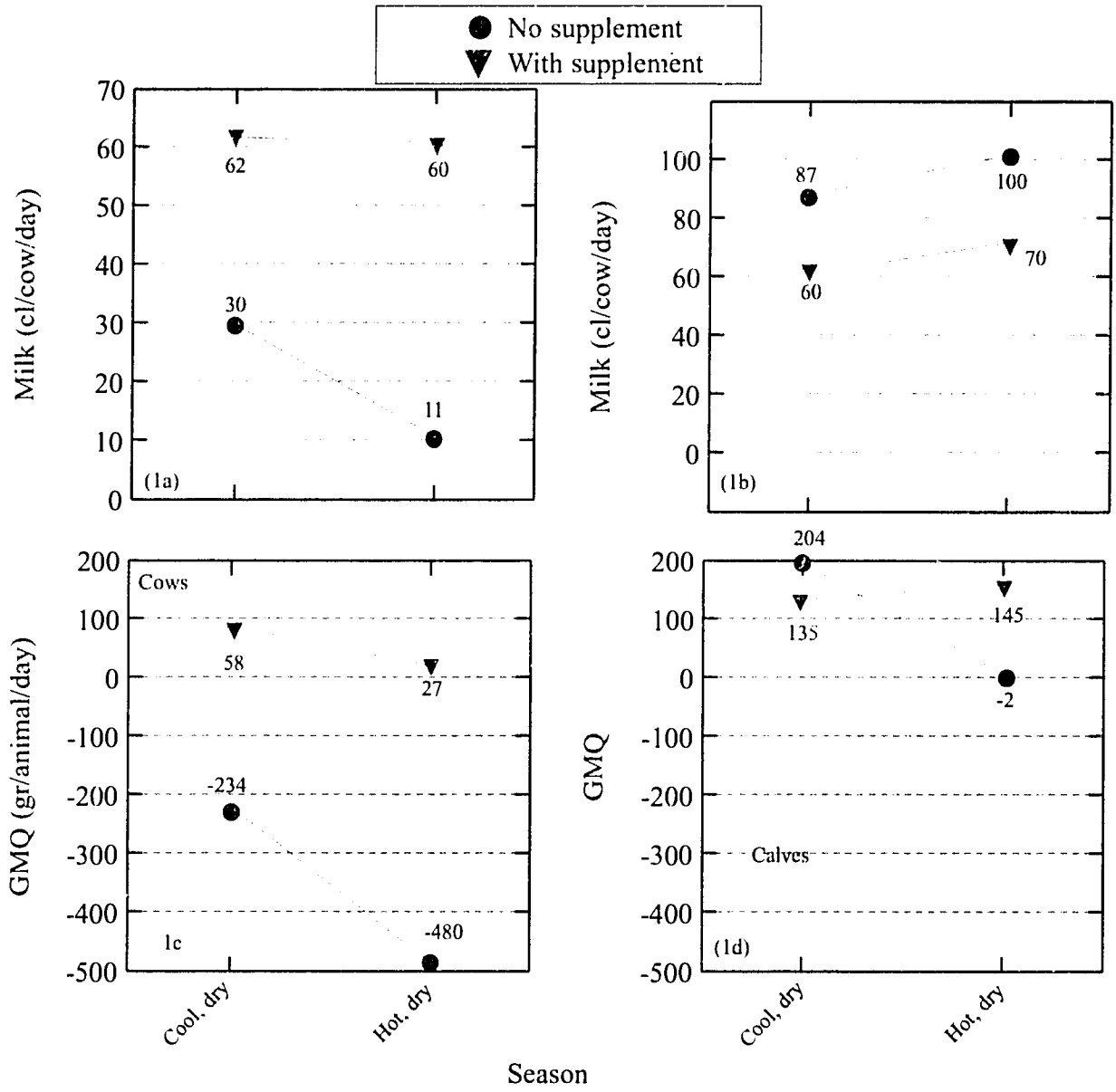


Figure 1. Milk production (1a), home consumption of milk (1b), growth rate of cows (1c) and calves (1d) according to diet and season.

Frequency distributions over the whole dry season (Figure 2b) show a cluster of individuals in the control group around a production mean ranging from 0 to 25 cl/cow/day. In contrast, most individuals in the supplemented group are scattered between 25 and 100 cl/cow/day.

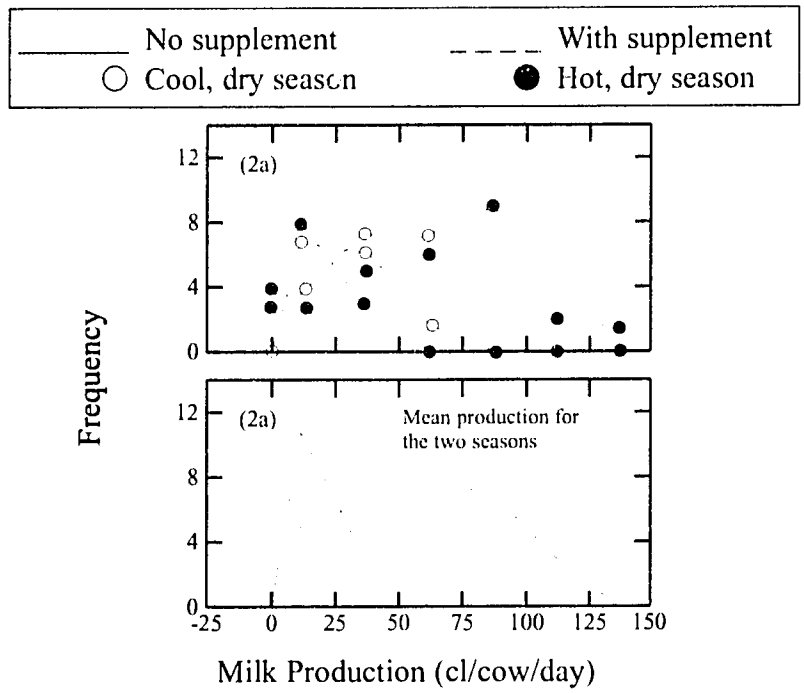


Figure 2. Milk production according to diet and season (2a), according to diet only for grouped seasons (2b).

Effect of supplementary feeding on cattle growth rate: Figure 1c shows the distribution of cattle weight gains by treatment. Supplemented cows displayed positive weight gain rates during the whole dry season, while a net weight loss was observed in control individuals ($p<0.001$ for comparison). Here again, the difference between the two periods is clear; the daily weight gain was lower in the hot, dry season in both groups ($p=0.02$ for comparison). The covariate (cows'initial weights) was significant ($p<0.001$) as was the group-by-period interaction ($p=0.05$). The latter due to the large drop in weight gain.

Figure 3a shows a similar distribution of the two groups at the start of the experiment on 20 January. At the end of the cool and hot, dry seasons (Figures 3b and 3c), most of the supplemented cattle tended to have gained weight, while unsupplemented animals displayed weight losses that were for the most part more severe during the hot, dry season (Figure 3c).

Figure 1d shows that all supplemented calves grew rapidly during the whole dry season. In contrast, after satisfactory growth during the cool, dry season, control calves lost weight during the hot, dry season.

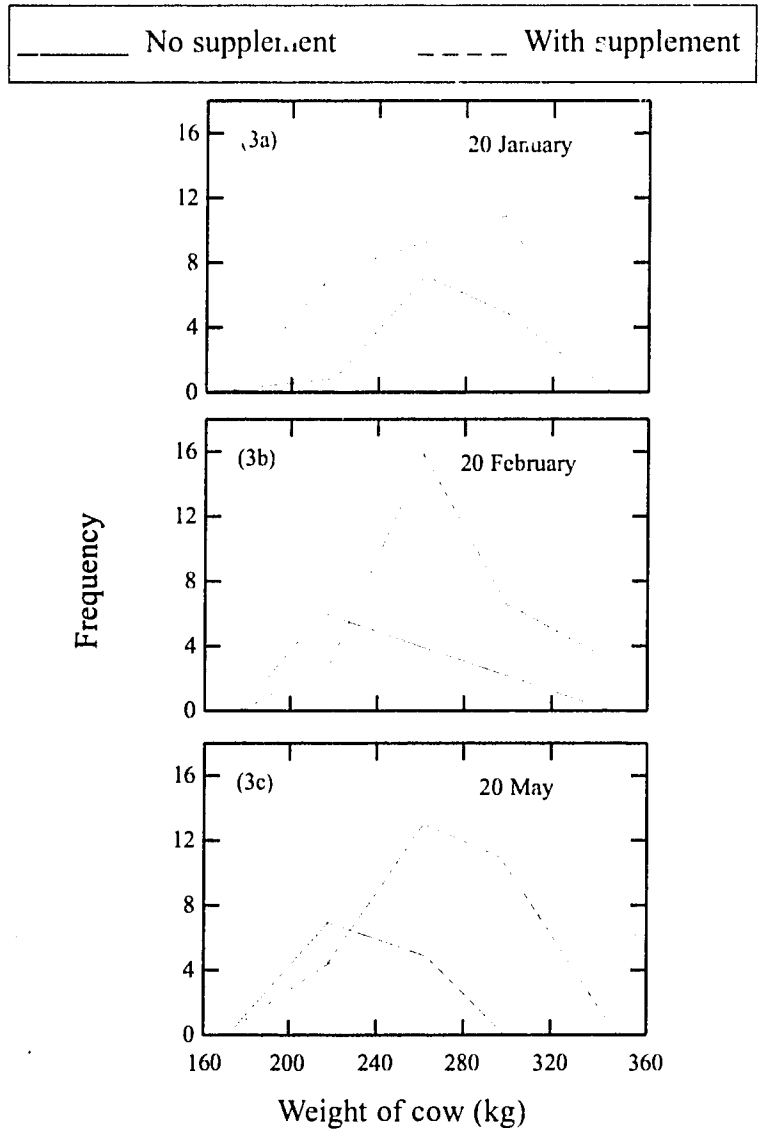


Figure 3. Weight of cow according to diet at the beginning of the cool dry season (3a), at the beginning of the hot dry season (3b), and at the end of the hot dry season (3c).

Economic aspects of production and marketing: Figure 1b shows that most of the milk produced by each farmer is for home consumption. During the hot, dry season, the percentage of milk consumed at home increased among the supplemented group due to the decline in milking, especially during the months of April and May. Home consumption prevailed among pastoralists of the control group during the cool, dry season and became the only use from the beginning of the hot, dry season. This period also corresponds to the end of milking for this group in April. From that time on, the little milk that was produced was given to calves.

Table 1 shows the economic profitability of milk and meat production in supplemented and unsupplemented cattle groups. Results show that the net return is tripled by supplementary feeding during the dry season. The positive effect was most visible during the hot, dry season when nutritional shortages are most intense.

Table 1. Estimated economic profitability of milk production for sale and home consumption by feeding treatment (F CFA)[a]			
Item	Control group group	Supplemented	Benefit from supplementary feeding (supplemented-control)
Gross product/animal-day in P1b	70	108	38
Gross product/animal-day in P2c	5	102	97
Variable costs/animal-day	0	30	30
Net return/animal-day in P1	70	78	8
Net return/animal-day in P2	5	72	67
Net return with an average of 7 milking cows from 01/20 to 05/30	22 295	67 159	44 864

[a]Total for an average of 7 milking cows
[b]P1=Cool, dry season from November to February (Period 1)
[c]P2=Hot, dry season from March to May (Period 2)

IV. DISCUSSION

Milk production and animal growth rates resulting from supplementary feeding confirm the efficacy of supplementing the diet of lactating cows with low quantities of concentrated feed (Rivière, 1978). One kilogram of cottonseed meal/cow/day supplies slowly-digested protein, which considerably increased cows'growth and milk production rates. The feed supplement satisfied cows'maintenance needs and allowed for surplus milk production and thus a stream of income during the whole dry season. From mid-March on, unsupplemented were not milked due to insufficient feed, and in order to leave their rather minimal milk production for nourishment of their calves. Later on, these very pastoralists had to move their hungry cattle to neighboring villages in search of pasture. Supplemented herds withstood this stressful period preceding the rains, in spite of the poor pasture conditions..

Production during the hot, dry season was lower in each of the two groups, yet the difference between the two periods was more pronounced in the unsupplemented group. This is due to the increased severity of nutritional stress of range-fed animals during the hot, dry season, rangelands provide the basic diet of ruminants in this extensive livestock production system. Cattle's diets must include a variety of nutrients, including fermentable carbohydrates (Preston 1988). These carbohydrates are provided by range vegetation and crop residues, which are not abundant during the cool, dry season, becoming rarer still during the hot, dry season. Overgrazing and bush fires considerably reduce fodder availability during the hot, dry season, which translates into a drop in production.

Under these conditions, significant withdrawals of milk in the dry season would considerably reduce calf growth rates (Nicholson 1984). This explains why pastoralists reduce or even discontinue milking at the onset of the hot, dry season. Milking becomes secondary in importance to the maintenance of the physical condition of calves and cows.

Three priorities are evident in milk production strategies in agro-pastoral systems. In order of importance, they are:

- the nutrition of calves before weaning
- home consumption of milk
- marketing of milk.

Supplementary feeding was found to be profitable in terms of gross economic production and net returns, considering only the additional value of milk for home consumption and sale. Others benefits included improved cow and calf growth rates (Figure 3) and survivorship.

The impact of dry season, supplementary feeding on the compensatory growth normally observed in cattle during the first half of the rainy season also needs to be assessed. Supplementary feeding may also have a positive effect on calving frequency and milk production during the following lactation, since healthy cows (due to accumulated muscle and fat tissue reserves) are likely to produce more milk and better resist disease.

V. CONCLUSIONS

Supplementary feeding of milking cows demonstrated that a protein supply in the dry season can considerably increase milk production while maintaining the physical condition of cows and calves. The low performance registered in the hot, dry season shows that concentrated feed cannot be fully utilized without additional fermentable carbohydrates, which are scarce during this period. These carbohydrates can be found in forage, crop residues, and forage crops.

One of the tasks awaiting on-farm research in the area of milk production is the development of appropriate feed systems (Brumby and Gryseels, 1984). In the agro-pastoral context, this entails finding production and storage alternatives for available feed resources to enhance milk and meat production levels. On-station research must define optimal milk production levels of local breeds to match available resources and the needs of animals.

The availability of concentrated feed in the form of agro-industrial by-products is another local constraint. The government and extension services should encourage pastoralist access to such products through the creation of decentralized structures responsible for the acquisition, transportation, and marketing of these feeds.

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Use of Unconventional Products in Animal Health Care: The Case of Draft Animals in Burkina Faso

Y. Samandoulgou

I. INTRODUCTION

A survey conducted in 1990 in the four Western RSP village sites revealed a large cattle herd size in these villages. Herds of the two cotton-producing sites, where animal traction is widely used, include a large number of draft oxen (Badini 1990). The survey shows that no veterinary services are available in any of these villages. The national vaccination campaign is conducted every year in the villages between February and June.

During the agricultural season farmers are nevertheless faced with animal health problems during the agricultural campaign, which require assistance from a livestock or veterinary professional. In principle, farmers have had no training in primary care of animals and should consult a veterinarian. However, the closest animal health station is about thirty kilometers away from the village. What do farmers resort to during the agricultural season when their draft oxen are ill?

In order to address this question, a preliminary survey was conducted in Kayao[1], one of the RSP villages, which represented a sub-zone characterized by subsistence cropping with some cotton production and a high rate of animal traction in 1990. There are 223 draft oxen, 88 donkeys, and 1189 cattle, in the village and 34 % of the villagers use animal traction (Badini 1990).

The objectives of this survey were to:

- Gather knowledge on farmer practices,
- Inventory the unconventional products used for draft animal health care,
- List the supply sources for these products, application methods and treatment costs.

II. METHODOLOGY

Data was collected through informal interviews with farm family members possessing draft oxen. The interviews especially focused on young individuals who work with these animals and maintain them. These individuals monitor the behavior of draft animals and know them best. The survey was initiated during the 1991-1992 season and was completed in January 1994.

A questionnaire was used throughout the survey. However, it should be noted that this questionnaire was not uniformly administered because some questions dealt with sensitive issues. Most people interviewed found it difficult to answer the questions, sensing that they had to

[1]Survey participants: Sanou Sogo and Dabilou Salam, technician-enumerators Fandié Kankéki, village enumerator

compromise their own interests. Clandestine vaccination is normally prohibited in Burkina Faso. Therefore, a combination of interviews and direct observations of farm practices was used.

Every year, the selected sample included 25 production units using animal traction and participating in RSP tests. However, observations were made on all farms having draft oxen.

Disease diagnosis by farmers. Farmers use their experience as a basis for diagnosing animal diseases. They do not have the necessary knowledge of specific pathogens, but often recognize aggravating factors such as change in climate, diet, work schedule, etc. Once an animal displays an abnormal behavior such as sadness, fatigue, lethargy, refusal of food, etc., farmers examine the animal (body temperature by touch, feces, eyes, snout, hair, nasal secretions, etc.). More knowledgeable farmers are called upon to determine the cause of the disease when they cannot do it themselves.

Reasons for the use of unconventional products. The survey results indicate that:

- To call the livestock agent of the village of Oronkua to Kayao is rather difficult, because appointments are often missed and the agent is often in field missions and so cannot be easily found at his office[2];

- Rarely can the prescribed remedy be obtained at the livestock extension station. Therefore, farmers have to go to a larger center such as the CRPA at 90 or 190 km distance. This causes a delay between the time of the visit and the beginning of the treatment. Additional problems arise when farmers cannot procure the product (because products are frequently out of stock) or when subsequent services of the agent are required, as in the case of injectable products.

Problems which discourage farmers from using conventional products are in order of importance:

- Difficulties of access to conventional products (70%)
- Unavailability of the livestock extension agent (20%)
- Confidence in unconventional products (10%)

Products used. Products used to treat draft animals are of various origins. They include drugs, pesticides, antibiotics and other illicit pharmaceutical products.

Table 1 indicates that none of the products used is specifically intended for animal care. Most pharmaceutical products are fraudulently imported from Ghana. They are confiscated by the police during checks of the local markets.

One of the advantages of unconventional treatments for farmers appears in Table 2. Treatment cost varies between 30 and 250 Fcfa, which is inexpensive relative to conventional treatments and affordable to those raising cattle.

[2]Little supervision

Antibiotics are all called "toupaï" (literal translation); This is because they are used to care for all diseases. They are of two kinds: Totapen and tetracycline, both in capsules.

Paracetamols identified are of several sorts:

- Daga: package of three 500 mg pills
- Alagme: package of twelve 500 mg pills
- Phenic: Paracetamol in 500 mg and 250 mg dosages

The range of paracetamols is quite broad.

Table 1. Percentage of farmers interviewed having used one of 6 unconventional products at least once to treat 8 frequent diseases (N=25)

Products	Diseases						
	Fever	Diarrhea	Wounds	Skin parasites	Fatigue	Skin disease	General ill-being
	%						
Antibiotics Totapen Tetracycline	75[a]	77	--	--	25	95	80
Paracetamols Daga, alagme	70	25	10	--	61	28	96
Sumicidine[b]	--	--	--	98	--	--	--
"Dissolution"[c]	--	--	84	--	--	--	--
Instant coffee	--	--	--	--	11	25	--
Undetermined other	5	--	--	--	--	--	6

[a]Nineteen farmers, for example, out of 25 (75%) said they used antibiotics against fever.
[b]Insecticide used in cotton production
[c]Manufactured to repair bicycle inner tubes

Table 2. Description of unconventional products and their costs

Disease	Product	Form/Unit	Unit cost (F CFA)	Dose	Cost (F CFA)
Fever	Totapen	Capsule	25	3	75
Fever	Tetracycline	Capsule	15	4	60
Fever	Daga	Pill	50	2	100
Fever	Daga	Pill	50	2	100
Fever	Alagme	Pill	25	4	100
Diarrhea	Totapen	Capsule	25	10	250
Diarrhea	Tetracycline	Capsule	15	14	210
Wounds	"Dissolution"	Bottle	150	1	150
Skin parasites	Sumicidine	Water jug	5000	<<1	200
Strepto-trichosis	Totapen	Capsule	25	6	150
Skin disease	Coffee	Packet	30	1	30
Gen. ill-being	Tetracycline	Capsule	15	8	120
Gen. ill-being	Totapen	Capsule	25	4	100

Directions for use. The directions for use of products depends not only on the manner they are administered but also on the disease to be treated, as one product can be used for the treatment of several diseases.

Products can be orally administered in three ways:

- Diluting it in drinking water. The animal is left for some time without drinking water, then, once thirsty, given a reasonable quantity of product-water mixture to be entirely drunk.
- Forcing the animal to swallow the entire product by pulling on its tongue
- Mixing it in food. This method is little used because of animal refusal.

The most widespread practice is intra-muscular injection in the shoulder or flank is also used. Some "specialized" farmers being especially skillful are called upon for injections. Two solvents are used to dilute products. Water is most widely used. Drinking water is used without any special treatment. It is not boiled nor filtered. "Koutoukou", an alcoholic drink derived from sugar distillation, is also used by some people. It is a popular drink and is sometimes called "who pushed me", or "zonzon", or "patècé". A liter of the sort with high alcohol content (about 90 degrees) costs 500 Fcfa, while the sort of low alcoholic content (9 to 20 degrees) is sold for 300 Fcfa a liter. The latter type is used as a solvent.

Syringes are generally designed for a single use, but they are used repeatedly until useless. Syringes sold in pharmacies have a capacity of 5 to 10 ml. When animals are familiar with the person doing the treatment, it is petted on the head for an easy intra-muscular injection. Otherwise, the animal has to be immobilized by the head or taken down.

Example of preparation of injectable products against fever. The origin of the fever is generally not identified. It is noted that the animal is sad with bristled hair and high body temperature. The treatment includes tetracyclines and "daga" paracetamol diluted in a bottle of "koutoukou" or water, which has to be strongly shaken for proper mixing. The solution is pumped into the syringe without the needle. Air is drawn out of the syringe before the intra-muscular injection.

In general, the dosage used is not well defined. It varies according to the person administering the treatment, the stage of development of the disease and the age of the animal.

Examples of products for external treatment.

Wounds. Mostly used for this purpose is the "dissolution", a glue product used to repair cycle inner tubes. It is an aseptic wound dressing. This product replaces Synexa and K'otrine more and more frequently. The glue is applied on the wound in a thin layer. A few moments later, the product is dry and protects the wound from flies and other insects. The dressing is repeated until the wound heals.

Tick control. There are two products used against ticks; both are pest control products used in cotton production: Sumicidine and decis. The first method consists in mixing eight to ten

volumes measured with a peanut shell (7 to 10 ml) in a bucketful of water and spraying the mixture on the body of the animal with a backpack sprayer. In the second method, fresh cattle feces are kneaded in the chemical liquid and the animal is coated with this paste.

General fatigue. The animal is tense. It cannot stand sustained effort. In order to give him a boost, three "daga" pills are administered orally or by injection.

Therefore, the main diseases treated which are commonly encountered are affections that do not require the intervention of a livestock specialist, with the exception of skin streptotrichosis.

Vaccination accidents. These medication practices are not without consequences. The use of products or treatment equipment can be traumatic to animals.

Solvents. Water used as solvent is not treated in any special way and may come from questionable sources. It may contaminate animals with other diseases.

Products. Antibiotics of unknown origin without written directions and known expiration dates may be dangerous. The use of bacteriostatic or bactericidal chemicals without the advice of a veterinarian can be overdone. Potential results include accidents and resistance to antibiotics.

Syringes. These can be sources of trauma and infection to animals, as they are not disinfected beforehand and are used repeatedly. Interviews revealed that there are accidents due to injections:

- Bleeding. A poorly practiced injection may result in bleeding which can then turn into swelling.
- Oedema. There is swelling where the injection was done. It can worsen and cause an abscess. Animals may even have reduced mobility on the side of the leg affected by the injection.

III. CONCLUSION

Interviews indicate that in order to care for their draft animals, farmers develop their own strategies and use fraudulent pharmaceuticals, pesticides, and other products (coffee, glue, etc.). The difficulty of access to veterinarian services and the high cost of conventional remedies (including transportation costs to Diébougou or Bobo-Dioulasso) on one hand, and, the availability of products and solvents (water, local alcohol) and of soiled equipment (used syringes) on the other hand make these practices easier and help to perpetuate them. Even though these practices are applied to animals, they give rise to serious problems for farmers and risk the health of their livestock.

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Dynamics and Management of Animal Traction in Western Burkina Faso: A 1990 Diagnostic Study

A. Lalba

I. INTRODUCTION

In Burkina Faso, the use of draft oxen is mostly concentrated in the West and Southwest, with a population of over 200,000 animals (GFA, 1990). In 1990, the western zone RSP team identified subzones in its area of intervention in order to take into account the various farming systems encountered in the area and selected one representative village site in each subzone. The proportion of animal traction users was a criteria for differentiation of the four subzones identified. The diversity of farming systems is such that the presence of animals is not evenly distributed over the zone. Among the four subzones defined by the Western zone RSP team, two have a low percentage of animal traction and are not located in the cotton-producing zone. The villages selected in these two zones are Kawara and Dimolo. The proportion of users of animal traction is relatively high in the other two subzones represented by Yasso and Kayao.

Whereas the change from 1990 to 1993 in the number of draft oxen in Yasso and Kayao, the two RSP villages of the cotton-producing zone, is hardly noticeable, it has drastically increased in Kawara and Dimolo, villages which had a low percentage of animal traction users in 1990.

In order to appraise the variability in use of animal traction and identify draft oxen adoption and management constraints, a survey was conducted on animal traction in 1990-91 in the four RSP village sites, each representing a homogeneous subzone. This paper reports results of the 1990-91 survey. Results for Yasso and Kayao villages can probably be considered as current, while those of Kawara and Dimolo would need to be updated. Special focus is placed on the identification of constraints and potentials related to draft oxen management in village farms. Aspects regarding the use of agricultural equipment were examined in a study conducted and reported by ESFIMA, the local agricultural mechanization research entity. The synthesis of both reports would establish a more complete diagnosis on animal traction.

II. METHODS

Farm selection: Based on the 1990 census of farms and farm resources in the RSP village sites (Table 1), the sample included a random selection of 20% of all farms from Yasso and Kayao, which are large villages with a high proportion of animal traction users. Because of the small number of farms owning draft oxen in Kawara and Dimolo, the survey included all censused farms using animal traction in these two villages.

Table 1. Farm sample selection for the survey on animal traction

Village site	No. of censused farms			No. of randomly selected farms			Survey sample size
	Total	D.O.* owners	Non-owners	Total	D.O. owners	Non-owners	
Yasso	283	179	104	86	56	30	56
Kayao	233	116	117	71	36	35	36
Kawara	106	5	100	—	—	—	5
Dimolo	94	3	91	—	—	—	3

*D.O.= Draft oxen

Data collection: A questionnaire including 15 data sheets was prepared and delivered to the heads of farming units in the sample. Two types of variables were considered:

History of animal traction. The chronology of events related to each farm draft animal was recorded based on farmer memory. Past constraints for the adoption of animal traction can be identified.

Draft oxen management. This part of the survey relates to data on acquisition, feeding, health, use and maintenance of draft oxen.

Results:

Distribution of draft oxen in sample farms:

The range of animal species used for animal traction varies geographically (Table 2). For example, in Yasso, draft animals used include oxen, donkeys and horses, in decreasing numerical order. In Kayao, horse traction is absent, while in Kawara and Dimolo the few animal traction farms only use draft oxen.

Table 2. Ethnic distribution of draft oxen in 1990 in sample farms in RSP village sites

Villages	Ethnic group	# of farms	Oxen		Donkeys		Horses	
			#	Avg per farm	#	Avg per farm	#	Avg per farm
Yasso	Dafing	37	85	2.3	43	1.2	0	0
	Mossi	11	27	2.4	5	0.4	0	0
	Dogon	6	4	0.6	5	0.8	2	0.3
Kayao	Bwaba	10	26	2.6	4	0.4	0	0
	Mossi	21	29	1.3	21	1.0	0	0
	Dagari	2	4	2.0	0	0	0	0
	Fulani	1	2	2.0	0	0	0	0
Kawara	Natioro	2	6	3.0	0	0	0	0
	Samogo	2	4	2.0	0	0	0	0
	Dioula	1	2	2.0	0	0	0	0
Dimolo	Lobi	2	3	1.5	0	0	0	0
	Mossi	1	4	4.0	0	0	0	0

The ethnic distribution of use and number of draft animals also varies within villages. In Yasso, the most ethnically diverse village, which included six ethnic groups in the 1990 census, the three dominant groups (the Dafing, Mossi and Dogon or Kaado) use animal traction. Smaller minority groups such as the Fulani, Bwaba, and Haoussa are not included in the sample. Besides being minority groups, they also settled more recently in the village than groups using animal traction. In Kayao, animal traction is used by all ethnic groups, whether dominant or not. However, due to the low representation of minority groups (Dagari and Fulani) in the sample, the proportion of animal traction cannot be extrapolated to the total number of farms for these ethnic groups. In the villages of Kawara and Dimolo, the number of farms owning draft animals is too small to allow reliable conclusions on the dynamics of ethnic distribution of animal traction.

Numerically, ox traction is by far the most common traction method in all villages (Tables 2 and 3). Herd size for oxen per farm is larger than for donkeys and horses in all ethnic groups in the four villages except for Dogon donkeys in Yasso. In Yasso, the average number of oxen per Dafing or Mossi farm is higher than for the Dogon. The Dafing population is indigenous to the village. Mossi farmers are considered old migrants and most of their farming unit heads were born in the village. These two ethnic groups adopted animal traction under the same circumstances around the 1960's and seem to have equal herd sizes. In Kayao, the number of farm oxen is twice as high among the indigenous Bwaba farmers as among the immigrant Mossi. Mossi settlement in Kayao is fairly recent (beginning in 1972 for the first settler, Ilboudo, 1992). Number of draft oxen per farm in Kayao, Kawara and Dimolo is fairly high. Even though conclusions should be stated with caution because of the small sample size, most farms using animal traction in the minority ethnic groups are progressive village elites. This is the case of the only Mossi farm using animal traction in Dimolo, which has 4 out of the 7 draft oxen in the village.

Donkey traction is second to ox traction. It is more widely used in Yasso than in other villages, and is used as much as ox traction there (78% vs. 76% of census) (Table 3). In most cases, farms own and use both donkeys and oxen, but many farms only own and use donkey traction. In Yasso and Kayao, 24% of farms use only donkey traction.

Horse traction is only used in Yasso by a few Dogon farmers who introduced it from Mali.

Table 3. Distribution of draft animal species used in sample farms

Villages	Sample farms owning and using exclusively		
	Oxen	Oxen + Donkeys	Donkeys
Yasso	22%	54%	24%
Kayao	38%	38%	24%
Kawara	100%	0%	0%
Dimolo	100%	0%	0%

Oxen breeds:

In Western Burkina Faso, there are three major oxen breeds. Transhumance and associated uncontrolled matings have resulted in significant interbreeding of cattle herds. Pure breeds cannot, therefore, be strictly spoken of, especially among zebus. Distinguishing criteria among genetic types are based on morphological observations (body form, horns, hump) and farmer characterization of breeds. Breeds used for animal traction depend on zones of optimal performance as well as farmer preferences.

- Sudanian Fulani zebu. Its optimal zone is the northern part of Southwestern Burkina Faso, that is, the zone of cotton production including Yasso and to a lesser extent Kayao. Taller than other breeds, the Sudanian Fulani zebu has long horns and a "falling" hump. It is the breed most sought after for traction because of its traction strength and its hump which facilitates the placement of the yoke. In Yasso and Kayao, 99% and 87%, respectively, of the sample animals belong to this breed, yet, as mentionned above, this breed has been crossed and these figures are based on pronounced zebu phenotypical observations. Draft oxen are 100% zebu in Dimolo, even though this is not the zebu's optimal geographic zone. This is due to extension activities for the promotion of animal traction and to the significant support of a local evangelical mission in providing credit for purchasing animals and equipment. In Kawara, only one zebu out of 19 animals was identified.

- Taurin. Usually called "Baoulé" or "Lobi", it is more often seen in the very south and southwest of the country next to borders with coastal countries. This breed is easily recognized by its lower height to shoulder, very short and forward horns and the absence of a hump. It is supposed to be less appropriate for animal traction because of its size and absence of hump. It makes up a large part of cattle herds in Kawara and Dimolo, which are located in its natural occurrence zone. It is used for traction only in Kawara where it makes up 47% of the village sample.

- Zebu-taurin crosses. Also called méré, this genetic type is probably the most common and geographically widespread breed in the Western zone. It is intermediate between the Fulani zebu and the taurin in morphology and is mostly used for traction in the taurin's zones of optimal performance due to two assets. First, its zebu characteristics are responsible for its improved size and consequent traction strength as well as its less developed hump which is more appropriate for yoke placement. Second, the taurin influence may have resulted in its trypano-tolerance. It represents 1%, 13% and 47% of the village sample in Yasso, Kayao, and Kawara, respectively.

  Kawara and Dimolo are located in zones infestated by glossina, a vector of animal trypanosomiasis. Zebu animals have to be treated with appropriate prophylactic healthcare measures due to their trypano-sensitivity.

Oxen characteristics:

1.) Sex

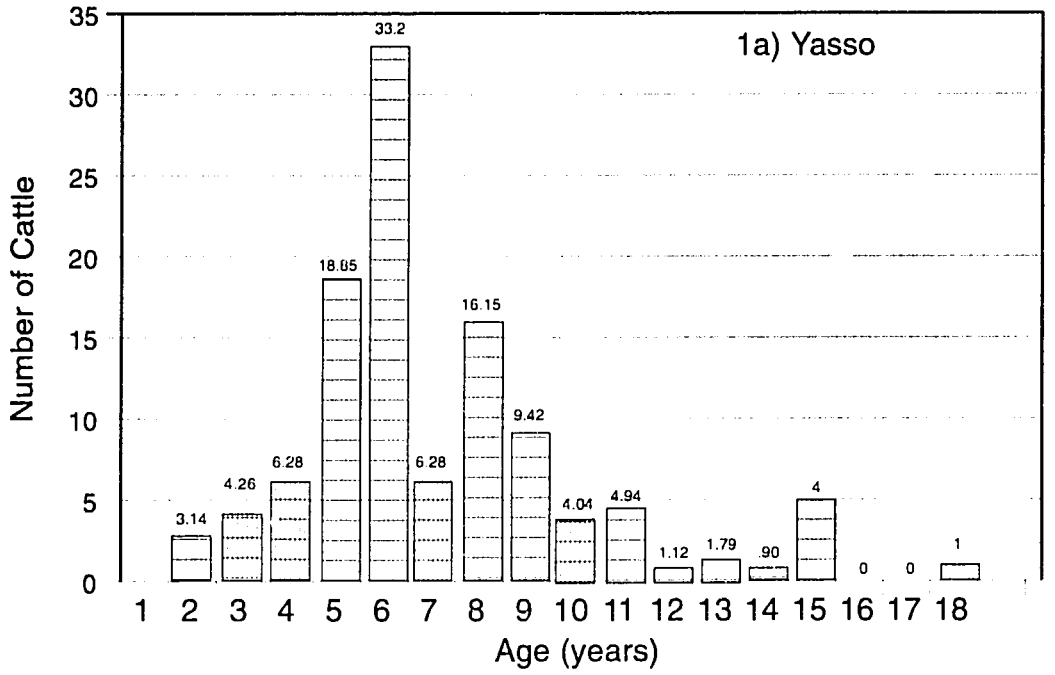
There are no cows used for animal traction in any of the four villages (Table 4). Mostly male cattle are purchased, and they are often castrated once the property of the farmer. With the exception of Kayao, which includes more whole than castrated males draft oxen castration is a common practice in the villages. Whole males are mostly found in Bwaba farms in Kayao. In general, castration takes place after the animals have been used for animal traction for one season. During that time, the temperament of the animal and the need to practice castration are assessed. Castration is traditionally practiced by villagers through the severance of spermatic cords with stones or wood sticks. No other less traumatic method, such as the use of Burdizzo forceps was observed in the sample. This farmer practice is not without hazards for animal growth and maintenance of condition. In addition to spermatic cords, blood vessels and nerves are often shattered causing mobility disorders and considerable weight loss.

Table 4. Sex of cattle in village sites

Villages	Entire male	Castrated male	Female
Yasso	33%	67%	0%
Kayao	51%	49%	0%
Kawara	11%	89%	0%
Dimolo	0%	100%	0%

2.) Age

Draft oxen age distribution in the four villages is variable (Figure 1). Figure 1a shows that the age distribution in Yasso is pyramid-like, with a large representation of ages 5 and especially 6 (46% of all individuals). The small number of cattle of age 7 and 10 is remarkable and may be due to miscarriages during drought years. The average age of cattle in the sample was 7.7 years in 1990, and the average age when starting their working life is 3.7 years. Up until 1978, this average was 3.2 years, thus indicating an increase over the years.



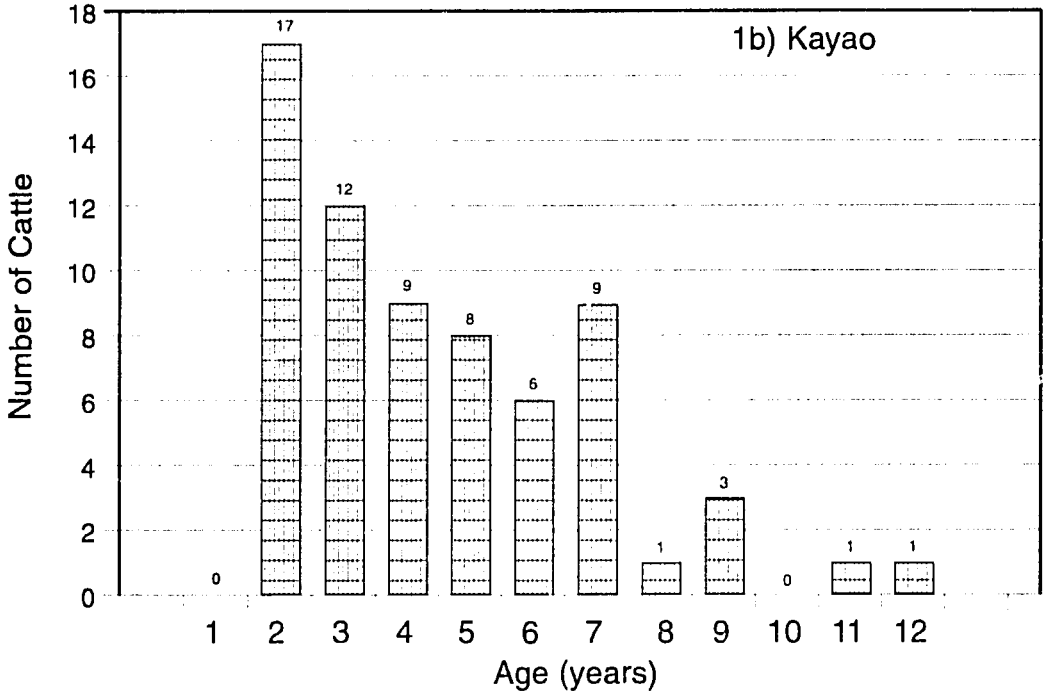


Figure 1. Draft oxen age distribution, Yasso and Kayao in 1990.

Figure 1b shows a high proportion of young animals between 2 and 4 years of age (35% of all individuals) in Kayao, while the oldest animal was 12 years old. The trend reflects a decline in the number of animals as age increases. However, the number of 5- to 7-year-old cattle is fairly high and constant (32% of all individuals), while only 12% are over 7 years of age. Eighty eight percent of the 2 year-old bull-calves were purchased in 1990 and 12% in 1989. These

individuals make up a fourth of all cattle in the village sample. The overall age average is 4.6 years in 1990. The average age when starting their working life is 2.3 years. This figure was 3.2 years when animal traction was introduced in the village, between 1975 and 1980, thus indicating a decrease over the interval.

Among the 12 cattle present in Kawara, all are between 3 and 6 years old, and 10 out of 12 are between 4 and 6 years old. The average age is 4.6 years and they start working as a traction animal at 3.3 years on average. The cattle age distribution in Dimolo is quite similar to that in Kawara. The 7 animals present in 1990 are 3 to 6 years old. The overall average age is 4 years and they start working at 2.4 years of age on average.

The age distribution of draft oxen in village sites in 1990 is a good indicator of farmer strategies in the selection and use of draft oxen. In Kayao and Dimolo, most animals are recruited at a very young age and for a short working life. Recruitment of 2 to 3 year-old bullcalves, which have not yet completed their growth cycle makes training easier according to farmers. However, this practice is likely to cause a delay in the animal's growth and result in a poorer traction performance, which will be aggravated by dry season range nutritional stress. Such a practice may be detrimental to the future traction efficiency of young animals. Recruitment at 3 to 4 years of age would be more appropriate.

Draft oxen acquisition and sale:

1.) Training

Training stage at the time of purchase and training methods were also investigated in the study. Very rarely did farmers purchase trained animals (Table 5). The introduction of animal traction was encouraged by credit (for animals and equipment). Credit was handled by extension services, which, however, did not supply farmers with already trained animals except for a few projects.

Table 5. Training stage of draft oxen at time of purchase in village sites

Villages	Not yet trained	Trained and already used	Trained, never used
Yasso	88%	12%	0%
Kayao	94%	7%	0%
Kawara	89%	0%	11%
Dimolo	100%	0%	0%

Farmers with the support of extension services should be responsible for the training of animals after their purchase. Extension services have implemented several strategies for farmer adoption of appropriate training methods. One of them, which was supposed to drastically improve the diffusion of draft oxen training methods as well as animal traction-related techniques, was the creation of rural animal traction training centers. For example, around 1978, the European Development Fund set up a secondary animal traction center in Sindou, located 6 km away from Kawara, through a project managed by the former Comoe ORD. One of the objectives of the center was the training of farmers from neighboring villages in draft

animal training techniques. A farmer from Kawara purchased a pair of trained and castrated oxen which had not yet worked in the fields from this center. Another training center was opened in Bonbourokuy in the Mouhoun province.

Despite the influence of these extension services, draft animal training techniques are not yet mastered in any of the four village sites. Nevertheless, these are an important part of farm operations. Several training methods are used (Table 6):

- Gradual training with a sliding tree trunk
- Use of a trainer animal
- Use of violence

In all cases, violence is always associated with other methods listed when untrained animals are directly harnessed for field operations.

Table 6. Various draft oxen training methods used in village sites

Villages	Sled	Trainer animal	Violence
Yasso	76%	21%	3%
Kayao	83%	9%	4%
Kawara	69%	0%	11%
Dimolo	100%	0%	0%

The gradual training method with a sled is the most common method in the whole area. Even though this method (recommended by extension services) seems to be adopted by farmers, it is unfortunately always coupled with violence. Violent treatment has caused serious bodily harm and even death to several animals in Kawara. This training difficulty may also be a disincentive for farmers to adopt animal traction. The trainer-animal method is only used in Yasso and Kayao, where draft oxen have been present for a long time resulting in a greater mastering of training techniques. In Dimolo and Kawara, farms are just beginning with animal traction and their draft oxen are not sufficiently experienced to be used as trainers.

Marketing of draft oxen:

1.) Conditions of draft oxen acquisition

In the sample, cattle were acquired in four manners: Cash payment, recruitment from the family herd, gift or loaned cattle, and credit. These types vary significantly by subzones and local farming systems.

In Yasso and Kayao, cash payment is the most common method, representing 79% and 77% of cases in the village sample, respectively. Cases of recruitment of draft animals from family herds are fairly limited, and more common in Yasso than Kayao. Seventeen percent of draft animals from Yasso, a village mostly focused on agro-pastoral activities, were acquired in this manner versus 8% in Kayao. In Yasso, 10 out of 43 animal traction farms selected animals for

traction from their own herds. In Kayao, 4 out of 27 farms did likewise. Gifts came in third position in Yasso (3% of all cases), while they were absent in Kayao. Cattle loans and CRPA credit were used for 6% and 5% of all acquisitions in this village.

In Kawara, most draft animals were recruited from family cattle herds. Out of 5 sample farms using animal traction, 4 of them owned non-draft oxen. Recruitment, cash payment and cattle exchange represent 68%, 21%, and 10% respectively of all sample animals.

In Dimolo, draft oxen are mostly acquired through credit. Except for the only farm which purchased two pairs of draft oxen with cash, all cattle were bought with credit, mostly obtained from a protestant evangelical mission located 25 km away from the village.

2.) Financing sources

Activities capable of financing the acquisition of cattle were investigated, especially in Yasso and Kayao, where most purchases were done with cash.

Figure 2a shows that in Yasso, animal traction was financed through personal savings from 1964 to 1969. From 1969 on, other sources came into play such as cotton sales, which took on a leading role for the whole time interval, as well as cereal sales. In 1974, animal sales originating mostly from the retirement of cattle first acquired became another source of financing. The change over time in these financing sources is linear until 1979, when there was a drastic expansion of ox traction with considerable investment of income from cotton and animal sales for acquiring draft oxen. Increased number of acquisitions and sales may result from farmer strategies of cattle turnover.

The large financial role of cotton and cattle sales receipts can also be observed in Kayao (Figure 2b), where ox traction was introduced later than in Yasso. In contrast to Yasso, cattle were purchased with cash from cotton sales, and to a smaller extent from animal sales until 1984. Financing sources became more diversified after 1984.

Random cases of cash payment in Kawara and Dimolo stem from various funding origins, including cereal and animal sales and income from petty trade and crafts for the most part.

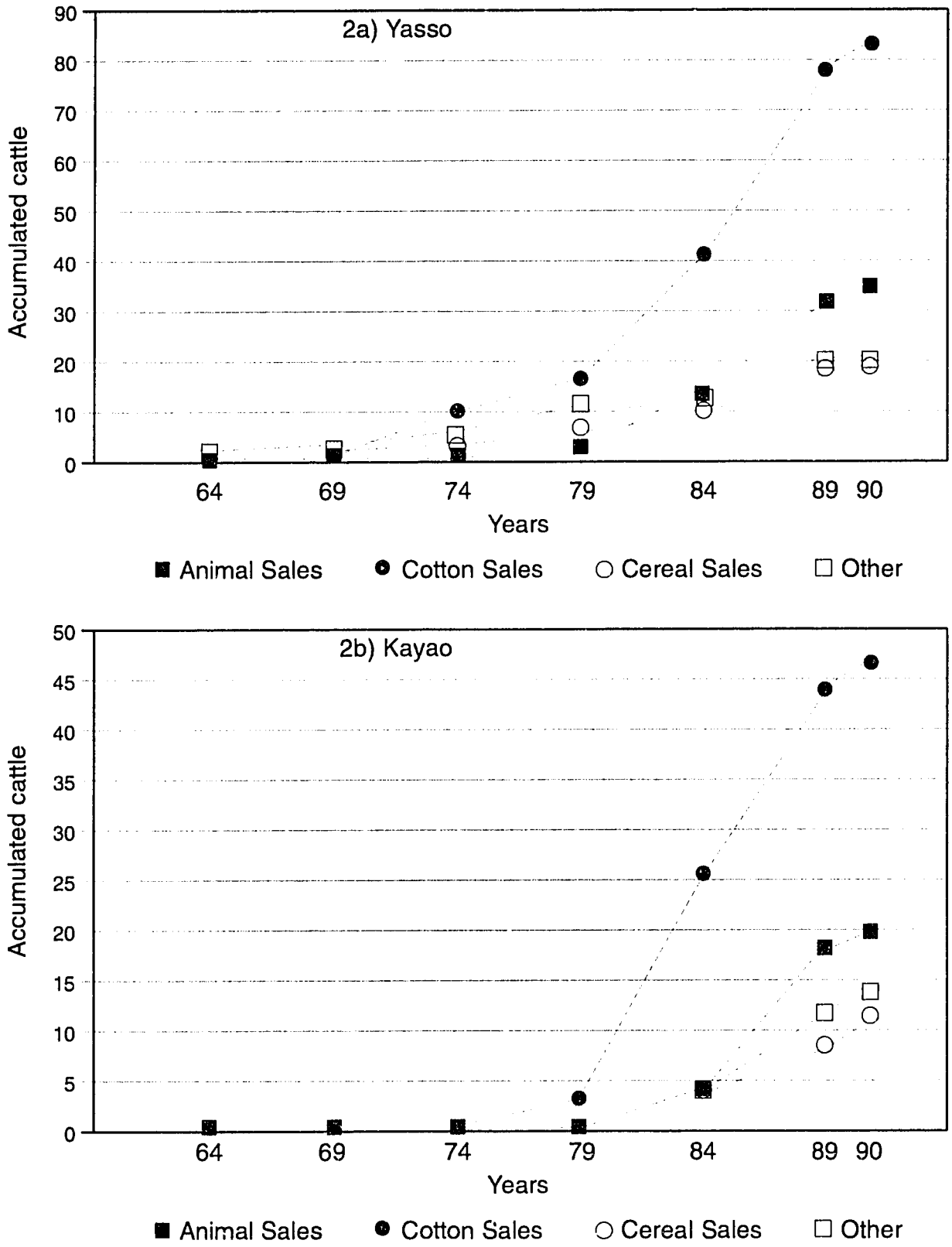


Figure 2. Financing sources for cattle acquisition from 1964 to 1990, Yasso and Kayao (Cash payments)

3.) Origins of draft oxen

The supply sources of draft oxen were studied in order to identify potential supply difficulties for farmers in the various subzones. Two variables under consideration are supplier types and purchasing locations. There are four main suppliers of draft oxen including farmers, sedentary and transhumant pastoralists, and cattle marketers.

In Yasso and Kayao, cattle have mostly and increasingly been supplied by Fulani pastoralists sedentarized in the village (Figure 3). A competing supplier is the cattle market in Yasso, which

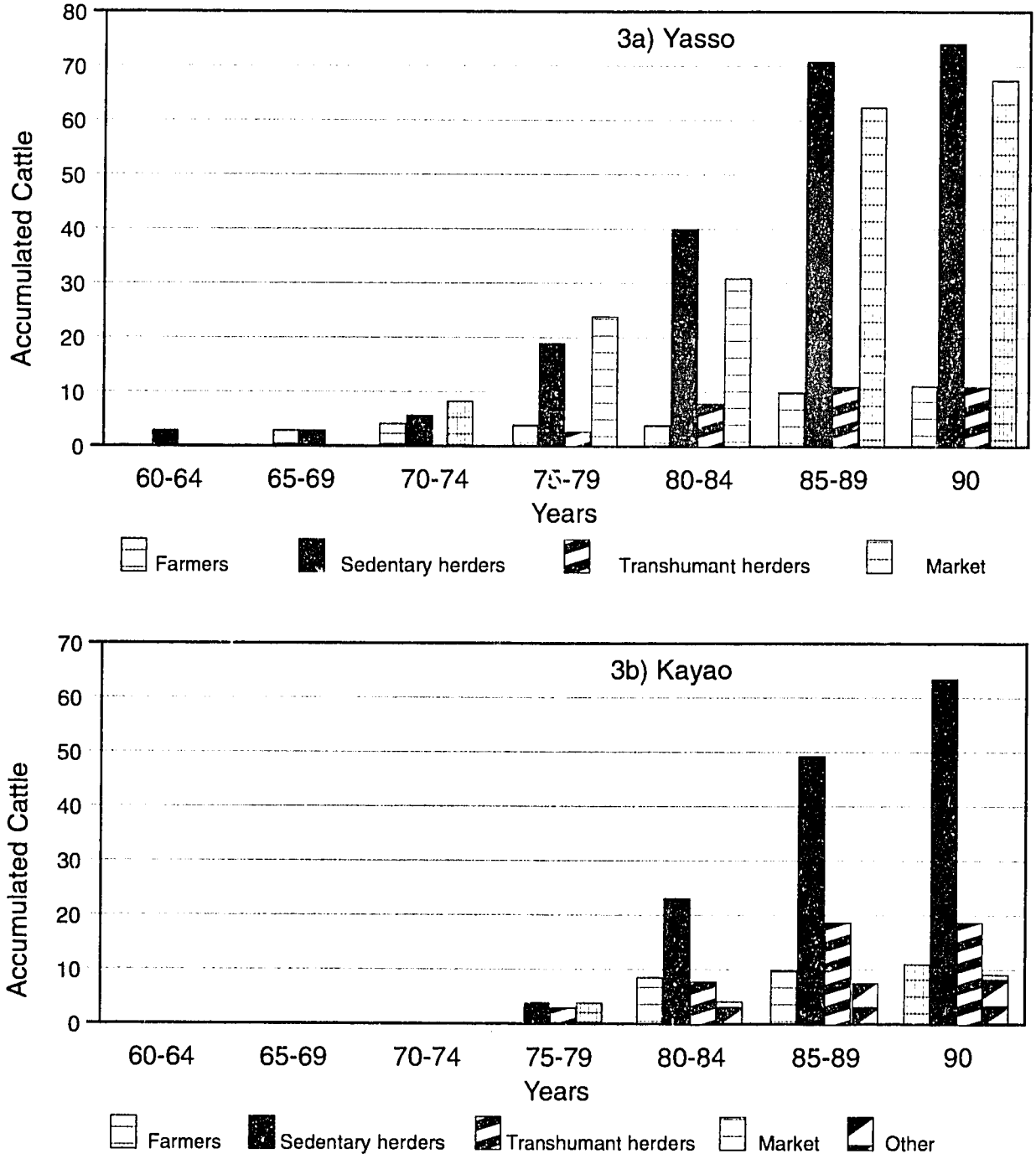


Figure 3. Suppliers of draft oxen from 1960 to 1990, Yasso and Kayao

draws pastoralists and farmers in the whole area for the sale and purchase of cattle. Supply by farmers and transhumant pastoralists is insignificant.

In Kayao, transhumant pastoralists became the second source of cattle supply during the 1980 to 1984 drought years. However, this supply path does not compete with sedentary pastoralists and is not increasing significantly. Third, cattle are supplied by farmers, yet this source has remained stationary and similar to that of the transhumant pastoralists between 1985 and 1990. Purchased cattle originate from the village research sites, villages adjacent to these village sites, and villages of neighboring "départements" (counties). Figure 4 shows that cattle have been

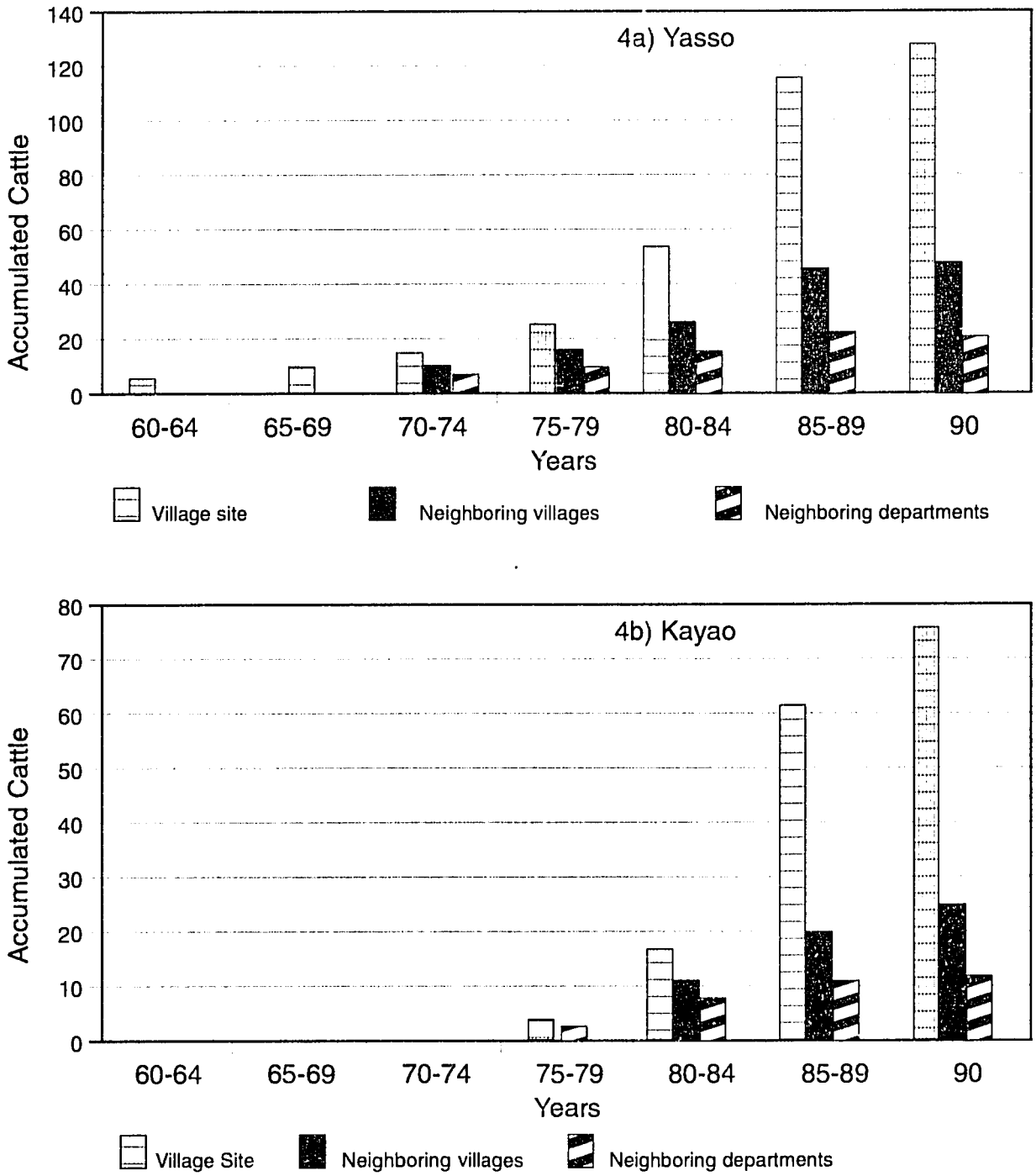


Figure 4. Purchase location of draft oxen from 1960 to 1990, Yasso and Kayao.

increasingly purchased within village sites in Yasso and Kayao until 1990. Cattle started to be purchased in adjacent villages ten years after the introduction of animal traction in Yasso. Even though it is increasing, this supply location remain minor. Rarely do villages of other "départements" supply cattle to farmers in village sites.

In Kawara, most draft animals were recruited by farmers from their own herds, as mentioned above. The only case of acquisition outside the village was the purchase of a pair of oxen at the CRPA in Sindou in 1980. In Dimolo, cattle were either purchased using credit offered by a protestant evangelical mission located in an adjacent "département", or paid for with cash by sedentarized Fulani pastoralists.

4.) Purchase price

Purchase prices gradually increased in Yasso and Kayao according to demand. They reached a maximum between 1985 and 1989, years of high demand in both villages. Based on increases between the time when animal traction was introduced and 1989, the annual increase rate of purchase prices was 9.6% in Yasso and 16.4% in Kayao.

In 1990, however, purchase rates declined in both villages. This may have been related to a significant reduction of cattle exports during this period, which contributed to a rise in domestic supply compared to local demand. Also, as previously stated, in Kayao, the price decline is closely linked to the replacment of retired cattle with younger bull calves at a lesser cost.

In Kawara, trends of cattle prices cannot be determined from the small number of cattle purchased for cash. Out of these 4 animals, one pair of trained animals was bought from the CRPA at 120,000 F CFA, while the second pair was purchased at 15,000 F CFA/ox from a Fulani village pastoralist.

In Dimolo, cattle sold on credit by the evangelical mission between 1984 and 1989 ranged from 20,000 F CFA to 22,500 F CFA. The price of animals acquired from Fulani village pastoralists ranged from 23,750 to 31,000 F CFA, and averaged 27,166 F CFA.

5.) Retirement of draft oxen

Villages having the lowest proportion of draft animals obtain highest returns from the sale of their retired draft oxen (Table 7). This may be due to the fact that these two villages are located next to neighboring countries where cattle prices, especially those of retired draft oxen, are higher. In fact, one Kawara merchant buys cattle from the village and conveys them to Côte d'Ivoire. Likewise, in the village of Dimolo lying close to Ghana and Côte d'Ivoire, draft animals in good physical condition are particularly sought-after by cattle merchants.

Table 7. Purchase and sale prices of draft oxen at retirement in village sites (in F CFA)

Villages	Mean purchase price	Mean selling price	Value added
Yasso	33,528	57,402	23,874
Kayao	26,143	40,375	14,232
Kawara	37,500	86,250	48,750
Dimolo	26,055	75,000	48,945

Care of draft oxen:

1.) Feeding practices

Feeding practices in the Western zone vary according to four distinct periods.

The beginning of the rainy season is the most intensive period of draft oxen use. In Yasso and Kayao, cotton production has resulted in an increase of arable land area. As the rainy season starts, animals are intensively used for plowing operations. However, during these months of May and June, range feed only consists of grass in early growth stages. Even though grass is of relative good quality, its quantity is often insufficient. This implies that cattle should be on the range during the time they are also most needed by farmers to avoid delays in their agricultural calendar. In May and June, cattle graze in fallow lands located next to crop fields during pauses (twice a day) from their day-long plowing work. Their diet is therefore limited and adds to nutritional stress after the end of the dry season.

The rains come earlier to Kawara and Dimolo, which are located further South. This contributes to a more rapid and substantial regeneration of range forage which becomes sufficient as early as the month of May. In addition, agricultural operations in the farming systems of these villages are initiated later than in the villages of the cotton-producing zone. This difference is partially due to the smaller number and size of agricultural plots. At the outset of soil preparation operations, cattle are in far better physical condition than those in the cotton-producing zone. Their condition will also be improved by greater availability of dry season range forage.

The rainy season takes place during the months of July, August and September. Rainfall is reliable during these months and results in abundant range vegetation. In all villages, this is the period with greatest feed availability. It is also the least constraining period for the use of oxen during the agricultural season. Rainy season operations are mostly weeding and ridging. The first operation is carried out manually for the most part, even by the most advanced farmers in the area. Ridging is mainly done with animal traction, especially in villages of the cotton-producing zone. The animal's good physical condition allows this operation to be carried out without difficulty.

In Kawara and Dimolo, lack of knowledge of agricultural techniques and the use of equipment limit the use of animal traction for these operations, even for ridging. Physical condition of draft oxen in these villages benefits, since they do not work when range feed is abundant.

No supplementary feeding of animals is practiced in any of the four villages, neither at the beginning of operations nor during the rainy season. Farmers limit the impact of work on nutritionally stressed animals by providing rest periods during initial plowing operations.

The first part of the dry season lasts from the end of the rains (October) to the end of the cool, dry season (late February). During this time, crop residues (mostly cereal stover, sorghum, maize, millet and rice) are available in fields. However, the availability of residues is limited in villages of the cotton-producing zone (especiallly Yasso) because of the high local animal density and transhumant activities. It also is limited by bushfires, a common practice in all villages.

During the cool, dry season, nutritional stress is less severe in Kawara and Dimolo than in Yasso and Kayao. In Kawara, there is a great abundance of stover left in lowland rice fields of the village during this period. All village ruminants are allowed to graze there.

However, cattle start losing weight at the end of the cool dry season in all four villages as range feed and crop residues become more scarce.

The second part of the dry season lasts from the beginning of the hot, dry season (early March) to the first rains (late April). The hot, dry season is characterized by insufficient range feed availability and quantity. Consequently, the physical condition of animals deteriorates as the season goes by. Stress is more severe in villages of the cotton-zone than in villages with lower use of animal traction.

Yasso and Kayao farmers develop strategies to limit the negative impact of this period, yet these are brief in comparison to animal needs. The first and most common strategy, which is practiced by all farmers owning draft oxen, consists of collecting and storing crop residues of different kinds (cereal, peanut and cowpea). Stocks are, however, insufficient for supplementary feeding during the whole season and are quickly exhausted. The second strategy, which is practiced by a limited number of farms in the two villages is the purchase of agricultural processing by-products, namely cotton seed supplied by a textile company (SOFITEX). Cottonseed meal has also been obtained by two Yasso farmers. The acquisition of these industrial by-products is difficult because of their limited market availability and their high prices. Low quantities obtained by a few farms are fed in tiny amounts and for only a short part of the hot, dry season.

In Kawara and Dimolo, farmer strategies for feeding draft oxen are limited to a change in herding practices, described in a later section. Therefore, rangelands provide the basic diet of draft oxen in all villages. Crop residues, even when fed as fodder, are not optimally used. The availability of agricultural processing by-products remains a problem, even though farmers have demonstrated the willingness to support their cost. Mineral supplements of kitchen salt are very common during all periods in sample villages. They are given at least once a month, and often combined with sugars in the form of locust bean or néré powder.

2.) Watering

Watering practices take into account range feeding. At the beginning of and during the rainy season, water availability is not a constraint in sample villages. Draft oxen drink in different places, such as puddles along field paths, and temporary and permanent water points.

However, dry season water shortages are a constraint of varying severity, depending on the village. In Yasso, permanent watercourses and water points dry out early. Well water is the only water source for cattle during most of the dry season. The village has enough wells, so labor for drawing water is the limiting factor.

In Kayao and Dimolo, water shortages are more severe than in other villages. The only source of water for cattle at Kayao is the Mouhoun river, 5 km away from the village. In Kawara, the water constraint is less acute in the dry season because their lowlands hold water during the whole dry season.

3.) Herding practices

Draft oxen are herded mostly by farm family members at the beginning of and during the rainy season as well as during the cool, dry season. Herders are teenagers from 8 to 12 years old, who are mostly familiar with draft oxen. In the two villages of the cotton-producing zone, teenage girls also participate in herding of animals. During the hot, dry season, when range feed and water become scarce, herding procedures in sample villages change.

During that period, draft animals are usually combined with other cattle. Such mixed herding is mostly practiced in Kawara and Dimolo. In Kawara, 5 ou of 6 farms owning draft oxen pay Fulani pastoralists for herding their non-draft oxen. These farms usually combine their draft animals with the rest of their livestock when they are not needed. In this village, where draft oxen are exclusively used for ridging, they are joined to the family herd for the rest of the time.

In Dimolo, draft oxen are entrusted to sedentarized Fulani pastoralists from the village during the dry season. Both draft and non-draft oxen are taken on transhumance early in the dry season to avoid water shortage.

In the two villages of the cotton-producing zone, Yasso and Kayao, draft animals are seldom mixed with non-draft oxen during the dry season. They prefer that they be range-fed during the day by children. Draft oxen remain under children's supervision even during the hot, dry season, and are fed stored crop residues or a cotton seeds and bran supplement after range grazing. Cereal bran is a kitchen by-product saved by women for supplementing the diets of draft oxen.

4.) Nighttime confinement

In the most common nighttime confinement method, animals are tied to a stake in the farm compound during periods of use. During the dry season, draft and non-draft animals are kept in

open pens enclosed with spiny bushes or tree branches. At night, animals herded by children during the day are most often secured to a stake under a shed, on top of which crop residues are stored. Animal droppings are insufficiently collected under all confinement methods.

5.) Animal health

No animal health station is available in any of the four villages. The most common contagious diseases in the area are, however, present in the villages. These include animal trypanosomiasis, bovine pasteurelosis and symptomatic smut. In addition to these severe affections, animals may have internal and external parasitosis, both being more common during the rainy season.

In all villages, the main healthcare protection service for draft oxen is the annual prevention campaign against bovine plague and contagious peri-pneumonia. Very rarely do farmers call upon animal health care agents for other preventive or curative care. A small number of farms in Yasso and Kayao requested assistance from animal health agents in 1990. Trypanosomiasis and smut were involved in the treatments. No farm in the Kawara or Dimolo samples called upon veterinary services for preventive or curative care in 1990.

Remarkably, farmers in all villages treat some afflictions with traditional medicine and to some extent with unconventional products (pesticides, etc.). One of the treatments commonly used in all villages is skin parasite (especially tick) control. Farmers apply cotton insecticides mixed with used engine oil on infestated body parts of cattle. Other unconventional treatment methods are described by Samandoulgou (1994).

III. CONCLUSION

This diagnostic study of draft oxen management in villages of western Burkina Faso identified several constraints. Considering the importance of animal traction to this relatively productive zone, research and development activities for increasing the productivity of draft oxen should be developed to address these constraints.

In regions of low animal traction use, extension services should support farms in their efforts to shift from traditional hand cultivation to more intensive, mechanized agriculture. Special emphasis needs to be placed on training farmers with newly acquired draft oxen, and priority should be given to:

- training young cattle
- maintenance of draft oxen

In these regions, potential cash crops should be researched in order to make animal traction technology profitable and encourage farmers to adopt it further. Credit incentives for purchase of animals and equipment must be widely developed.

In regions with a great deal of animal traction use, technical competence of farmers in draft oxen management is fairly high. However, villages in these regions are subject to land saturation (crowding) and to a gradual, significant degradation of natural resources and its consequences, including dry season range feed shortage and soil fertility decline. Research tasks seem more obvious in these regions. Possibilities for an effective integration of crop and livestock production should be investigated in order to satisfy needs for cattle feed production and soil fertility improvement.

The precarious health condition of draft oxen is a constraint common to the broader region of western Burkina Faso. The diagnosis of major epidemics is achievable, but intervention procedures are still out of the farmer's reach. Considering the key role of animal traction in the development of the nation's agriculture, healthcare issues should be studied closely. Credit for draft oxen healthcare with similar reimbursement procedures to those for agricultural inputs could be established.

Finally, the increased flow of cattle exports toward neighboring countries associated with the devaluation of the CFA franc justifies a study of the draft oxen sector in the regional economy.

Section IV
Agroforestry

Researching Tree Management Strategies in Thiougou Village, Central Plateau, Burkina Faso

E. Robins

ABSTRACT

The management of trees in crop fields is an important component of Sahelian farming systems. Trees satisfy needs in rural populations for food, fiber, fuel, fodder, wood, and may improve soil fertility and crop performance. Rational natural resource management, including the management of trees, will be even more important in the future. This research attempts to identify factors which determine how trees are managed on agricultural land in Thiougou village, Central Plateau, Burkina Faso. The first phase of the research activity, reported here, presents the results of an informal survey of village men and women. Results show that when fields are cleared, standing trees are selected on the basis of 1) utility (species) and 2) condition and age. The number of trees retained (spacing or density) is a function of the perceived trade-off between tree utility and crop production. It is not yet established whether trees improve cereal yields in crop fields. Yields under tree crowns are probably lower. While trees themselves have an important economic value aside from their influence on crop performance, women and men producers unequivocally state that their first priority is crop production. Thus, trees are managed to control their perceived negative impact upon cereal yields. Other factors which influence crop performance -- such as soil fertility and animal traction -- are likely components of tree management strategies. The current and future roles of women in tree management must be ascertained as they derive important revenue from the sale of tree products. Finally, State policing of forest resources is likely having an impact upon tree management strategies and should be researched.

I. INTRODUCTION

This paper describes research on the farming systems of the Central Plateau of Burkina Faso. In particular, it focuses on the management of trees in agro-silvo-pastoral systems. The key question being researched is: What are the factors which determine how trees are managed on agricultural lands?

It is well-established that trees serve multiple uses for rural families; it is less clear how trees are managed, largely through selection and regeneration in parkland configurations, to meet the needs of family members and for sustainable agricultural production. The research described in this paper is an effort to identify those factors which determine tree management decisions at the research site. This research is one component of a larger effort being implemented by the Central Team of the Production Systems Research (RSP) program of Burkina Faso's Institute of Agricultural Research and Studies (IN.E.R.A) which examines variation in agricultural practices by agro-ecological zone, producer resource endowment, and economic strategy.

The management of trees in West African farming systems has been the focus of considerable research (see, for example, Fortmann and Bruce, 1988; Fortmann 1985; Fortmann and Riddell, 1985; Pullan 1974). Increasing population in the region is causing reduced fallow, shrinking pasture, and more intensive farming. The use of chemical fertilizers and animal traction is increasing. More than before, rational resource management is a priority for individuals and communities.

Trees are important features of Sahelian farming systems. They satisfy needs in rural populations for food, fiber, fuel, fodder, wood, and can improve soil fertility and crop performance. Managing trees rationally is of particular concern in the Sahel (see Kessler 1992; Sollart, 1986; Weber and Hoskins, 1983; Winterbottom, 1980), where the convergence of agricultural and livestock systems require careful allocation of land to crop and tree resources. Trees are also appreciated by Sahelian producers for creating a shaded micro-environment which is solace to workers during the heat of the day.

Producer strategies for managing trees are conceived in the context of larger agro-pastoral systems and may be deeply tied to rights to land. Research has shown that rights to land and rights to trees may or may not coincide (Bruce, 1989). Identifying who has rights to land and rights to trees is essential for understanding how tree resources are managed. The incentive structures of traditional resource management systems have evolved in specific contexts and failure to appreciate this will undermine efforts to conserve existing systems or introduce new ones.

II. APPROACH

This paper reports the results of the first phase of the research project: An informal survey of men and women agricultural producers on the subject of tree management. The objective of this first phase is to identify priority factors influencing producer decisions on selecting and maintaining trees in crop fields. In the second phase of research a formal survey will be conducted with a larger sample to determine the wider distribution of management criteria and their potential relationship to other agricultural practices and conditions.

The literature on land and tree tenure describes factors which may be important at the research site (see, in addition to the sources cited above, Boffa 1992; Barrows and Roth 1990; Rocheleau 1989; IRBET 1989; De Leener 1988; Sidebé 1988; Poda 1988; Bonkoungou 1987; Hoskins 1984; CILSS 1983) . These include, for example, rights to land and trees or perceptions of the relative economic value of trees in crop fields. Inquiries on the relevancy of these factors were pursued in the informal interview process. Interviews, conducted in Mooré, the language of the Mossi villagers, were open-ended, following the interests and experiences of producer respondents on the questions under review. Results are discussed below.

Thiougou village, in the south-Sudanian zone, is located in Zoundwéogo Province, at 11° 5' N latitude and 0° 5' W longitude. Average annual rainfall is between 800-900 mm. The village

consists of approximately 8500 ha. of which about 75% is in arable crops. The remainder is devoted to pasture. Sorghum and millet dominate the cropping pattern.

The total resident population of Thiougou is 1935 persons, divided among 232 production units. Eighty-six percent of the population is Mossi; the remainder are Peuhl herders who have settled in the village and practice some crop production as well as herding. About 60% of the population uses animal traction. The value of trees is important to consider with regard to plowing, which may be rendered more difficult by the presence of trees, and for fodder production.

Interviews were conducted with 11 men (*Chefs d'Exploitation*), mostly individually, and 20 women (divided into two groups). Conclusions are drawn from their practices, perceptions, and opinions about whether one or another factor is of priority in deciding how to manage trees. Other RSP research in Thiougou is investigating complementary problems, *viz.*, crop performance in the vicinity of karité (*Vitellaria paradoxa*) of different ages, and soil fertility on these same parcels. A continuing analysis of crop performance by tree density on agricultural parcels will furnish important information about the results of producer tree management decisions.

III. FACTORS INFLUENCING TREE MANAGEMENT DECISIONS

Discussed below are potential dimensions of tree management strategies in Thiougou which prior research has shown to be important in Sahelien countries (see, especially, Bruce 1989; Matlon 1989; Wiersum 1987; Sollart 1986; Fortmann 1985; Pullan 1974). Our research supposes that they are relevant at the research site, Thiougou village. In fact, some are shown to be more important than others in Thiougou.

Rights to Land. Ownership or proprietary rights to land generally include rights to trees growing on that land, although other factors may come into the equation. Individuals who plant trees on land which is not their own may retain exclusive rights to harvest them, for example. Usufruct rights, by contrast, may or may not include rights to harvest trees or tree products. Planting trees on borrowed land may, in some cases, not be permitted as it would constitute a claim to that land. Under either proprietary or usufruct conditions certain categories of individuals may be excluded from exploiting particular trees or tree products. The identification of rights (individual or group rights on owned, loaned, or borrowed lineage or non-lineage land) must be empirically determined.

Rights also may be changing if there is a move away from traditional to national (State) law. Land use practices (e.g. loans), too, may change with increasing land pressure. Matlon (1989) hypothesizes that short term loans increase relative to long term loans in proportion to land pressure and access to preferred markets. Land in Thiougou is generally inherited or borrowed. Save for the case in which a field is loaned for a specific period of time, a practice which is becoming more common as land availability decreases, land exploited by a producer, whether inherited or borrowed, tends to be regarded as his own. The producer makes all management decisions, including those regarding the selection of trees to maintain when the land is cleared for

cultivation. Continuous cultivation of a borrowed parcel increases the borrower's security on the parcel. Bush fields, in particular, may be acquired and retained by families in this fashion.

Rights to Trees. Trees themselves can be the object of property rights. These rights may be coincident with rights to land or separate from them. Trees may be owned, loaned, leased, inherited, disposed of, protected from others, and so on. Rights may vary by tree species, utility, location, and status of the individual. Trees may secure land tenure, especially when planted on borrowed land.

In Thiougou, rights to trees and tree products inhere in rights to land. The producer decides which trees to retain, which seedlings will remain, which trees will be cleared. Rights to the products of some trees, such as the edible fruit of *karité* (but not *néré*), may extend to others outside the family. Any villager may harvest a quantity of fruit, for example, from someone else's land. Similarly, neighbors may exploit one another's tree resources if informally agreed to.

Interviewed women stated that they advise men on which trees to retain when fields are cleared and, in most cases, may harvest fruit, nuts, and fallen wood when they want to without authorization from men. Given that the nuts of *karité* and *néré* are an important source of income to women, and that womens' economic autonomy may be circumscribed by men, it is important to pursue further in the follow-on formal survey women's role in tree management.

Conservation of tree resources appears to be (and to have been) a priority concern of producers whether land is owned (that is, inherited) or borrowed. Currently, agents of the forestry service (*Direction des Eaux et Forêts*) are advising villagers to maintain trees as a conservation measure.

Location of Trees. Bruce (1989) speaks of *tenure niches* related to specific management arrangements and ecological conditions: agricultural holding, the commons, and government reserve. In Thiougou village other *niches* are more pertinent: household field (*champ de case*), village field (*champ de village*), and bush field (*champ de brousse*). This last category is particularly revealing of current tree management practices as these are the lands most recently cleared and put into crop production.

Trees are found on land immediately surrounding the residence (*case*) and further away in village and bush fields. Results of the interview process indicate that producers select and maintain trees, regardless of location, by utility (species), age, and condition. Tree density and crop performance may be hypothesized to vary with tree location, however; more fertile and productive house fields, for example, being devoted more exclusively to crop production. This may be a function of 1) the perception that trees inhibit crop production and 2) the age of house fields. In house fields, which may be in continuous production for 20 years or more, older trees no longer producing have been removed while seedlings are not permitted to regenerate.

Uses of Trees. Trees may provide fruit, fodder, fiber, leaves, wood for construction, fuelwood, shade for humans and animals, medicines, and serve to house hives and hang hides. Tree management in Thiougou is most commonly expressed in decisions to retain existing trees when clearing land destined for crop production. These decisions are based first on the perceived utility

of the tree. Preferred species include *Vitellaria paradoxa* (karité or shea nut), *Parkia biglobosa* (néré or locust bean), *Lannea microcarpa* (raisonnier or wild grape), *Bombax costatum* (kapok or silk cotton), *Adansonia digitata* (baobab), and *Tamarindus indica* (tamarind).

Trees which are left after fields are cleared, according to Thiougou producers, always have a utility which governs their selection. It may be edible fruit, nuts to be processed and commercialized, or wood for construction or fuel. These same trees provide shade for workers and infants, a priority use of the tree cited by all respondents. The roots, bark, or leaves of some species are used in traditional pharmacopoeia.

Trees which have no practical utility are eliminated from fields when they are cleared for cultivation. Their seedlings also are cut, leaving only a population of the most desired species. Seedlings or young trees of desired species are retained typically after a period of fallow.

Planted vs. Wild Trees. Tree planting decisions indicate the needs of planters. Tree planting has profound implications for improving land and may constitute a claim to land. Thiougou villagers who were interviewed do not plant trees. They argue that seedlings will be consumed by roving livestock. Natural regeneration appears to satisfy their current needs for tree products.

Trees in Crop Fields. Trees in crop fields may serve several important purposes, as already noted. The presence of the tree in the field also may improve soil fertility through manure dropped by browsing animals, decomposition of roots and leaves, or changes in the micro-climate. Trees mine and recycle plant nutrients and may contribute nitrogen through fixation. Trees may shade crops, house birds, or in other ways impact negatively upon crop performance. An accompanying research activity is focused on tree impact on crop performance.

Trees in crop fields is the predominant pattern in Thiougou village. Trees are selected when fields are cleared according to their utility (see pt. 3 above), condition, and age. While some individuals speak of keeping 25-40 trees/ha (according to what they claim is the recommendation of forestry agents), spacing/density for others appears to conform more to whatever "looks right" to the individual. It is apparent that what "looks right" is a function, in part, of the estimated or anticipated value of tree products. Producers indicate that they consider the (potential) utility of standing trees when clearing fields.

The presence of trees is said by producers to decrease yields in cereal crops growing underneath their crowns, the result of shading and increased humidity (this latter benefitting the development of vegetative matter at the expense of grain). Crops growing somewhat further from the tree, however, may benefit from leaf litter and satisfactory sunlight, and perform better than crops either closer to trees or yet further away. Leaves also serve as mulch and help to retain soil moisture. This is especially true for *karité*; *karité* leaves contain oils which inhibit their decomposition (Kessler 1992).

Producers conclude that the economic value of *karité* and *néré* more than makes-up for the loss in yield of crops growing under their crowns. *karité* nuts and *néré* seeds may be sold (for 125

FCFA and 350 FCFA, respectively, per plate). Kessler (1992) also argues that the overall benefits of tree products compensate for the loss in cereal yields.

Whether or not there is a tradeoff between tree and crop production in Thiougou has not yet been determined. Kessler (1992) reports that yield of sorghum and millet is lower where trees are present. Thiougou villagers, as noted above, report that yield is greater away from trees but on parcels where trees are present. This is confirmed by RSP research at Thiougou (see Bertelsen and Kaboré, 1993). In either case, trees have a utility and economic value recognized by producers which is evident in their management strategies.

At what tree density is the relative value of trees to crops perceived to diminish? While it may be possible to demonstrate that total returns to land increases with tree density, producers likely will not increase density beyond that point where they estimate it will threaten household food security. That is, household self-sufficiency in food crop production predominates in their agricultural strategy.

Tree-Livestock Interactions. Leaves of some species may serve as fodder. Livestock, too, may seek the shade of trees and drop manure on crop fields. Livestock exploiting young trees as forage may inhibit regeneration.

Thiougou respondents do not use tree products as fodder. Trees make plowing fields more difficult when using animal traction. Trees which block work are removed.

Trees and Fertility Management. Trees themselves may increase soil fertility through mining and nutrient recycling through root recycling and the deposition of dropped leaves and fruits, and nitrogen fixation (as discussed in point #6). Increased organic matter levels near trees may improve nutrient and water status and retention.

Trees also are a factor in fertility management in the larger context of land tenure. Borrowed land, for example, may be fertilized as a means of improving crop performance. By increasing the investment in a parcel a producer also is increasing tenure security (see Matlon, 1989). To the extent that tree management (i.e., selection and maintenance) may be linked to tenure security, trees will encourage other investments in fertility (such as the use of slow-acting fertilizers like rock phosphate).

Bush parcels in Thiougou are not fertilized by survey respondents. Such parcels may be cultivated for 6-10 years and fallowed for 3-5 years. The presence of trees on these parcels may improve crop performance, as noted earlier.

Type of Parkland.

A typology of tree parks may be revealing of different management strategies and may be associated with socio-economic status and other socio-economic variables. Types may be based on:

- tree origin (residual, selected, or constructed)
- tree species (see point #4)
- tree density
- spatial structure (limited, extended, or distant)
- time since land clearing
- agronomic or pastoral practices
- attitudes toward trees/perception of local ecology.

Thiougou parks generally are composed of selected species, predominated by *karité*. Tree density appears to be quite variable. Parks may be distinguished by their location and structure, although there appears to be a fairly continuous presence of trees from the house to the bush. Fields containing the most mature trees may have been cultivated for the first time several generations ago.

The criteria cited above may be used to generate a typology of parks. Tree management may vary by type of park.

Socio-Economic Status. Tree management may vary with some socio-economic variables. The agricultural production units of Thiougou village have been classified by village resource persons according to relative level of wealth. Discriminant analysis showed that this classification corresponds roughly to the number of livestock, and particularly cattle, owned. Other potential proxy indicators of relative wealth, such as size of holdings and number of family laborers, are under study.

A sample taken from each village "class" will be queried in the formal survey to reveal differences, if any, in management strategy by relative level of wealth.

Other factors which may be linked to different tree management practices include the status of the producer (indigenous villager or migrant), and the mode of acquisition of the field.

IV. CONCLUSIONS FOR FURTHER RESEARCH

The objective of this research is to elucidate producers' strategies for managing trees in crop fields. It is implicit that 1) producers *manage* trees (that is, their decisions are *intentional*) and 2) that this management is *rational*, seeking to optimize some set of conditions relating land and trees to production objectives. In this first phase of research questions related to tree use, tree density, and crop performance predominated. Other dimensions discussed here, such as the

socio-economic status of the producer, are important as independent variables and may demonstrate variation in tree management practices by level of resource endowment.

When fields are cleared, standing trees are selected on the basis of 1) utility (species) and 2) condition and age. The number of trees retained (spacing or density) is a function of the perceived trade-off between tree utility and crop production. It is not yet established whether trees improve cereal yields in crop fields. Yields under tree crowns are probably lower.

While trees themselves have an important economic value aside from their influence on crop performance, women and men producers state that their first priority is crop production. Thus, trees are managed to control their perceived negative impact upon cereal yields.

Other factors which influence crop performance are likely components of tree management strategies. Soil fertility, as a function of the number of years a parcel is under cultivation, soil amendments and conservation measures which have been applied, and initial fertility (these three features themselves a function of the *location* of a parcel), may vary with the tenure status of the parcel. Other research (Matlon 1989) shows that short term borrowing increases with increased land pressure. There may be little investment in the improvement of these parcels and this too may be exhibited in tree management strategies.

Animal traction is rendered more difficult with trees in crop fields. Tree density in Thiougou is lower on parcels where traction is practiced. Is this pattern likely to continue as animal traction spreads? Or will traction and trees be managed to retain the advantages of each as land is used more intensively?

The evolution of womens' economic role toward diversity and greater participation in marketing implicates them in tree management. Currently, village women report no conflict with men over the selection of trees to remain in crop fields. Will this be the case for a larger sample? Is it the same for women regardless of the presence of co-wives or according to other demographic variables (number and age of children, for example)? Is it equally true for individual as well as communal fields?

Finally, State policing of forest resources is likely having an impact upon tree management. This impact should be ascertained, as should new tree management strategies which result from it.

The follow-on survey will attempt to answer these and other questions in order to reveal how producers manage important natural resources for sustainable agricultural production.

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The Economics of the West African Parklands Agroforestry System: Preliminary Evidence from Two Central Plateau Villages in Burkina Faso[1]

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ABSTRACT

The economics of the West African parklands agroforestry system is analyzed. The purpose of the analysis is to explain tree densities and cereal yields within the system, factors which affect these densities and yields, and the relationship of tree densities to soil fertility. Unlike previous studies which have concentrated upon the specific tree-yield relationship immediately surrounding the tree during a limited time period (e.g. a single production year), this study analyzes the relationship between tree densities and farmers' expected yields for entire fields. This research strategy has the advantages of explicitly recognizing the long-run nature of tree management decisions as well as considering the benefits trees may provide beyond their immediate areas. Two-stage least squares procedures are used to estimate a simultaneous system of equations with crop yields and tree densities as endogenous variables. Yield data are based on farmer recall. Field area measurements and tree counts for fields in the study were obtained from aerial photography. Additonal data was gained through surveys. Using this methodology and contrary to previous research, we present evidence that the net effects of trees on parkland sorghum and millet yields is positive over the range of tree densities found in the study.

I. INTRODUCTION

The vast West African parklands agroforestry system has survived centuries of periodic drought and other environmental stress. Recently however, increasing population pressure in combination with continuing environmental stress has challenged this survival. An understanding of the economics of the farmed parklands will assist decision-makers and others in determining what strategies might be undertaken to better manage this unique system.

The West African parklands agroforestry system is found in the arid and semi-arid areas of West Africa and is characterized by widely spaced trees inter-cropped with (usually) cereals. Tree densities within the system are remarkably uniform within each agro-ecological zone. Generally, higher tree densities (>20/ha) are found in the wetter south and lower densities (<10/ha) in the drier north. Similarly, the principal inter-cropped cereal changes from maize and sorghum in the south to pearl millet in the north. Tree species vary considerably as does the heterogeneity of the species within any given area.

The shifting cultivation practiced within the parklands is typically very low input with 'bush fallow' (long periods of minimum management and no cultivation during which the land returns to 'bush') playing the major role in regenerating soil fertility. The fallow period also provides time for the natural regeneration of tree species. Recently, increasing human population pressure

[1]An earlier version of this paper was presented at the International Symposium on Farmed Parklands in the Semi-Arid Land of West Africa held in Ouagadougou, Burkina Faso 25-27 October, 1993.

has greatly reduced the practice and/or length of bush fallow throughout the region (Otegbeye, 1994). As a result, soil fertility problems are becoming more severe, causing pressure to expand production by increasing the area cultivated. This, in turn, causes still greater decreases in bush fallow and still another iteration in the vicious cycle. It is clear that major changes must be made within the system or large areas of the parklands are destined to disappear.

Objectives. Given the phenomena of declining bush fallow and decreasing soil fertility, understanding the role of the tree in the parklands system becomes crucial. That the tree contributes substantially to the welfare of the rural population is evident (see for example, Ford 1982) but since tree densities globally are destined to decline naturally as a result of the reduced bush fallow, the future of trees within the system becomes problematic. Unless the trees' net contribution is viewed positively by farmers, their numbers will decrease even more rapidly as they are eliminated from current parkland stands.

The trees' effects on cereal production is key. Although a technical understanding of the effects of different tree species on soil fertility and production is important, especially important is the *perceived* role of the tree. The mix and density of trees in any given area results from the decisions taken by individual and groups of farmers over a long period of time. Since it is the farmer who makes the everyday decisions resulting in the tree-crop densities and interactions, it is (s)he who will decide the future of the parklands. The farmer's perceptions of cause and effect, complementarity and competition inform these decisions. Although other social and environmental criteria condition these decisions, African farmers must be considered as essentially no different than other farmers: they seek to extract the maximum satisfaction (or utility) from natural and other resources under their control. They are therefore, economic actors whose actions can be described, analyzed and illuminated with the help of economic theory.

In this paper we seek to provide this analysis of the parklands system. The purpose of the analysis is to explain tree densities and cereal yields within the system, factors which affect these densities and yields, and the relationship of tree densities to soil fertility. In so doing, we present evidence that the net effects of trees on parkland sorghum and millet yields is positive over the range of densities found in the study. Unlike previous studies which have concentrated upon the specific tree-yield relationship immediately surrounding the tree during a limited time period (e.g. a single production year), this study analyzes the relationship between tree densities and farmers' expected yields for entire fields (parcels). This research strategy has the advantages of explicitly recognizing the long-run nature of tree management decisions as well as considering the benefits trees may provide beyond their immediate areas. Farmers' expected yields are assumed to be closer to the long-run mean yield on any given parcel than the observed yield of the parcel in any given year. Also, since benefits from trees may extend well beyond arbitrary limits imposed by researchers, it is important to study the entire area under the same management[2].

[2]For example, the presence of trees within a parcel may draw many more animals (and manure) than a parcel without trees. Similarly, wind and water may move tree residues over a wide area and thereby enhance soil fertility throughout the field. Also, there are intuitive reasons to assume farmers perceive some positive long-run yield effects for trees: farmers have the option of removing them from cropland and still enjoy the other, non-yield enhancing benefits of trees managed in higher densities on their marginal, unfarmed lands.

The next section summarizes the production economic theory applied to the parklands. A description of the methodology, the statistical model and data follows. The paper concludes with a discussion of results and conclusions wherein the implications of the analysis for animal traction and the future of the parklands are examined.

II. PRODUCTION THEORY APPLIED TO THE PARKLANDS

The theory of production is embodied in the concept of the production function. The production function defines the maximum amount of an output theoretically attainable with a given level of inputs. Both inputs and outputs may be measured in physical units. Mathematically, a production function may be expressed:

$$Q = f(X_1, X_2 .. X_n)$$

where Q represents the quantity of output and the Xs represent the quantities of all inputs and other contributing production factors. For example, at a somewhat less abstract level, a 'tree' production function for a certain area within the parklands system might be represented as:

Trees = f(soil fertility, rainfall, technology, crops, other)

where:

Trees = an idealized unit of output measuring all services (outputs) provided by a given combination (e.g., species, ages) of trees with a given spatial distribution within a unit of land area (parcel).
Soil fertility = a measure of soil fertility and potential
rainfall = a measure of rainfall per unit of time
technology = the level of technology used by the production unit exploiting the parcel
crops = the yield given the cultural characteristics of the crops sown in association with the trees.
other = all other factors

Four salient points are apparent from the above example. First of all, a production function is a economic tool which demands abstraction. It is necessarily a simplification of a very complex process. For example, even enumerating all of the marketable and non-marketable services of trees (lumber, shade, aesthetic and religious values, etc.) is problematic to say nothing of trying to reliably measure them. Consequently, at this theoretical[3] level, both inputs and outputs are measured in idealized, intangible units.

Secondly, given the definitions of variables, an infinite number of individual production functions could be estimated if data were available. For example, a different production

[3]At the empirical level, imperfect 'proxy' variables representing inputs and outputs must be substituted. For example, in the case of the services of trees, tree densities could be used with tree density units being represented by the mythical average (species, age) tree. This would implicitly assume that the all the services of trees are a function of tree numbers.

function could be estimated for each tree species, each mix of tree species, each mix of tree species with a specific geographical distribution, etc.. Consequently, from a practical point of view, the best that can be done is to estimate *an average or typical* production function representing all tree outputs within a given area of parklands. The results in this case would indicate average input levels and production response behavior for trees measured in idealized tree units.

Thirdly, the above production function specification must necessarily be incorrect if it does not explicitly take into consideration the long-run nature of tree-related decisions. The services of trees are not provided instanteously and consequently must be planned for. Consequently, all variables should be considered long-run and assume their long-run or 'expected' values. In particular, farmer expectations of yields are crucial to guiding crop and tree management. Furthermore, these expectations should be assumed to be fairly accurate over the long-run. West African farmers have a long experience with parklands production. Mistaken estimates involving food for the family are obviously serious. The farmer cannot afford to be mistaken often.

The last point concerns the specification of the model. Specifically, the relationship between tree density and crop yield needs to be clarified. The model posits a unidirectional causal flow between crop yield and tree density. That is, holding all other factors constant, if the farmer decided to modify the long-run expected crop yield of a parcel, tree density would be changed as a result. However, this assumes that the causal flow is only one way. If tree densities and crop yield decisions are jointly determined then a two-equation, simultaneous model must be specified: tree densities are a function of crop yields and, at the same time, crop yields are a function of tree densities.

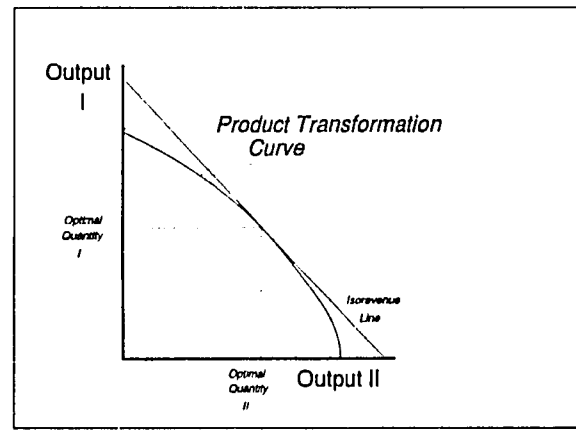


Figure 1. 'Normal', Concave-From-Below Product Transformation Curve

In fact, researchers recognize the interdependence of crop yields and tree densities. Furthermore, most would argue that crop yield and tree density are generally negatively related (see for example, Kessler, 1992). This type of joint production gives rise to the 'normal' product transformation curve (PTC) with its concave-from-below shape illustrated in Figure 1. Production of one more unit of one Output I can be accomplished only by sacrificing increasing amounts of Output II. The slope of this curve is called the rate of product transformation (RPT) and measures how much of one output must be given up to produce another unit of the other

output. Maximum profit for any level of revenue is achieved where the slope of the RPT is equal to (tangent to) the isorevenue line. The isorevenue line describes the trade-off between the two outputs in the market. Its slope is equal to the (negative) of the ratio of output prices. Global profit maximization occurs at the most extreme product transformation curve where the value of the marginal product of each variable input in the production of each output is equal to the price of the variable input.

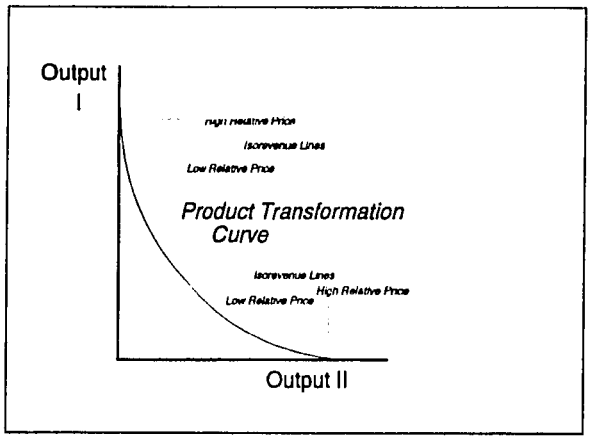


Figure 2. Convex-From Below Product Transformation Curve

Another possible shape of the PTC is illustrated in Figure 2. In this case, production of one more unit of Output I is accomplished by sacrificing decreasing amounts of the Output II. Optimum production in this case involves a 'corner solution': the producer will maximize profits by producing either only Output I or only Output II. The ranges of possible output price ratios necessary to bring about either of these case are illustrated by the high and low relative price isorevenue lines in the Figure.

The principal hypothesis of this study is that neither Figure 1 nor Figure 2 adequately describes the PTC for the parklands agroforestry system. Rather, the relevant curve is a hybrid such as that represented in Figure 3[4]. The production of trees and crop yields are interdependent but there is some range over which the land and associated variable inputs can and do produce more of both. It is beyond this range on the PTC that farmers in the parklands system operate (illustrated by the isorevenue lines). Because only a limited range of possibilities is 'rational', this production structure has important implications for the stability of the system. It also has implications for the role of the tree in the farmers' strategy to maintain soil fertility and the long-run future of the parklands.

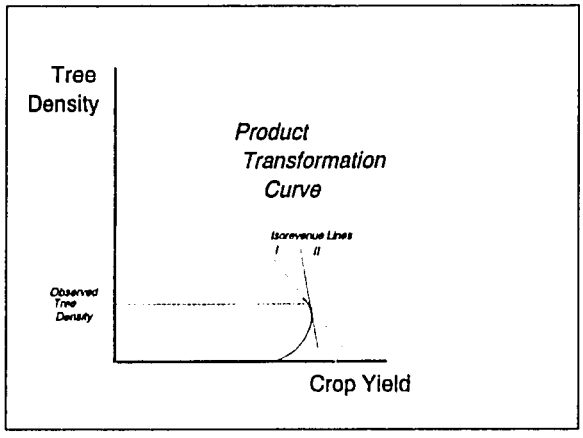
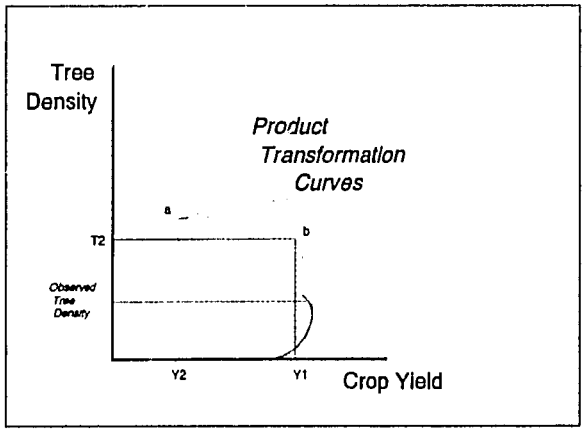


Figure 3. Hybrid Product Transformation Curve

[4]The actual shape of the PTC is unknown. Two possibilities are illustrated below. We argue for the shape illustrated in Figure 3 (a in the Figure below) for two main reasons. If the PTC were of shape (b), it would permit the production of crop yield Y1 with two tree densities – one very low and one very high (T2). Practically and conceptually, this is difficlt to accept. It seems more reasonable to expect that a doubling of t4rees would cut production by a substantial amount. Also, the (a)-shaped PTC explains rather well the observation that tree densities are rather static. As illustrated in Figure 3 above, virtually the same density would result for a wide range of relative tree and crop prices. If the (b)-shaped curve were relevant, one would expect to see densities increasing and decreasing over time in response to changes in relative prices.



III. METHODOLOGY

Production functions may be estimated from empirical data in order to assess the individual contribution (or productivity) of the variable inputs and other factors. Regression analysis using ordinary least squares (OLS) techniques is generally used for such analyses (see Dillon, 1977). As indicated above, however, a complication develops when more than one product emerges from the same production process. If, for example, two outputs result from the same production process, the joint production function may become:

$$Q_1 = f(Q_2, X_{11}, X_{12} .. X_{1n})$$

and,

$$Q_2 = f(Q_1, X_{21}, X_{22} .. X_{2n})$$

The production of one output (Q_1) depends on the production of the other output (Q_2) as well as a number of other factors (X_i). In this case one of the principal OLS assumptions is violated since the error terms in each equation are correlated with each of the endogenous variables. The use of OLS techniques results in 'least squares bias', the estimation of biased and inconsistent parameters incapable of identifying the underlying, production structure.

To estimate such simultaneous structural relationships, two-stage least squares (2SLS) procedures may be used. 2SLS procedures are used extensively in economics to sort out and estimate complex economic structure. 2SLS overcomes the correlated-error problem by substituting uncorrelated, estimated endogenous variables after the first stage of estimation. Resulting 2SLS estimators from the second stage are consistent and can be used to interpret underlying structure. In order for 2SLS procedures to appropriately identify structure, however, at least one unique variable for each of the equations must be included in the model. Such variables should be excluded from inclusion in both equations on theoretical grounds. This mechanism allows for the system of equations to be "identified" and for the 2SLS procedures to go forward. See Theil (1971) for a thorough discussion of 2SLS techniques.

The following model is hypothesized for the parklands cereal-tree production relationship:

$$Y = f(T, Tn, Age, Mi, A, C, B, Br, C1, Lp, At)$$
$$T = f(Y, Tn, Di, Age, Mi, C, B, Br, C1, Lp, At)$$

where,

Y = Expected yield/hectare of sorghum and millet
T = Tree density (Trees/hectare)
Tn = Tenure of parcel (1 = Inherited, 0 = Other)
Di = Distance of the parcel from the household
Age = Age of parcel (years).
Mi = Crop is millet (1 = yes, 0 = no)
A = Parcel area (Hectares)
C = Compound field (1 = yes, 0 = no)
B = Low land field (1 = yes, 0 = no)

Br = Bush field (1 = yes, 0 = no)
C1 = Farmer's socio-economic class 1 (1 = yes, 0 =no)
Lp = Permanent labor available (active persons)
At = Animal traction (1 = yes, 0 = no)

Cereal Yield Equation. Yields are expected to be influenced by tree densities as well as other factors. Since farmers are assumed to form expectations of yield based on past yield histories, expected yields are assumed to be a better indicator of long-run yields than the yields observed during the course of any given year and are retained for the model. It is considered essential that a long-run measure of yield be used since cereal yields in West Africa are notable for their wide fluctuations between years. This variability is caused by a variety of factors including rainfall and the use of a long-run measure of yield essentially allows the analysis to proceed while holding these factors at their mean, long-run values. Also, the tree density decision is inherently a complex, long-term problem for the farmer. Therefore long-run yields should be considered more appropriate for any analysis of the potential trade-offs between yields and the services of trees.

Other independent variables in the yield equation include the tenure 'dummy' variable. Inheritance is the most secure form of tenure and would be expected to exert a positive influence on expected yields since it is more likely that the benefits of any long-run improvement would accrue to the owners.

The age of the parcel (since it was last in 'bush') is one measure of soil fertility in the model. Age should exert a downward pressure on expected yields, all other factors held constant, as soil fertility decreases with time as the field is exploited.

The type of cereal (millet or sorghum) planted in the parcel is another measure of soil fertility. Millet and sorghum respond similarly to production factors but millet is generally planted on poorer soils. Consequently this variable should negatively affect expected yields.

The size of the parcel would be expected to negatively influence expected yields. A common empirical finding, the use of productive inputs by farmers per unit of land apparently decreases as the size of the parcel increases. Size is included in this equation but excluded from the tree density equation since there is no theoretical reason to expect parcel size to affect tree densities.

The types of parcels are also expected to exert an influence on expected yields vis-a-vis the 'village' fields used as the control. Low land fields, naturally more fertile with fewer water problems, and compound fields, located immediately next to the compound and benefitting from household wastes, are expected to have higher expected yields than village fields. Bush fields which are generally planted later and managed less intensively, should be less productive than the village control fields.

The socio-economic class of the farmer is expected to affect expected yields. The richest farmers (class 1) would presumably have more means to combat insect infestations and hire more help as needed and should, therefore, positively affect expected yields.

The availability of permanent labor for the exploitation is another 'wealth' variable and should positively affect expected yields.

Finally, animal traction should positively affect expected yields although the literature is not unanimous in this view (see, for example, Singh, 1988).

Tree Density Equation. The tree density equation includes the expected yield variable which should be positive if cereal yields and trees services are perceived to be complementary by the farmer, *at least over the ranges of tree numbers included in the study,* and negative if competitive. It is clear that at some density, yield and tree density must become competitive with gains in one occurring only as a result of reductions in the other.

Secure tenure (inheritance) is expected to positively influence tree densities to the extent that trees are seen to be a productive investment and the same ownership rights are transferred to the trees as to the land.

Distance should influence tree densities positively. The farther away from the household compound, the more trees one should expect to find. The distance variable is excluded from the yield equation since there is no theoretical reason to expect distance to affect yields.

The age of the parcel should negatively influence tree density. Unless definite strategies are in place to replace dead and dying trees over time, densities should decrease with age, all other things remaining constant.

The fertility of soil as measured by the millet variable should be positive if more trees are grown on poorer soil and negative if densities are higher on good soils.

The influence of type of parcel (compound, bush, low land) on tree densities is viewed as an empirical question without prior expectations concerning signs. It is reasonable to assume that the farmer has a strategy for each type of field and the role played by trees within that strategy will determine the sign.

The influence of the 'wealth' variables (class and permanent labor) are also difficult to specify a priori although to the extent trees provide normal goods and services, the signs should be positive.

The expected sign for animal traction is unambiguous. The presence of trees cause definite problems for those farmers with animal traction. These problems include the increasing difficulty of maneuvering around the field and the broken plows and other implement accidents which trees may occasion. The sign should be negative.

IV. STATISTICAL MODEL

The power or Cobb-Douglas functional form was chosen for the analysis. Linear functions were estimated but performed less efficiently than the power function with lower R-squares and levels of significance in every compound. Power functions have been used extensively in

production function estimation for a long time (see, for example, Heady and Dillon, 1961). The power function's multiplicative nature takes into account factor interactions and has the additional advantage of being able to directly yield coefficients which may be interpreted as production elasticities (percentage change in output given a percentage change in input). The fact that a power function never achieves a maximum is not thought to represent a problem for the present analysis since it is unlikely that a maximum value for a production function would ever be observed in the real world. The positive prices of inputs virtually assures that the economic maximum would be achieved before the physical, production function maximum. Consequently, over the range of data in this analysis, the power function can appropriately represent the true underlying production structure. A generalized power production function may be specified:

$$Q = b_o X_1^{b1} X_2^{b2} .. X_n^{bn}$$

where:

Q = quantity produced per unit of time and space
X = inputs (1..n)
b_i = parameters to be estimated

For estimation purposes, the linear version of the power function becomes:

$$\log Q = A_0 + b_1 \log X_1 + b_2 \log X_2 + . . + b_n \log X_n$$

where A_0 is the intercept term and all other symbols are as above. The estimated bis are individual production elasticities indicating (at mean input values) the percentage change in output resulting from a 1% change in that particular input. Care must be taken when interpreting the elasticities for the endogenous variables, however, since the normal assumption that everything else remains constant is untenable in this simultaneous case. The elasticities are strictly valid for only very small changes from mean levels.

Effects of 'Dummy Variables'. Qualitative variables usually enter the data as '0' or '1' indicating the absence or presence of the particular attribute associated with the observation. In the log formulation, '0' and '1' are replaced by '1' and 'e' which yield the same results after the natural logs of each variable are taken. The effect of a dummy variable is to act as a function intercept shifter, raising or lowering the entire production surface due to the effects of the qualitative variable. To prevent 'perfect' multicollinearity from developing due to the explicit inclusion of all categories of each qualitative variable, one category is omitted from each qualitative variable in the analysis. For example, if there are two variables possible to explain a qualitative situation (say, presence and absence of animal traction in a field), only one new variable is created (say, animal traction present) and may be coded '1' if there is animal traction and '0' if not. The effects of the omitted categories are said to be confounded with the effects of all other non-included variables implicit in the estimated equation's intercept term. Again, care must be taken in interpreting the elasticities of the dummy variables since they deal with large changes (all or nothing) rather than the small changes normally considered.

The Data. Survey data on farmer perceptions, activities and inputs were collected during the annual 'Farmer Strategy' survey of a random sample of farmers in two Central Plateau villages (Donsin, Thiougou) of Burkina Faso. Included in the survey were questions concerning farming practices on all fields of each exploitation. Additionally, farmers were asked to identify specific fields and were asked their latest actual and expected harvests of all crops (in local units) from these fields. Later, the fields were identified on aerial photography[5] (1:10,000) of the villages and were measured by planimeter to obtain area. Tree counts were also obtained from the aerial photography. The vast majority of the trees encountered were shea nut *(Butyrospermum paradoxum)*. Shrubs were omitted from the count. Yields were converted to kilo/hectare values. A total of 87 fields of millet and sorghum were retained for the analysis.

V. RESULTS AND DISCUSSION

Estimated Model. Table 1 presents the results of the analysis.

Table 1. Results of the Analysis (Two-Stage Least Squares Model)

Variable	Yield	Tree Density
Yield	-	0.51***
Tree Density	1.01***	-
Tenure	0.50	-0.13
Age	0.01	0.08
Parcel Area	-0.40***	-
Distance	-	0.25^
Millet (soil fert)	-0.71**	0.74***
Compound	1.53***	-1.34***
Low land	1.31**	-0.75^
Bush	0.72**	-0.57^
Socio-Econ Class	-0.22	0.24
Permanent Labor	0.23	-0.13
Animal Traction	0.83*	-1.07***
Constant	2.70***	0.98
R-Square (Adj)	0.34	0.43
n	87	87
F Statistic	5.07***	6.94***

Significance ^ 0.2, * 0.1, **0.05, ***0.01

[5]The photography used was unrectified. Unrectified aerial photos may significantly distort area estimates. To check for possible bias, field measurments of a small, representative sample of parcels were taken. Errors of less than 5% were found in every case.

The model indicates that tree density, parcel size, soil fertility and type of field are the primary variables which determine expected yields. The presence of animal traction also (positively) affects expected yields. Tree densities, in turn, are primarily determined by expected yields, soil fertility, type of field, distance and animal traction. In general, the results conform to expectations concerning variable importance and sign.

The yield equation indicates that there is a significant, positive and strong relationship between expected yield and tree density. It should be noted, however, that this relationship holds and is relevant for only the range of tree densities included in the study. The tree density equation also indicates a significant, positive relationship between tree densities expected yield. It is interesting to speculate on reasons why increasing expected yields might lead to higher tree densities. Within the ranges examined, if trees provide relatively higher volumes of organic matter and other positive influences per unit of (negative) shading and other effects, it may be that trees are perceived as being particularly important for maintaining soil fertility within the field. Consequently, the management of trees becomes a major long-run strategy for managing soil fertility.

Somewhat unexpectantly, tenure and age of parcel variables are not significant in either equation. Tenure has the expected sign in the yield equation but is not significant. Its sign in the tree density equation is negative but also not significant. Age of parcel is positive but not significant in both equations. Apparently, expected yields and tree densities are not declining over time, all other factors held constant. This surprising finding is perhaps the best evidence provided by this study that parkland farmers have a long-run tree and yield strategy in place and that, at least up until now, it has been sustainable.

The parcel size and distance variables, the two variables which appear in only one equation on theoretical grounds to allow and model identification, are both significant and of the expected sign within their respective equations. Expected yields decrease as the size of parcel increases and tree densities increase with distance from the household compound.

The soil fertility variable (millet) is highly significant in both equations. As expected, poorer (millet) soil leads to decreased expected yields. Also, poorer soils lead to higher tree densities. The type of field contributes positively and significantly to expected yield. In particular, the relatively fertile compound and low land fields contribute strongly to expected yield in the model. Somewhat surprisingly, the bush fields also contribute positively to expected yield. Perhaps the improving soil fertility characteristics of adjacent fallow fields causes some positive spill-over effects. Also, uncontrolled-for shrubs may positively affect expected yields. The indicated yield effects are relative to village fields used as the control.

The type of field also contributes negatively and significantly to tree densities. The farmers' apparent strategy to use the compound and low land fields more intensively militates against greater tree densities. Bush fields are populated with young trees more likely to be classified as shrubs using our methodology and also have a negative sign.

Socio-economic class 1 is insignificant in both equations. Permanent labor is also insignificant. Apparently, wealth is not an important factor in either of the equations.

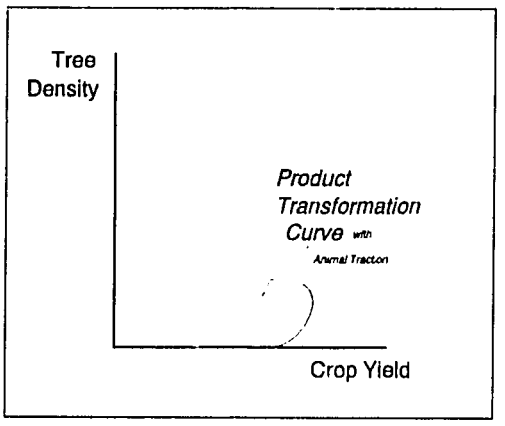


Figure 4. Shift in Product Transformation Curve due to Adoption of Animal Traction

Animal traction is important in both equations. As expected, it is especially important in determining tree densities. Given the nature of the PTC hypothesized and supported in this study, a situation such as that presented in Figure 4 may be occurring. Adoption of animal traction fundamentally alters the nature of the production function: the (at least) short-run benefits of trees are more than offset by the negative effects of trees. Consequently, the relevant PTC shifts partially downward, making possible slightly higher yields in the short-run but lowering the new optimum tree density. Over time, the curve may shift all the way down to the crop axis, causing only crops to be produced[6]. If, in fact this is happening as more and more farmers adopt animal traction, it would have the most important consequences for the long-run soil fertility and future of farmed parklands in West Africa.

VI. CONCLUSIONS AND IMPLICATIONS FOR FURTHER RESEARCH

Contrary to previous evidence, this study has found a strong positive relationship between tree densities and cereal yield on West Africa's farmed parklands. This analysis differs from previous studies in two principal ways: expected (long-run) yields rather than short-term yields are used and the effects of trees on entire field rather than limited areas near trees are considered. The analysis uses expected yield rather than the actual yield in any given year because tree density decisions are seen as inherently long-run in nature. Because expected yields are assumed to be closer to true, long-run average yields than are the yields in any given year, expected yields are better indicators of the perceived potential trade-offs between yields and tree densities. The use of expected yields has the effect of holding variation inducing variables (such as rainfall, pest incidence, etc.,) at their long-run, average expected values. The use of expected yields for entire fields also recognizes the fact that trees may have influence well beyond the arbitrary distance limits imposed by previous researchers.

The results of this study suggests that a long-run farmer strategy to manage the productivity of parklands is in place. This strategy apparently involves the management of tree densities as at least one factor in managing overall soil fertility. The fact that the age of field variable was insignificant suggests this strategy, up to this point at least, has been sustainable.

[6]This would be especially be the case if motorized traction were to used.

The most important finding of this research for the continued sustainability of the parklands system is that for animal traction. By official design but also of perceived necessity, the use of animal traction is spreading throughout West Africa. This study suggests that as this trend continues to occur, tree densities on parklands will decrease significantly. Whether this leads to an absolute reduction in tree numbers or a redistribution of tree numbers to higher density woodlands remains to be seen. If this study is correct, however, it is certain that the crucial soil fertility role played by trees within the parklands system will have to be replaced by something else or long-run yields will decrease.

Further Research. The results and conclusions presented in this study are necessarily tentative since, although dealing with long-run concepts, they concern only one year's data and a relatively small sample. Further analyses will have to await data from surveys in future years. Meanwhile, some data gathering procedures will be refined: for example, tree species data will be gathered and more field visits will be made. Also, concurrent surveys specifically designed to investigate the socio-economic role of trees within the RSP village farming systems will be undertaken. Additionally, complementary research on the technical soil fertility effects of trees should help to test further the results of this study.

Finally, if the results of this study are confirmed by additional research, traditional thematic research programs will also have to get involved. In particular, agroforestry and animal traction specialists will need to investigate alternative technologies and tree alignment possibilities to minimize the negative aspects of animal traction on tree densities within the parklands in the future.

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Economic Analysis of Some Activities of Women Linked to the Use of Non-Woody Products of Local Forest in the South West of Burkina

A. Sidibé

I. INTRODUCTION

Since 1987, certain nations and international organizations, notably the World Bank, have chosen to prioritize action to be taken to consolidate the participation of women in development efforts of African countries. Indeed, the significance of the role of women in the rural development process merits particular attention. Their role is not only crucial to agricultural activities but also to non-agricultural areas, where women constitute approximately 60% of the workforce. (World Bank, 1988)

In many cases it is the women who are responsible for producing 80% of food supplies, yet they receive scarcely 10% of the revenue (Ismail 1989). Statistics, despite their imprecision and weaknesses, do show that poverty is most acute among women and children. In Africa, it appears that women have a crucial role to play in development, which cannot proceed without their full participation.

As far as non-agricultural activities are concerned, it is known that non-ligneous products from local forest species provide a source of revenue and food in rural areas and that they are generally produced by women. What is not known is quantitatively how great a role is played by these products in providing food security for rural farm households.

The object of this study is to evaluate how much non-ligneous products of local forest species contribute to women's incomes and to family food supplies.

The results from the study are anticipated to be in several categories, including:

- Identification of activities able to benefit easily from state support or from certain organizations within the framework of the promotion of women's activities, improvement of women's living and working conditions by facilitating, among other things, their access to production factors and to credit designated for agricultural and non-agricultural activities;

- The protection and reproduction of species utilized by the rural populations by stimulating the consumption of agroforestry products;

- Identification of researchable topics concerning these products.

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II. METHODOLOGY

The site chosen for this study is the village of Yasso, in the province of the Kossi, Burkina Faso. Yasso is one of the four research sites of the western team of the Production Systems Research Program (RSP) of the Burkinabé INERA (Agricultural Study and Research Institute - l'Institut d'Etudes et de Recherches Agricoles). Yasso is a site which is representative of a well-equipped, cotton-producing zone, of the Western Zone. This translates into a relatively high income for farms, by comparison with other regions in Burkina, taking into account the importance of cotton production, as Burkina Faso's main agricultural export. The infrastructure and research technicians already in the field enabled us to conduct our surveys with ease.

Of a population of 287 farms which make up the site, 25% were selected for the sample i.e. 71 farms. Some 170 women from these farms were involved in the survey. A questionnaire was used to collect data on the profitability of their activities , their ethnic group and religious affiliation.

Another questionnaire focused on the costs and revenues of production of the principal non-woody products. This questionnaire was used with three women for each major product made from local species and produced for sale. The data was supplemented by a survey in the local market on the price of products involved. In this way budgets were constructed for the principal activities and rates of return calculated.

III. RESULTS

Identifiction of activities. Table 1 gives the breakdown of women's activities according to their importance. It is clear from this table that activities associated with non-ligneous products from local species/resources? are important. Also observes that about 30% of the women interviewed are involved in preparing Shea butter . The preparation of soap made with a base of shea-nut butter comes second on the list, employing/keeping busy about 10% of these women, whereas only 4% of women are involved in the preparation of *Soumbala*, which uses seed from the *Néré* tree. The preparation of the sorrel (*hibiscus sabdaroffa)* flavoring commonly called "datou" is also an important activity, which employs 3% of the women.

Table 1. Classification of the activities of women in Yasso.

Activity	Percentage	Resources
Shea butter	29	Local species
Soap making	10	Local species
Dolo	9	crops
Cowpea fritter	7	crops
Sale of agricultural products/crops?	6	crops
Fruit sales	6	exotic species
Sales of various foodstuffs	5	various
Spinning	4	crops
Preparation of soumbala	4	Local species
Wheat fritter/?doughnut	3	Imported inputs

Sorrel Aroma	3	Crops
Pottery	3	Clay
Galette	3	Crops
Drink	2	Livestock
Milk vendor	1	product
Other	5	other
Subtotals by resource:		
Non-ligneous species	43	
Crops	32	
Exotic non-ligneous species		
Miscellaneous	5	
Imports	5	
Land	3	
Livestock Raising	1	
Other	5	
Total	100	

ESTIMATED REMUNERATION RATES:

1. Shea butter

Approximately 30% of the women were kept busy preparing shea butter. Shea nuts are gathered and stored in cylindrical pits during the production period. The pits have an average volume of about 1.68 cubic meters, an amount which yields after processing about 10 *tines* of kernels. From the kernels, the process of producing shea nut butter takes about 72 hours from start to finish. About 70% of the women who produce the butter, only do so for their own consumption. The remaining 30% keep half of the butter, and sell the rest. It is notable that the biggest shea nut butter producers are those who are also involved in other activities and who use the butter as an intermediate food product to minimize the production costs. These include, for example, fritter sellers, or vendors of soap.

Analysis of the profitability of Shea butter production. From the table it is clear that the net profit from making shea butter is 408 Fcfa for each preparation. Producers of shea nut butter earn around 41 Fcfa per hour. This sum is higher than paid for agricultural work, especially from cotton farming which is around 31 Fcfa per hour. These estimates are based on the work of Faure (1992).

The rate of return for preparing shea nut butter is positive and estimated at 196%.
De boer (1991) found that in Niger, rural activities with small investment had very high remuneration, going up as high as 1000%. On the other hand, activities associated with higher investment were those associated with the lowest remuneration rates.

This relatively low rate can be explained by the price of shea butter at the producer level. The shea butter is a staple. However, the weakness of income in rural areas limits the buying power of producers, who are obliged to be as self-sufficient as possible. Thus about 30% of farms produce

their own butter. This self-sufficiency in shea nut butter reduces market demand and limits the price level.

Another, complementary reason is that the production is primarily destined for consumption. Sales respond, in general, to a need for cash, so much so that the prices do not always relect the production value.

Investment involved in the preparation of shea butter.

Investment	Cost
Mortar	1500
Cooking-pot	7500
Earthenwar jar	1500
Working capital	
Tine of Sheanuts	350
Total	10850

Budget for one preparation of shea butter.

Item	Unit	Quantity	Price	Sum-Cost
Gross Revenue	Fcfa			950
Cash Cost				350
Shea nuts	*Tine*	1	350	350
Net Cash Income	Fcfa			600
Labor[1]	Hour			
- preparation	Hour	6.5	10	65
- sales	Hour	7	10	70
- wood	Hour	1	10	10
Cash Income per hour	Fcfa/Hour			41
Depreciation[2]	Fcfa			
- Mortar	Fcfa	1500	0.0026	4
- Cooking pot	Fcfa	7500	0.0019	14
- Earthenware jar	Fcfa	1500	0.0192	29
Net Profit per preparation	Fcfa			408
Annual rate of return[3]	Fcfa			196%

2. Soap Preparation

[1] The opportunity cost of labor was estimated on the basis of an average of women's pay , notably during harvesting. This is 10 Fcfa per hour of work

[2] This is a straightline depreciation of the equipment which is used once a week, or 52 times per year. The equipment is expected to last as follows: 8 years for the mortar; 10 years for the aluminium cooking pot, and one year for the earthenware jar.

[3] The annual remuneration rate is calculated as the net profit per year, divided by the sum of the value of the equipment and the working capital.

Fewer women are involved in soap making than in shea nut butter preparation, in fact approximately 10% of Yasso women are involved in soap making. According to the results of the study, 70% of these women were producing soap solely for their own use, whereas the remaining 30% have turned soap-making into a commercial activity. Soap making is a specialty of certain ethnic groups, notably of the Dogon who constitute about 5% of the total population.

Analysis of the profitability of Soap-making. According to Table 2, the net profit for soap preparation is more than shea butter, estimated as being 480 Fcfa per preparation. This yields an annual rate of return of 428%, double the rate for shea butter.

The net difference between these rates of return is to be explained by the intensity of work required in making shea butter,. This is why the income per hour of work preparing soap is higher (54 Fcfa per hour) than for making shea butter (41Fcfa per hour).
The economies of scale are another reason for this difference. The frequency of soap making is once a week in the dry season and twice a week in the dry* season. Shea nut butter is only prepared once a week.

Investment for one preparation of soap.

Investment	Cost
Earthenware jar	7500
Working capital	
Sheanuts	350
Potash	450
Total	8300

Budget for the preparation of soap.

Item	Unit	Quantity	Price	Sum
Sales				1350
Home consumption by producer				50
Total gross income				1400
Cash cost				800
- Shea nuts	*tine*	1	350	350
- Potash	*tine*	1	450	450
Net cash income				600
Labor				110
- Preparation	Hour	2	10	20
- Sales	Hour	7	10	70
- Wood	Hour	2	10	20
Cash income per hour	Fcfa/hour			54
Depreciation of equipment:				
Aluminum cooking-pot	Fcfa	7500	0.0013	10
Net profit per preparation	Fcfa			480
Annual rate of return	Fcfa			428%

One of the limiting factors to soap production mentioned by the women concerns the availability of potash. In fact, potash and shea butter are the principal intermediate products utilized in the

preparation of soap. The scarcity of solid, concentrated potash obliges the women to produce their own liquid potash from ash that they buy at the market. It is certain that the production of this ash involves using a substantial quantity of firewood.

3. *Soumbala* preparation

Soumbala is a local food flavoring prepared from *néré* tree seeds. According to our survey, 4% of the village women are engaged in preparing *soumbala*.

Of the three activities considered, *soumbala* is the one which:

- Brings in the highest cash income per preparation (750 Fcfa, compared with 600 Fcfa for the shea nut butter and the soap);
- has the highest rate of return (461%, compared with 196% for sheabutter and 428% for the soap); which has the highest net profit per preparation (529 Fcfa compared with 480 Fcfa for the soap and 408 Fcfa for shea butter);
- but which has the lowest income per hour of work (36 Fcfa as opposed to 54 Fcfa and 41 Fcfa for the soap and shea butter, respectively.

These levels (net cash income, income per hour, net profit and rate of return) can be explained in the following way:

The relatively high level of monetary income involved should substantially affect the net profit, due to the intensive labor required. However, the low level of opportunity cost of labor (10 Fcfa) nullifies this.

The level of investment is almost identical for the other activities, resulting in a higher rate of return.

This level of profitability of *soumbala* production is linked to demand. More than with the other two products, *soumbala* is largely destined to satisfy urban demand.

Investment for one preparation of *Soumbala.*

Investment	Cost
Cooking pot	7500
Working capital	
Néré seeds	1000
Total	8500

Budget for one preparation of Soumbala.

Item	Unit(s)	Quantity	Price	Amount
Sales				1500
Home consumption				250
Total gross revenue				1750
Cash Cost of Nere seed	Pamore	4	250	1000
Monetary income				
Labor				
Preparation	Hour	10	10	100
Washing	Hour	0.5	10	5
Preparation again	Hour	1	10	10
Drying	Hour	0.30	10	3
Making into ball	Hour	0.30	10	3
Sales	Hour	7	10	70
Wood	Hour	10	10	20
Net Cash Income per hour	Fcfa/hour			
Depreciation:				
-Aluminium Cooking-pot	Fcfa	7500	0.0013	10
Net profit from the soumbala: preparation	Fcfa			529
Annual profitability rate				461%

In certain areas of Burkina, the profitability is increased by the relatively high price of *soumbala*. This is the case, for example in Thiougou (in the province of Zoudweogo) where Lowenberg De Boer (1992) found an annual rate of return around 2000% with a net profit per preparation of about 1500 Fcfa.

It should be noted, however, that the *soumbala* has stong competition in urban areas, for the important flavorings that have taken an important part of the market to the detriment of this product.

IV. CONCLUSION

The survey conducting an economic analysis of the use of non-ligneous products of local forest species led to the following conclusions. Firstly, that these activities are financially profitable. Of all the activities subject to this economic analysis, i.e. the preparation of shea butter, soap and *soumbala*, the latter appeared to be the most profitable activity.

The results of the survey show that the zone studied is characterized by a micro-economy which imposes a strategy of home production and home consumption. This translates into an economic environment characterized by low income, especially among women, which diminishes the level of effective demand.

The profitability of women's activities could be improved by increasing the income by improving productivity, by specializing and by improving the product quality.

Specialization aims to increase the level of effective demand.

Improvements in productivity and product quality would have the objective of improving the quality-price ratio of products in order to be competitive.

These objectives can only be attained by taking action in the form of providing training, and facilitating access to factors of production, as well as to a credit system.

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Establishment and management of karité (Vitellaria paradoxa) parklands in Sudanian Burkina Faso[1]

Boffa J. -M., L. Lompo and D. M. Knudson

ABSTRACT

Tree management during establishment and development of agroforestry parklands as well as farmer perceptions were studied through field inventories and interviews in Thiougou, a village of Southeastern Burkina Faso. Parklands result from drastic changes in tree diameter distribution, and species richness and density of the original woody vegetation. Slight declining density, rising dominance of a few species and increasing average tree diameter characterize developing parklands. As a central process in karité parkland development, fallow contributes to rejuvenate tree populations and broaden species richness, yet a lower species diversity in fallowed fields than in new fields is favored by farmers. Fallow history and field age are reflected in diameter class distributions. The number of trees and species per unit area were higher in fields of female farmers than in family fields. Original karité density, method of field cultivation, soil mapping type and farmer preception of the effect of trees on crop production affected parkland tree density. This study provides evidence that parklands are actively and deliberately managed by farmers through successive cultivation and fallow intervals and opens avenues of further research to better understand the management of this agroforestry system.

I. INTRODUCTION

In Sudano-Sahelian Africa, crops are often grown under a discontinuous cover of scattered trees. This agroforestry landscape, called farmed parkland is defined by the regular occurrence of well-grown trees scattered through cultivated or recently fallowed fields (Pullan 1974). Trees are associated to the cropping environment due to their numerous significant physical (food, fodder, fuel and construction wood, medicinal products, crafts, etc.) and qualitative roles (shade, climate moderation, soil fertility, landmark).

Origins and dynamics of parklands have been studied from various perspectives. Gallais (1967) identified limited, extended or distended parklands from a spatial perspective. A functional classification was established by Seignobos (1982). Pélissier (1964) classified them according to the degree of their similarity to the original uncultivated vegetation. There are residual, selected, constructed or planted parklands. Parkland structure and composition are closely related to human density and settlement patterns, and, agricultural land use and management practices (Pullan, 1974; Raison, 1988).

[1] A preliminary and partial version of this paper was presented at the International Symposium on Agroforestry Parklands in the Semi-Arid Lands of West Africa in Ouagadougou, Burkina Faso, 25-27 October 1993 (Boffa et al. 1993).

Parkland composition is usually dominated by one or a few species of particular importance to the local agricultural system and economy. *Acacia albida* parklands, probably the most studied African parklands, are generally found among sedentary livestock-raising communities on permanently cultivated fields. The nutritional forage of this species, its nitrogen-fixing capacity and reverse foliation makes its association with agriculture particularly suitable. In contrast, karité (*Vitellaria paradoxa*) parklands have been less studied. They occur among cultivator ethnic groups which traditionally did not raise cattle and their development relies on the alternation of cropping and fallow periods (Agbahungba and Depommier, 1989).

As other productive resources of their agricultural system, farmers manage trees intentionally and rationally in order to optimize production. The productivity of the agricultural and silvicultural components of the system and the nature of their interaction, as well as farmers' perceptions of these are likely to influence their parkland management decisions. The karité-sorghum interface and karité nut productivity have also been investigated and are reported elsewhere (Boffa *et al.*, 1995a, 1995b).

While research has focused on the description and comparison of parklands, their historical development and geographical distribution at the village or regional levels, a relative lack of interest in the practices and strategies of farmers as actors of parkland management has been reported (Serpantie, 1993). Also, limited quantitative data is currently available on parkland management and characteristics.

The objectives of this study are:

- to assess woody vegetation changes resulting from parkland establishment,
- to identify farmer practices and strategies of tree management, and,
- to identify farm attributes and farmer perceptions which influence parkland management

II. STUDY AREA

This study was conducted in the village of Thiougou, located between 11(29' and 11(24' latitude N and 0(49' and 0(54' longitude W 110 kilometers southeast of the capital city, in the Zoundwéogo Province, Burkina Faso (Figure 1). Thiougou is the village with least advanced natural resource degradation among the three research villages of the Farming Systems Research Program (RSP) of the Institut d'Etudes et de Recherches Agricoles in Burkina Faso's Central Plateau. The village extends on approximately 8500 ha including an agricultural area cultivated by Mossi farmers in the North as well as a zone to the South of the village used by Fulani pastoralists settled in the last twenty years who represent 15% of the total population. Average rainfall in Manga[2] is 723 mm/year and was 805 mm/year in Thiougou between 1990 and 1993. The village is composed of 249 production units, 60% of which use animal traction (RSP, 1991).

[2]Post-1969. For West African sites, rainfall means including post-1969 data are considered a better indicator of current rainfall expectations than means including pre-1970 data. This is because a relatively rainy period of what appears to be a long-term climate cycle came to an end in about 1969. Post-1969 means for RSP villages are from 150 to 200 mm less than means for pre-1970 data.

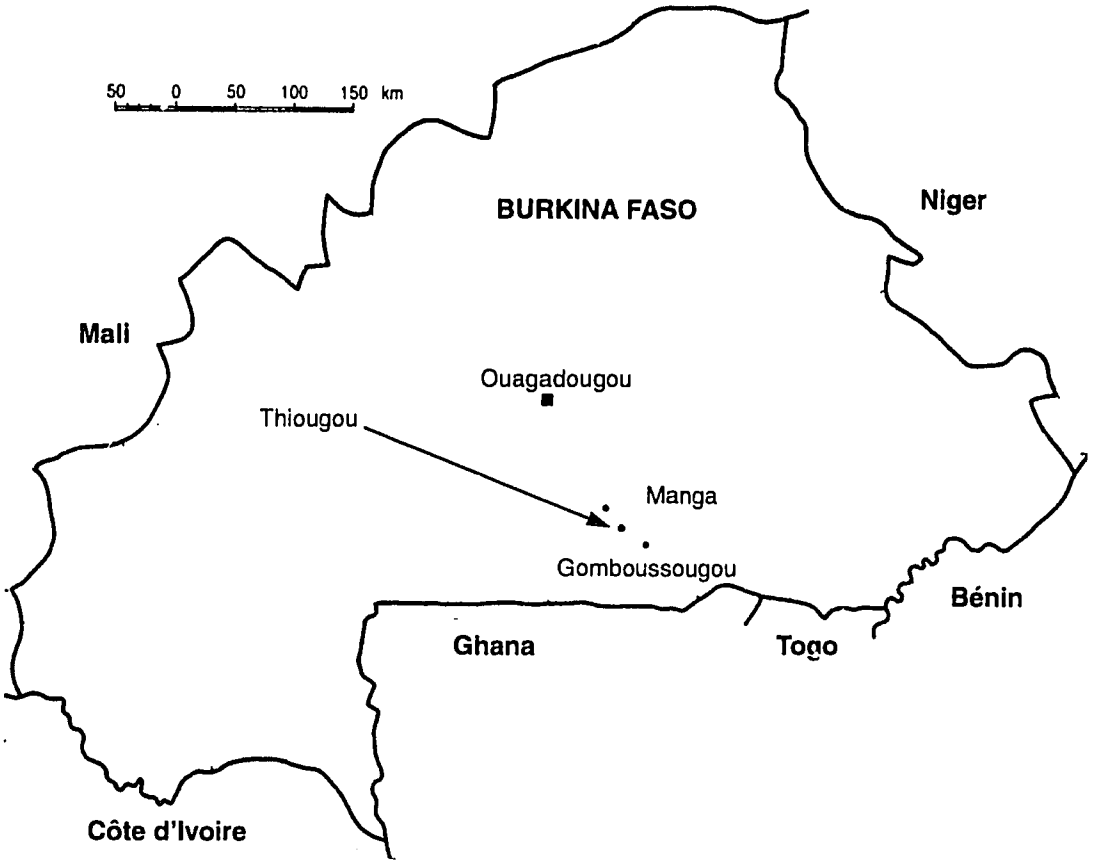

Figure 1. Location of research site

Main crops are sorghum, millet, peanuts, cowpeas, maize and secondary crops include earth peas, rice, cotton and sesame in order of frequency in farmers'fields. Sorghum is often grown in association with millet, and also with cowpeas or peanuts. An intensive agricultural system including continuous cropping and the application of manure, crop residues and household refuse is practiced on village fields located in the proximity of residential compounds. Tree cover in village fields is scarce and includes mostly *Adansonia digitata* and planted species such as *Mangifera indica, Azadirachta indica, Cassia siamea* and *Eucalyptus camaldulensis.*

In contrast, a more extensive agriculture is practiced in bush fields located up to several kilometers from farmer's residence where soil fertility restoration is based on long fallows. Often, parkland development is most elaborate in bush fields.

III. MAIN TREE SPECIES

The karité or sheanut tree is part of the Sapotaceae family under the accepted name *Vitellaria paradoxa C.F. Gaertn.*, after having been also called *Butyrospermum paradoxum Gaertn. f.* (Henry *et al.*, 1983). It is a widely encountered tree in Sudanian savannas, occurring on an estimated 1 million km^2 between western Senegal to northwestern Uganda where annual rainfall ranges between 500 and 1200 mm (Sallé et al., 1991). It occurs on different soil types

such as sandy clays, sands, stony soils and laterites but not in alluvial hollows or land subject to flooding. A fat is extracted from its nuts and processed into shea butter which is extensively used locally for cooking. Shea nuts are also the third most important export product in Burkina Faso after cotton and livestock. Karité trees are mid-size trees; they grow slowly and start producing fruits after 12 to 15 years but offer optimal yield after 30 years or more. Individuals over 150 years of age have often been reported.

IV. METHODOLOGY

Field sampling

The boundaries of all fields located in the main agricultural sections of the village were identified on the ground with local informants and mapped on 1:10,000 enlargements of 1:20,000 post-harvest aerial photographs of the village from the previous year. Field owners were also recorded. A random sample of 68 fields representing 208 ha and belonging to 65 farmers was selected. Male farmers were primarily heads of farming units (chefs d'exploitation). Farmers often clear a piece of land to which they attach adjacent additional tracts as they feel a need for it with time (Figure 2). Hundred and fifty such single-aged field sections were identified in the 68 sample fields. A physiographic map based on an extensive soil survey in the village (Guillobez and Taonda, 1993) was used to assign a soil mapping type to each field. Distance between field and residence was also calculated.

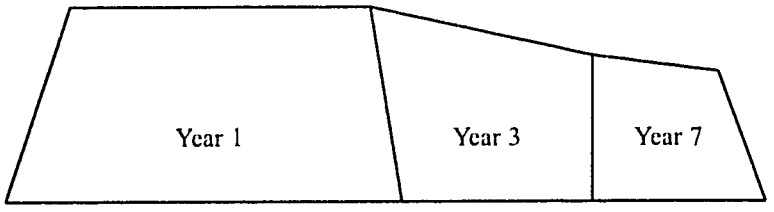

Figure 2. Example of a field made up of 3 single-aged sections cleared on various years

Tree mensuration

All trees in each field section were censused. Species, diameter at breast height, crown diameter in the East-West and North-South directions through vertical projection were recorded for every tree. Species were identified with the aid of plant identification handbooks (Geerling, 1987; Maydell, 1983). The number of pruned branches was also recorded on every other tree. Additionally, nine fields cleared during the year of the study and the previous one were surveyed for karité stumps with farmers and reasons for cutting them were investigated.

Measurement of surface areas

Surface area of field sections was planimetered from field maps. Fields cleared during the year of the study, which did not appear on the aerial photographs was surveyed on the ground using a compass, a 50 meter tape and a rod.

Census of natural bush plots

In order to compare parkland characteristics to those of the natural vegetation, one to eight 900 m^2 square bush plots adjacent to every sample field on similar toposequence were inventoried. Quadrats were located at 50 and 100 m on transects perpendicular to field edge when at all possible. Total surface area for the 130 quadrats is 11.7 ha. Species and diameter above 2.5 cm were recorded. The number of shoots under 2.5 cm in diameter at breast height of every species present was also counted. Only the largest stem of individuals with multiple branches was measured.

Farmer survey

Data on farm characteristics were collected during several village assemblies and individual interviews with a 30-item open-ended questionnaire delivered to all farmers in the sample. Variables included duration of most recent and previous field cultivation and fallow cycles, cultivation method, farmer classification of soil texture, field topography, land tenure, number of active family labor, number of wives and farmer gender. Questions elicited farmer opinions on the effect of trees on crop performance and tree management.

V. RESULTS AND DISCUSSION

1. Structural characteristics of Thiougou's parklands

Thiougou is located between the watersheds of the Nazinon (Red Volta) river to the South and the Nakambe (White Volta) river to the North. Onchocerciasis (river blindness), a series of epidemics in the 1940's preceded by nineteenth century slave raiding and warfare contributed to the lack of extensive settlement in this area (McMillan *et al.*, 1990). Over fifty percent of the sample fields have been created on land never cultivated before[3], which indicates that Thiougou's lands have been subject to agricultural activities only recently. They are part of a zone of cultivated area expansion located to the south of Thiougou's settlement area, This study, therefore illustrates the early phases of parkland establishment.

Average field cultivation time in the sample is 5.8 years, when considering only the most recent cultivation interval, while average duration of fallow is 5.6 years. A total of 74 woody species were encountered either in fields or in adjacent uncultivated areas of the study (Table 1). General characteristics of tree cover in farmer fields are presented in Table 2.

[3]Regardless of how long they have been cultivated, these fields are referred to as new fields, as opposed to fallowed fields, which have been subject to an earlier period of cultivation.

Table 1: List of woody species encountered in Thiougou, Southeastern Burkina Faso

Species	Family	Species	Family
Acacia dudgeoni	Mimosaceae	*Heeria insignis*	Anacardiaceae
Acacia gourmaensis	Mimosaceae	*Hymenocardia acida*	Euphorbiaceae
Acacia raddiana	Mimosaceae	*Isoberlinia doka*	Caesalpinaceae
Acacia seyal	Mimosaceae	*Khaya senegalensis*	Meliaceae
Adansonia digitata	Bombacaceae	*Lannea acida*	Anacardiaceae
Afrormosia laxiflora	Papillonaceae	*Lannea microcarpa*	Anacardiaceae
Albizia chevalieri	Mimosaceae	*Lannea velutina*	Anacardiaceae
Annona senegalensis	Annonaceae	*Maytenus senegalensis*	Celastraceae
Anogeissus leiocarpus	Combretaceae	*Mitragyna inermis*	Rubiaceae
Balanites aegyptiaca	Balanitaceae	*Nauclea latifolia*	Rubiaceae
Bombax costatum	Bombacaceae	*Ostryoderris stuhlmannii*	Papilionaceae
Burkea africana	Caesalpinaceae	*Parinari curatellifolia*	Chrysobalanaceae
Cassia sieberiana	Caesalpinaceae	*Parkia biglobosa*	Mimosaceae
Combretum glutinosum	Combretaceae	*Piliostigma reticulatum*	Caesalpinaceae
Combretum micranthum	Combretaceae	*Piliostigma thonningii*	Caesalpinaceae
Combretum molle	Combretaceae	*Prosopis africana*	Mimosaceae
Combretum nigricans	Combretaceae	*Pseudocedrela kotschyi*	Meliaceae
Combretum velutina	Combretaceae	*Pteleopsis suberosa*	Combretaceae
Crossopteryx febrifuga	Rubiaceae	*Pterocarpus erinaceus*	Papilionaceae
Daniella olivieri	Caesalpinaceae	*Sclerocarya birrea*	Anacardiaceae
Desmodium laxiflorum	Papilionaceae	*Securidaca longipedonculata*	Polygalaceae
Detarium microcarpum	Caesalpinaceae	*Securinega virosa*	Euphorbiaceae
Dicrostachys glomerata	Mimosaceae	*Sterculia setigera*	Sterculiaceae
Diospyros mespiliformis	Ebenaceae	*Stereospermum kunthianum*	Bignoniaceae
Entada africana	Mimosaceae	*Strychnos inocua*	Loganiaceae
Erythrina senegalensis	Papilionaceae	*Strychnos spinosa*	Loganiaceae
Febrifugum sp.	Unidentified	*Swartzia madagascariensis*	Caesalpinaceae
Feretia apodanthera	Rubiaceae	*Tamarindus indica*	Caesalpinaceae
Ficus gnaphalocarpa	Moraceae	*Terminalia avicennioides*	Combretaceae
Ficus platiphylla	Moraceae	*Terminalia macroptera*	Combretaceae
Gardenia erubescens	Rubiaceae	*Trichilia roka*	Meliaceae
Gardenia laxiflora	Rubiaceae	*Vitellaria paradoxa*	Sapotaceae
Gardenia sokotensis	Rubiaceae	*Vitex diversifolia*	Verbenaceae
Gardenia ternifolia	Rubiaceae	*Vitex doniana*	Verbenaceae
Grewia bicolor	Tiliaceae	*Ximenia americana*	Olacaceae
Grewia mollis	Tiliaceae	*Ziziphus mauritiana*	Rhamnaceae
Guiera senegalensis	Combretaceae	*Ziziphus mucronata*	Rhamnaceae

Table 2: Mean and range of parkland description variables in 68 farmer fields

Variables	Mean	Range
Tree density (trees/ha)	26.5	5-62
Species richness	6.1	1-16
Percentage of karité (%)	82	25-100
Crown cover (%)	4.7	1.32-12.5
Basal area per hectare (m2/ha)	3.33	0.3-13.2
Mean karité diameter* (cm)	22.2	12.0-43.4
Diameter of largest karité individual (cm)	42.1	21-102
Diameter of smallest karité individual (cm)	10.4	2.7-42.2
Standard deviation of karité diameter (cm)	7.4	1.7-15

*Diameter at breast height

The diameter distribution of the sheanut tree sample population (3975 trees) in crop fields presented in Figure 3 shows that 60% of sheanut trees have a diameter at breast height ranging

from 10 to 25 cm. This is in contrast to earlier descriptions of well-established parklands such as those in the Korrhogo area with 42% of tree diameters over 50 cm (Ruyssen, 1957) and shows that Thiougou's parklands have been in existence for a relatively short time. Figure 4 shows that karité populations in uncultivated conditions are characterized by smaller diameters than those in crop fields, which are positively influenced by reduced plant competition and protection from annual bush fires. Most karités of diameter higher than 35 cm inventoried in bush quadrats are found in areas cultivated before which are now under fallow. No time data was obtained on these fallows.

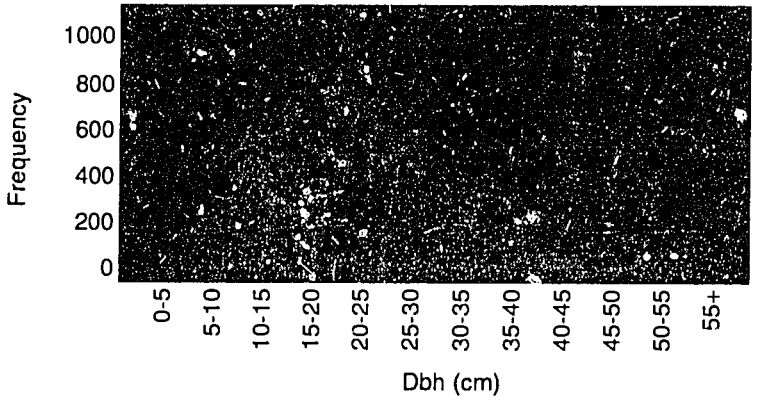

Figure 3. Karité size class distribution in farmers' fields

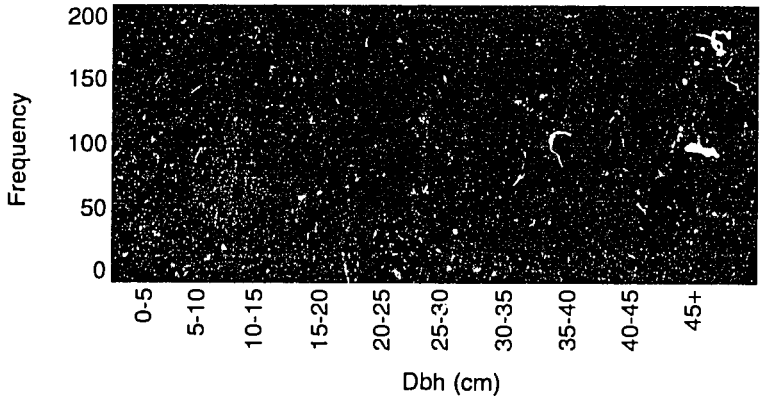

Figure 4. Karité diameter distribution in uncultivated land adjacent to crop fields

2. Farmer management of woody vegetation for parkland establishment

Parklands are the product of drastic changes in species richness and density of the original woody vegetation. In this study, 46 and 64 woody species respectively were identified in the total sample of cultivated fields and adjacent bush quadrats. Seedlings (dbh<2.5 cm) of an

additional 5 species *(Acacia raddiana, Cassia sieberiana, Febrifugum sp., Trichilia roka, Ziziphus mauritiana)* were found in bush quadrats. As a comparison, Bernard and Peltier (1994) and Gijsbers et al. (1994) found 46 and 43 parkland species in Northern Côte-d'Ivoire and in the Northern part of Burkina Faso's Central Plateau, respectively.

Species abundance, density and frequency in agricultural fields and adjacent uncultivated bush quadrats are grouped according to the ratio of observed densities in fields and adjacent bush plots and presented in order of frequency in fields in Table 3. Five groups of species are identified. Density and frequency ratios are calculated as mere indicators of species dynamics during parkland establishment.

The first group includes 26 species occurring at a relatively similar range of densities in fields and adjacent uncultivated bushland. It also includes most of the frequent parkland species. Sub-table 1 indicates that Vitellaria paradoxa alone, and with seven additional species, namely *Parkia biglobosa, Detarium microcarpum, Lannea acida, Bombax costatum, Pterocarpus erinaceus, Afrormosia laxiflora,* and *Lannea microcarpa* represent over 83% and 94% of the total sample population, respectively. The remaining 38 parkland species make up only less than 6% of the parkland tree sample population. Thiougou's parklands are therefore strongly dominated by karité and there are only few other frequent parkland species. In Northern Côte-d'Ivoire, 9 species occurring at a relative abundance higher than 1% were recorded, yet the three dominant species, *Parkia biglobosa* (28%), *Faidherbia albida* (27%), and *Vitellaria paradoxa* (16%) had a more even importance (Bernard and Peltier, 1994).

The density ratio in this group is variable, yet most of the useful and frequent parkland species *(V. paradoxa, P. biglobosa, B. costatum, P. erinaceus, L. microcarpa)* and some of the useful and less frequent species (T. indica, D. olivieri, K. senegalensis have a density ratio under 15. Relatively, the density of these species is therefore maintained or only partially reduced. All of these species were also more frequent in fields than in adjacent bush quadrats, which suggests that farmers have favored the development of these species and perhaps those of Group 5 in parklands. In contrast, the densities of *D. microcarpum, L. acida, A. laxiflora* and *B. africana,* useful and frequent parkland species were reduced to a greater extent because they are relatively very frequent and occur in fairly high densities in the natural vegetation. Their natural density thus exceeds farmers' needs for these species' products.

It is more difficult to draw positive conclusions about less frequent parkland species because of their higher chances of not being sampled. Nevertheless, *G. laxiflora, S. madagascariensis, L. velutina, G. erubescens, S. birrea, A. leiocarpus, E. africana* appear in greater frequency in natural vegetation than in fields. Consequently, their numbers may be lowered during parkland establishment. In contrast, the low and similar frequency of the remaining species in fields and adjacent vegetation suggests that they are rare and may not be eliminated during clearing.

Group 2 includes 15 species which occurred in far higher densities in bush vegetation than in agricultural fields. They are thinned heavily during field establishment as demonstrated by a ratio of densities in bush quadrats and fields ranging between 100 and 1700. Interestingly, this group is exclusively composed of species of small trees or shrubs. They have a high rate of regeneration and are very frequent in bushland to the exception of *Strychnos inocua.* To the

exception of five species *(A. dudgeoni, C. febrifuga, S. spinosa, T. avicennioides* and *A. gourmaensis)*, only a few individuals of the species of this group appear in Thiougou's sample parklands. The question whether these species are maintained because of species utility, tree conformation, fertility management, labor considerations or pure chance is raised.

Table 3: Comparison of quantitative vegetation parameters in cultivated fields and adjacent uncultivated bush quadrats (A=Crop fields, B=Adjacent bush quadrats)

1. Parkland species occurring in densities of a similar order in fields and adjacent bushland

Species	Number of individuals[a]		Relative abundance[a] (%)		Density[a] (trees/ha)		Density[a] ratio	Frequency[c]		Frequency ratio
	A	B	A	B	A	B	B/A	A	Bb	Bb/A
Vitellaria paradoxa	3975	576	83.33	16.05	19.111	49.23	2.6	100.0	92.3	0.9
Parkia biglobosa	168	14	3.52	0.39	0.808	1.20	1.5	42.6	10.8	0.3
Detarium microcarpum	81	131	1.70	3.65	0.389	11.20	28.8	27.9	58.5	2.1
Lannea acida	68	84	1.43	2.34	0.327	7.18	22.0	36.8	56.2	1.5
Bombax costatum	67	13	1.40	0.36	0.322	1.11	3.4	41.2	17.7	0.4
Pterocarpus erinaceus	65	54	1.36	1.50	0.313	4.62	14.8	36.8	25.4	0.7
Afrormosia laxiflora	44	96	0.92	2.67	0.212	8.21	38.8	27.9	43.1	1.5
Lannea microcarpa	36	12	0.75	0.33	0.173	1.03	5.9	25.0	13.1	0.5
Burkea africana	19	29	0.40	0.81	0.091	2.48	27.1	13.2	14.6	1.1
Combretum velutina	18	8	0.38	0.22	0.087	0.68	7.9	19.1	6.2	0.3
Tamarindus indica	17	3	0.36	0.08	0.082	0.26	3.1	16.2	3.1	0.2
Entada africana	15	48	0.31	1.34	0.072	4.10	56.9	14.7	56.9	3.9
Diospyros mespiliformis	11	10	0.23	0.28	0.053	0.85	16.2	13.2	18.5	1.4
Daniella olivieri	8	3	0.17	0.08	0.038	0.26	6.7	10.3	2.3	0.2
Anogeissus leiocarpus	8	9	0.17	0.25	0.038	0.77	20.0	8.8	20.8	2.4
Sclerocarya birrea	4	10	0.08	0.28	0.019	0.85	44.4	2.9	10.0	3.4
Gardenia erubescens	4	9	0.08	0.25	0.019	0.77	40.0	5.9	26.2	4.4
Balanites aegyptiaca	4	7	0.08	0.20	0.019	0.60	31.1	4.4	3.8	0.9
Sterculia setigera	3	6	0.06	0.17	0.014	0.51	35.6	2.9	6.2	2.1
Ostryoderris stuhlmannii	2	4	0.04	0.11	0.010	0.34	35.6	2.9	4.6	1.6
Lannea velutina	2	2	0.04	0.06	0.010	0.17	17.8	2.9	13.8	4.7
Khaya senegalensis	2	1	0.04	0.03	0.010	0.09	8.9	2.9	0.8	0.3
Ficus platiphylla	2	3	0.04	0.08	0.010	0.26	26.7	2.9	1.5	0.5
Swartzia madagascariensis	1	3	0.02	0.08	0.005	0.26	53.3	1.5	7.7	5.2
Pseudocedrela kotschyi	1	2	0.02	0.06	0.005	0.17	35.6	1.5	3.1	2.1
Gardenia laxiflora	1	3	0.02	0.08	0.005	0.26	53.3	1.5	39.2	26.7

2. Parkland species occurring in far greater densities in bushland than in fields

Acacia dudgeoni	31	347	0.65	9.67	0.149	29.66	199.0	23.5	65.4	2.8
Crossopteryx febrifuga	22	408	0.46	11.37	0.106	34.87	329.7	20.6	86.2	4.2
Strychnos spinosa	17	278	0.36	7.75	0.082	23.76	290.7	20.6	74.6	3.6
Terminalia avicennioides	16	362	0.34	10.09	0.077	30.94	402.2	14.7	90.0	6.1
Acacia gourmaensis	13	88	0.27	2.45	0.063	7.52	120.3	13.2	33.8	2.6
Combretum glutinosum	5	212	0.10	5.91	0.024	18.12	753.8	5.9	98.5	16.7
Pteleopsis suberosa	4	72	0.08	2.01	0.019	6.15	320.0	5.9	65.4	11.1
Gardenia sokotensis	3	53	0.06	1.48	0.014	4.53	314.1	4.4	60.8	13.8
Maytenus senegalensis	2	89	0.04	2.48	0.010	7.61	791.1	2.9	75.4	25.6
Combretum nigricans	4	147	0.08	4.10	0.019	12.56	653.3	1.5	63.1	42.9
Dicrostachys glomerata	1	11	0.02	0.31	0.005	0.94	195.6	1.5	21.5	14.6
Grewia bicolor	1	14	0.02	0.39	0.005	1.20	248.9	1.5	19.2	13.1
Piliostigma reticulatum	1	94	0.02	2.62	0.005	8.03	1671.1	1.5	74.6	50.7
Securidaca longipedonculata	1	29	0.02	0.81	0.005	2.48	515.6	1.5	32.3	22.0
Strychnos inocua	1	8	0.02	0.22	0.005	0.68	142.2	1.5	5.4	3.7

3. Species with dbh>2.5 cm found exclusively in uncultivated bushland

Annona senegalensis	0	1	0.00	0.03	0.000	0.09	-	0.0	80.8	-
Securinega virosa	0	1	0.00	0.03	0.000	0.09	-	0.0	48.5	-
Stereospermum kunthianum	0	12	0.00	0.33	0.000	1.03	-	0.0	37.7	-
Guiera senegalensis	0	1	0.00	0.03	0.000	0.09	-	0.0	30.8	-
Combretum molle	0	32	0.00	0.89	0.000	2.74	-	0.0	28.5	-
Vitex doniana	0	34	0.00	0.95	0.000	2.91	-	0.0	23.8	-
Feretia apodanthera	0	12	0.00	0.33	0.000	1.03	-	0.0	20.8	-
Terminalia macroptera	0	8	0.00	0.22	0.000	0.68	-	0.0	19.2	-
Grewia mollis	0	9	0.00	0.25	0.000	0.77	-	0.0	17.7	-
Ximenia americana	0	11	0.00	0.31	0.000	0.94	-	0.0	16.9	-
Ziziphus mucronata	0	4	0.00	0.11	0.000	0.34	-	0.0	16.2	-
Heeria insignis	0	6	0.00	0.17	0.000	0.51	-	0.0	15.4	-
Hymenocardia acida	0	15	0.00	0.42	0.000	1.28	-	0.0	14.6	-
Parinari curatellifolia	0	74	0.00	2.06	0 000	6.32	-	0.0	10.0	-
Acacia seyal	0	5	0.00	0.14	0.000	0.43	-	0.0	6.2	-
Desmodium laxiflorum	0	2	0.00	0.06	0.000	0.17	-	0.0	6.2	-
Piliostigma thonningii	0	2	0.00	0.06	0.000	0.17	-	0.0	4.6	-
Albizia chevalieri	0	3	0.00	0.08	0.000	0.26	-	0.0	2.3	-
Gardenia ternifolia	0	1	0.00	0.03	0.000	0.09	-	0.0	2.3	-
Combretum micranthum	0	1	0.00	0.03	0.000	0.09	-	0.0	1.5	-
Nauclea latifolia	0	1	0.00	0.03	0.000	0.09	-	0.0	1.5	-
Erythrina senegalensis	0	1	0.00	0.03	0.000	0.09	-	0.0	0.8	
Mitragyna inermis	0	1	0.00	0.03	0.000	0.09	-	0.0	0.8	-

4. Species occurring only in agricultural fields

Adansonia digitata	7	0	0.15	0.00	0.034	0.00	0	8.8	0.0	0.0
Ficus gnaphalocarpa	7	0	0.15	0.00	0.034	0.00	0	10.3	0.0	0.0
Isoberlinia doka	6	0	0.13	0.00	0.029	0.00	0	2.9	0.0	0.0
Prosopis africana	1	0	0.02	0.00	0.005	0.00	0	1.5	0.0	0.0
Vitex diversifolia	1	0	0.02	0.00	0.005	0.00	0	1.5	1.5	1.0

5. Species with dbh<2.5 cm found exclusively in uncultivated bushland

Trichilia roka	0	0	0.00	0.00	0.000	0.00	0	0.0	13.1	-
Acacia raddiana	0	0	0.00	0.00	0.000	0.00	0	0.0	5.4	-
Febrifugum sp.	0	0	0.00	0.00	0.000	0.00	0	0.0	3.1	-
Cassia sieberiana	0	0	0.00	0.00	0.000	0.00	0	0.0	2.3	-
Ziziphus mauritiana	0	0	0.00	0.00	0.000	0.00	0	0.0	0.8	-

[a]for dbh (2.5 cm
[b]for all diameters
[c]percentage of inventoried units in which the species occurred

The next group includes 23 species which were absent in fields. The absence of frequent species (frequency>10%) in this group probably results from their elimination by farmers because they do not offer significant uses. However, the absence of less frequent species (frequency<10%) suggests that they may have been non-existent in the original vegetation of sample fields or were also eliminated.

Five species are present in fields but not in the adjacent uncultivated vegetation (Group 4). These species are uncommon and their non-occurrence in sister plots may be due to the limited extent of the sample area, except for *Adansonia digitata*. In this sample, fields with baobabs were former "champs de case" or house fields from older settlements. The association of this species with human settlement is common (Seignobos, 1982). The last group includes five species which were only found as young shoots under 2.5 cm in dbh in bush quadrats.

In fields overall average tree density (for dbh>2.5 cm) was 23 trees/ha, while it was 307 trees/ha in the adjacent bush vegetation.

3. Farmer perceptions of the effect of trees on crop production

Virtually all farmers state that sheanut trees have a negative impact on grain production of millet growing underneath. Several farmers also report that plants growing under the trees have better vegetative growth than those growing elsewhere. In 3 out of 61 cases, the effect of trees was said to depend on tree size or to be positive. Farmers attribute this negative effect to shade (53%), bird depredation (29%), excessive air and soil moisture under trees (8%), falling tree insects or water droplets causing cereal bud destruction or rot (7%), comparatively higher weed growth (3%). The effect of sheanut trees is also assessed to be negative on sorghum, yet no clear consensus among interviewed farmers is apparent concerning its comparative performance to millet (the performance of sorghum is considered higher, similar and lower relative to millet by 45%, 20% and 35% of them, respectively). When sorghum's performance is considered better than that of millet, it is attributed to the compactness of millet grain heads which favors

higher bird depredation. While there was an almost unanimous consensus on the localized depressive effect of sheanut trees on cereal production, 16 % of the farmers in the sample state that these trees have a neutral or positive effect on cereal production at the whole field level, due to their roles in organic matter production, moisture retention and soil protection from the sun. All farmers also recognize that tree influence depends on field tree density. When asked the question "What would production be like if all trees in your field were cut down?", aimed at differentiating farmers in respect to their attitude toward trees, 24% of them declared that crop yields would be low, whether in the short or long term. Soil dessication, lack of organic matter production and crop damage by wind are the main reasons stated. In contrast, 76% of farmers in the sample believed that crop yields would be positively affected as the negative effects of trees (shade, bird depredation, excessive moisture, bud failure, weed growth) would be eliminated. Members of the "tree-proponent" group had 30% more trees in their fields on average than members of the group with the opposite opinion (P=0.05) (31 and 24 trees/ha, respectively).

4. Tree management practices

The objectives pursued by farmers during land clearing are ranked by frequency of farmer answers in Table 4. Most are directly related to gathering adequate conditions for crop growth. Farmers declare selecting trees they intend to save according to species usefulness (48%), tree size (32.9%), species rarity (15.8%) and field tree density (10.5%).

Table 4: Objectives of field clearing

Objectives	Percentage
Create cropping space	35.1
Reduce shade	20
"Aerate" the cropping environment	17.2
Produce nutrients by burning woody matter	15.2
Chase birds away	7.5
Eliminate useless tree species	2.0
Create space for maneuvering of traction animals	1.3
Avoid root competition	0.7

Farmers do not only eliminate trees which do not offer tangible services, but also thin useful tree populations such as the karité. Out of 135 karité individuals cut at clearing stage, 61% were eliminated in order to favor neighboring individuals, 15% for space for traction animals, 14% due to their small size, and 10% because of the unsatisfactory tree condition (only 2% for nut productivity prognosis). Most farmers state that, given two pieces of land characterized by differing sheanut tree densities, they will cut a larger number of sheanut trees in the densest area. In fact, a sheanut stump count in 9 fields cleared in the current or previous year shows that the number of eliminated sheanut trees per unit area is highly correlated to the original karité density (R^2=0.97). The denser the plot in karités, the larger the number of karités cut. On average, the thinning ratio of karités in these 9 fields was 2.2. This value is consistent with the density ratio obtained for *V.paradoxa* Table 3. Additionally, all farmers report saving a

larger number of other useful trees when the sheanut tree density is naturally low than they would if it was high.

Sheanut tree selection is also based on its productivity. Most farmers (63.5% of answers) evaluate the potential of a karité tree over a period of 2 to 6 years. Some farmers (26.5%) also reported distinguishing productive karités through tree condition (trunk with burn patches or base openings, diffuse or partially dead foliage), nut, leaf and bark characteristics. For example, narrow leaves may be a distinguishing sign of a "tam daaga" or "male" karité which produces small and nutless fruits. Also, the nuts of some individual karités called "zoonpela" fall before maturity. The time interval necessary for sheanut selection indicates that tree management takes place at clearing stage as well as later on in time. Thirty-five percent of farmers interviewed reported practicing continuing tree selection after clearing time in order to obtain a more appropriate field tree density by making space for their traction animals or cutting down useless trees, or to eliminate defective sheanut individuals. Most fields of farmers who did not report practicing continuing selection were cleared fallows. Their tree density may have been already reduced during the first cultivation cycle and thus may not have needed further tree removal. Nevertheless, field tree density was found to be significantly higher ($P<0.05$) in fields where continuing selection had not been practiced.

Besides density management, farmers also enhance the association of trees in the cropping environment by pruning the lowest branches of trees. Unlike other parkland species such as the néré *(Parkia biglobosa)*, the karité tree usually has an ascending branch architecture. Out of around 2000 karités surveyed, 56% of them displayed cuts where one or multiple branches ranging in diameter up to 15 cm had been cut at their base. This practice increases the space for crops underneath the tree. Even though it was not quantified, pruning was also observed on other species.

A third of the interviewees report having protected woody regeneration. Regenerating candidates must have reached a substantial height and have a single fast-growing shoot. The smallest tree diameter observed in fields was 2.7 cm at breast height.

Farmers were asked whether the current tree density of their fields was appropriate, too high or too low. Corresponding percentages were respectively 67%, 26% and 7%. Reasons for a lower tree density were related to crop production increase (77% of the answers), presence of useless species (15%) and low sheanut production (8%). Interestingly, the mean tree density in the group which desired less dense a tree cover was lower than that of the group which was satisfied with the current parkland density.

These results show that farmers have their own perception of the role of trees in the cropping system, regardless of the actual optimal tree density recommended by research or extension, and that they may manage parkland trees according to these perceptions.

5. Influence of farm attributes on Thiougou parkland characteristics.

The following results are preliminary as they derive from simple regression analyses on continuous variables and one-way ANOVA analyses on discrete variables. More definite

conclusions will be reached with the integration of significant variables in a multiple regression model.

Duration of cultivation period

Aerial photographs spanning the last thirty years (Gijsbers *et al.*, 1994) reveal that densities of mature trees are declining in some agricultural areas of the Sahel region. However, the observed density decrease could not be attributed to initial clearing or continuing tree elimination. Pullan (1974) also indicated a possible relation between parkland tree density and cultivation time. From a cursory examination of Thiougou's aerial photographs, fields which appeared to be in cultivation for a recent time as evidenced by the limited size of tree crowns also tended to display higher tree densities than older fields with wider crowns. In the analysis, field age was the factor which explained most variability related to tree densities (R^2=0.20, P=0.001) in new fields. Density decreased at a rate of -1.1 tree/ha per year of field cultivation.

No relationship was found between field age and percentage of crown cover. Because of the dependence of density and percentage of crown cover (R^2=0.5) and diameter at breast height and crown surface area (R^2=0.65), the decline of tree density may balance the increase in tree crown area with time.

The influence of field age on parkland tree species richness was negative, but corresponding R-squares were very low, except when considering oldest field sections for new fields (R^2=0.17, P<0.01). Species richness in oldest field sections was half the overall field species richness (P<0.0001) for fields made up of at least two sections of different ages. This shows that as adjacent land is cleared, new sections serve as a reserve of additional species, which are probably saved for their various subsistence or medicinal uses. Species richness also increases with field size (R^2=0.21, P<0.0001). Because karité is one of the most rewarding tree crops in economic terms, farmers tend to favor its dominance in all fields. In fields of large size, which allow for substantial karité nut production as well as for space for other important species, farmers tend to diversify parkland production.

Average sheanut tree diameter at breast height was also positively correlated to field age. The highest correlation (R^2=0.61, P<0.0001) was found when considering oldest plots of fields never cultivated before (Figure 5). The regression line has a slope of 0.73 cm/year and an intercept of 16.2 cm. This estimate of yearly diameter increment falls in the range of increments measured in the past. Picasso (1984) reports annual average increments of about 4 mm in Niangoloko, while Delolme (1947) mentions increments of 1.6 to 2 mm per year in Ferkessedougou in Côte-d'Ivoire.

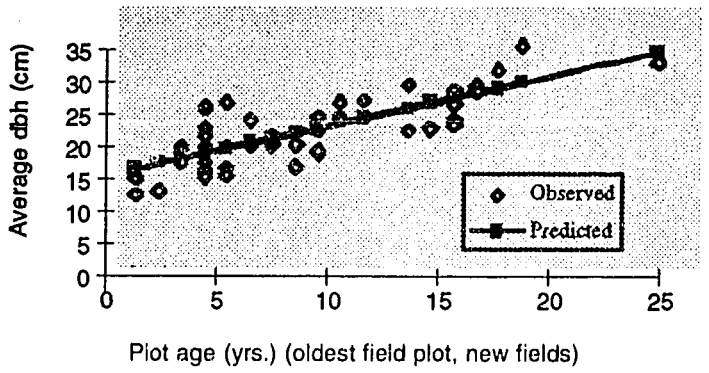

Figure 5. Relation between plot age and average karité diameter at breast height (R^2=0.61)

Field age was also correlated to the smallest and largest karité diameter (R^2= 0.27 and 0.39, in youngest sections of new fields and oldest field sections, respectively). Average diameters of tree stands in fields established at a given time can therefore serve as an indicator of field history. Because of the absence of woody competition and annual fires in agricultural fields, parkland trees can develop to large sizes. This is in contrast to the diameter class structure of surrounding uncultivated forest land where large individuals are far less common.

Fallow

Effect of fallow on parkland parameters include an increase in crown cover, basal area, largest karité diameter and range of tree diameter (Table 5). This is the logical result of trees growing larger in diameter and crown size with time, while the protection of smaller regenerated trees increases the spread of tree diameters in fields. However, tree density is not significantly higher on fallowed fields than on new fields. Farmers may take advantage of tree regeneration occurring during fallow for increasing low tree densities, if they wish to, yet fallowed fields appear to be managed for density the same way as new fields are.

Additionally, species richness is significantly lower on fields which have been fallowed than in new fields. Respective species richness averages at the field level were 4.5 and 7.7 (P=0.0002). Parkland species are thus restricted to a smaller number at the outset of a fallow interval or in the following years than they are for new fields. This phenomenon as well as the lower number of species in oldest field sections than in whole fields with multiple sections noted earlier show that farmers favor the dominance of one or a few species only as parklands develop with time. When amplified in the long term, this selective process may lead to "constructed" parklands characterized by drastic differences with the local natural vegetation promoted by human intervention. Such differences are reflected in the small number of species present, sometimes limited to a single one, and in more elaborate tree size and configuration as may be the case of *Acacia albida* parklands (Pélissier, 1980; Raison, 1988; Baumer, 1994). Within the sample of fallowed fields, duration of fallow, which ranged from 1 to 15 years in the sample, had a positive effect on parkland species richness (R^2=0.15, P=0.05).

Table 5. Effect of fallow on tree cover parameters in field sections

Variables	New fields	Fallowed fields	One-way ANOVA P values
Tree density (trees/ha)	22.6	25.0	0.14
Species richness	4.1	3.0	0.02
Crown cover (%)	0.0388	0.0498	0.009
Basal area (m^2/ha)	0.98	1.34	0.003
Largest karité diameter (cm)	35.3	43.5	0.002
Standard deviation of karité diameters	6.2	9.1	<0.0001

Figure 6 shows that field history is directly reflected in its tree diameter distribution. Two cultivation periods separated by a fallow period of different duration (reported to be over 25 years (Fig. 6a right) and less than 10 years (Fig. 6a left)) are reflected in bimodal tree diameter class distributions in fields. Figure 6b illustrates how the spread of diameter classes can vary in parkland tree populations in fields which have not been cultivated before (unimodal curve). This variability may be due the natural site diversity of tree diameters and/or farmer selection.

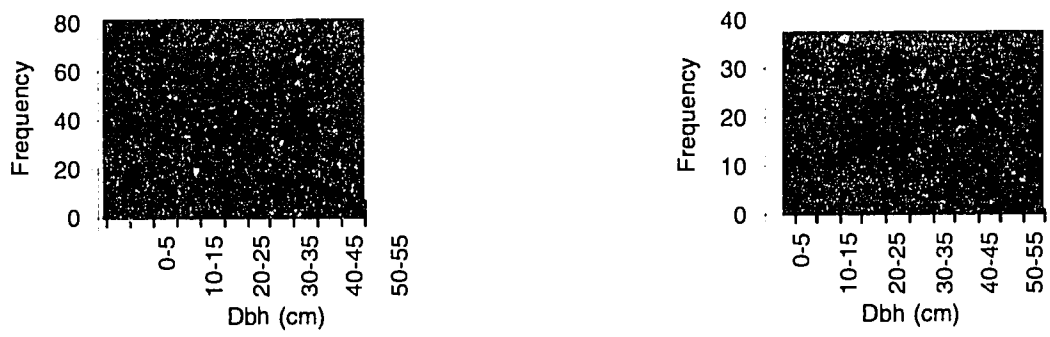

Figure 6a. Example of karité diameter distribution in two fallowed fields

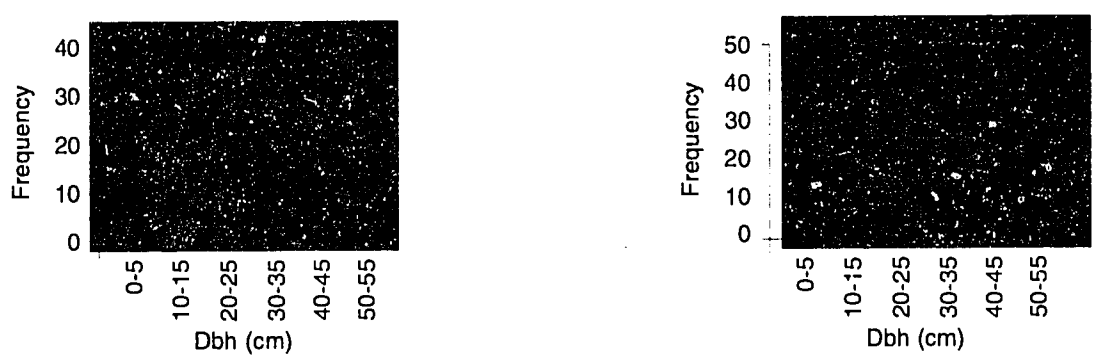

Figure 6b. Example of karité diameter distribution in two new fields

Soils

All fields in the sample are located on the flat and intermediate part of the toposequence which is suitable for agriculture (Guillobez and Taonda, 1993). A preliminary analysis reveals that two soil mapping types may be characterized by lower tree densities (Table 6). These two units are the least common in the sample. A pan at low depth and gravely texture are likely causes of lower site productivity. Topography and soil texture as assessed by farmers during interviews did not affect parkland tree density significantly. A single recorded value for texture may not have reflected texture variations within field sections.

Table 6. Average parkland tree density as affected by soil mapping unit in field sections

Soil mapping unit	n	Mean tree density	Variance
"Sols ferrugineux remaniés" (Gravely material)	2	6	2
"Sols peu évolués d'érosion" (Pan at low depth)	2	10.3	1.9
"Sols peu évolués d'apport, sableux " (Sandy material with gravely layer)	11	29	145
"Sols peu évolués d'apport, sableux et gravillonnaires" (Sandy material with gravely layer)	20	26	126
"Sols ferrugineux lessivés" (Kaolinitic alteration of acid rock)	32	28	195

Farmer gender, method of field cultivation and tenure

In the sample, tree density in fields of female farmers was significantly higher than in male farmers' fields, 35 and 24 trees per hectare respectively. Women's fields generally are intended to complement the household main cereal production with extra grain, vegetables and spices and thus serve a different purpose than main family fields. Average surface area of men's and women's fields differ significantly, 3.6 ha and 1.1 ha respectively. Women's fields were cleared mostly by the husband, preceding farmer, relatives or an invited work party. The number of species found in women's and men's fields were not significantly different. However, species richness per unit area was twice as high for women as for men ($P=0.0004$). This is probably due to the fact that women, who are primarily responsible for cooking and family care, value these woody species for various culinary and medicinal recipes and find it advantageous to keep some of these species in their fields. Intra-household decision-making regarding tree management was not extensively investigated in this study and deserves more attention.

Parkland tree density also varied according to method of field cultivation. On average, farmers using hand cultivation, donkey and ox traction had densities of 31, 25 and 21 trees per hectare, respectively. This difference was only significant between manual farmers and those using oxen ($P<0.01$). Oxen are used in pairs and require ample space to maneuver. Tree roots also hamper their progress during plowing or mounding activities. The negative effect of animal traction on tree densities has been previously reported in the interior Niger delta (Gallais, 1967)

and in southern Mali (Bagnoud, 1992 cited in Cissé (1994)). In contrast, donkey traction is usually carried out with a single animal and a lighter plow, and is less affected by tree density. Animal traction allowed for the cultivation of larger areas. On average, field size was 1.35 ha, 2.7 ha and 4.8 ha for fields where hand cultivation, donkey traction and ox traction were used, respectively. These averages were all highly significantly different from one another ($P<0.01$). The fact that parkland tree density was negatively affected by field surface area ($R^2=0.11$, $P<0.05$) may be due to the larger field size of fields cultivated with animal traction and by men.

In this study, land was acquired through relatives (40%), mostly for land previously cultivated, and for new land by requesting it to the village chief (15%) or without any notification (45%). Tree density averages were respectively 29.7, 24.7 and 23.1 trees per hectare for these three groups. A significant difference was found between fields transmitted through kinship and fields spontaneously cleared ($P=0.02$). This may reflect a more extensive approach to clearing and land use on the latter fields yet other factors such as fallow may be responsible for this difference.

While distance between residence and field location is an important factor in farming systems with concentric rings of variable land use intensity (Prudencio, 1983), this factor was not significant in explaining any parkland cover characteristic in this sample of bush fields. Fields in Thiougou are either house/village fields or bush fields. However, the comparison of woody plant cover variables in both field types would reveal drastic differences.

VI. CONCLUSIONS

In areas where arable land has not entirely been used for agriculture, the analysis of uncultivated vegetation characteristics yields significant insight on how parkland tree density and species diversity are managed during and after establishment. Such an approach may also be helpful in cases of higher land saturation. It documented the more favorable conditions for tree development in fields relative to the natural bush environment in Thiougou. This study provides quantitative evidence that tree resources are actively and deliberately managed by farmers through successive cultivation and fallow intervals. In Thiougou, long-term parkland development trends include a slight decline of tree density and increased dominance of a limited number of species, of karité in particular.

Fallow contributes to parkland rejuvenation and species enrichment. Farmer strategy of parkland specialization are more evident in the management of fallowed fields. In Thiougou's parklands of recent development, the distribution of tree diameter classes helped decipher fallow history and field age. Whether this can be extended to older villages should be verified. Finally, this study identified several variables which influence the management of tree resources, such as original karité density, farmer perception of the effect of trees on crop production, method of field cultivation, farmer gender, soil type.

This study has shed some light on the functioning of Thiougou's parklands and the general trends of tree management according to a few technical farm charactersitics. Socio-economic studies aimed at analyzing the relationship between tree management strategies and farmer

objectives and constraints in agricultural production are currently needed to better understand observed differences in parkland tree density management.

Parkland management parameters considered here are mostly determined by agricultural production strategies. Additional important criteria in the management of this agroforestry system could be identified from the tree product utilization side by studying economic and non-economic tree products used, location of collection, income and appropriation of income. As tree management differs among Thiougou's women and male heads of farm units, both agricultural and tree production objectives are likely to vary among household members (head of farming unit, head of nuclear family, wives, unmarried male and female members). These objectives as well as traditional resource allocation and attribution of tasks related to tree products should therefore be investigated.

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Section V
Research and Extension Issues

Farmer Participation in a New FSR Program in Burkina Faso, West Africa

E. Robins, W. Fiebig, and S.J.B. Taonda

I. INTRODUCTION

Farmer participation in diagnostic processes is a cornerstone of FSR. It informs researchers of potential research themes and of the relevancy of innovations according to the assessments of end-users. Farmer participation increases the probability that innovations will be adopted.

Farmer participation also increases farmer investment in the research process. With a greater stake in the outcomes of research, farmers are more interested in collaborating with other research partners.

Farmer participation in the research process serves another important objective. In our experience, farmer input requires an effective communication network for identifying, transmitting, evaluating, and improving knowledge of agricultural systems. The farmer is the starting and ending point in this network which includes also, in the Burkina setting, field technicians, enumerators, supervisors, and researchers. Genuine farmer participation presupposes a structure linking communication between the research station and the farm.

In this paper we discuss some of the methods which the RSP *(Recherche sur les Systèmes de Production)* program in the central zone of Burkina Faso is using to involve farmers in the evaluation of on-farm agronomic trials and, more comprehensively, in diagnosing the agricultural milieu. This effort is still experimental. The methods were tried last year for the first time. The basic objective of the RSP program is to generate agricultural development through research which is responsive to the conditions and constraints facing farmers. Methods which identify relevant farm-level data to incorporate into research agendas are fundamental to this process. Last year's efforts along these lines will be improved and tried again this year.

The RSP program has taken actions to promote farmer input into agricultural research as it builds a valid date base. The significance of the results of last season's agronomic trials, as discussed later in this paper, needs to be established. Trials conducted again this year are more appropriately designed and will help further to build the scientific credibility of the research program.

While this occurs, credibility with farmers is also promoted. Their opinions of research are solicited and research results are shared with them. The farmer opinion survey and other measures for involving farmers in the research process will help RSP to define meaningful research agendas at the same time that they increase the role of farm families in rural development.

In this paper we present first a brief summary of the research setting in Burkina Faso. Following that we discuss last year's agronomic tests and how test results were interpreted and

portrayed to team members and farmers. There follows a presentation of the "Farmer Opinion Survey" and the ways it helped the program to get closer to the needs and interests of farm families. Finally we look at the consequences of these activities on planning and implementing the 1991 research program.

II. SETTING

Burkina Faso is located at the southern extreme of the Sahel. Agricultural production in much of Burkina is exposed to the climatic stresses of the Sahelian region. Farmers face irregular rainfall, shortened growing seasons, and low soil fertility. Related hardships, the results of labor shortages and competition with herders over agricultural land, together have shaped the diverse strategies which are realized in existing farming systems.

To respond to the realities of agricultural production, the Burkina agricultural research institute, IN.E.R.A. *(Institute National d'Etudes et de Recherches Agricoles)*, initiated a farming systems research program (RSP) in 1985. The program covers about two-thirds of Burkina at the present time.

The ARTS project (Agricultural Research and Training Support), a USAID-funded activity (Project No. 686-0270), provides support to RSP in the areas of research, research management, and training. The objective of the project is to assist the RSP program in developing a capacity to conduct farming systems research in the central and western zones of Burkina. A technical assistance team consisting of an agronomist, a rural sociologist, and an agricultural economist are implementing the project. The team arrived in July, 1990, shortly after RSP had installed agronomic trials in the central zone. In the western zone, RSP devoted 1990 to fundamental, reconnaissance-type data collection.

III. AGRONOMIC TESTS

On-farm agronomic trials in 1990 were conducted in three villages to address several key constraints to crop production in the central plateau. Data were collected from varietal trials on white sorghum, millet, maize, cowpea, and groundnut at different levels of fertilization and under various soil management techniques. Maize tests were simple observation plots of breeders' varieties. A cowpea-sorghum association trial was conducted but proved to be problematical and was not analyzed.

The objective of the varietal trials was to evaluate the performance of shorter cycle varieties in the low management systems of limited-resource farmers given the erratic rainfall of recent years (Table 1). Fertility treatment levels were tested to evaluate the effects of organic compost and different rates of NPK on crop growth. Land preparation techniques were applied to test simple ridging and tied-ridging versus non-ridging for soil moisture conservation.

Table 1. Description of research sites

Site	Zone	Average Rainfall	Rainfall 1990 Season	Rainfall After Installation of Tests
Donsin	Sudano-sahelian	650-750 mm	534 mm	425 mm
Kamsi	Soudanian	700-800 mm	562 mm	418 mm
Thiougou	Sudano-guinean	800-1050 mm	577 mm	379 mm

The 1990 trials were similar to other trials conducted throughout the 1980s by various national and international farming systems-type research organizations operating in Burkina. The repetition of research themes over a ten-year period suggests that feedback from the field may have been insufficient for a thorough evaluation of the tested technologies.

Trial Results. There was much that was rewarding about the 1990 agronomic campaign. Field technicians received on-the-job training in trial implementation, trial maintenance, and in harvesting techniques and procedures. Their uses of technical *fiches* required careful monitoring of the trials and improved their powers of observation. The trials required contact and collaboration with farmers and helped to establish the credibility of RSP. Farmers, in their turn, offered time, land, and labor for the trials. Importantly, RSP researchers along with the technical assistance team grew to know and respect each other and to exchange ideas and experiences.

At the agronomic level, trial results were compromised by weaknesses in design. Each site was considered a replication; treatments were not replicated several times within a site to account for within site variability. There was no randomization of varieties in the varietal trials; the extreme variability within sites of slope, soil fertility, soil structure, etc., along with the treatments, all influenced varietal performance. There was no site characterization of soils, rainfall was not monitored at specific trial sites, and "local" varieties may have varied from one trial to another. In three of the four trials discussed here there was a highly significant difference associated with the variability of data between sites (repetitions); the varietal performance observed thus may have been due to site differences rather than solely to treatment effects.

Trial results were similar in all three central plateau village sites. In general, as the result of late and poorly distributed rainfall, local varieties out-performed improved varieties in grain yield.

This being the case, a comparison between the results of the agronomic trials and farmers' perceptions of them is revealing. If differences in performance can not be attributed exclusively to the effects of tested variables, when analyzed quantitatively, for the reasons noted above, they were nonetheless perceived by farmers to be of interest. Drought resistence or quality of forage in improved varieties, for example, was appreciated by farmers in spite of the relatively lower grain yields of those same varieties. As we discuss below, it is the process of involving farmers in the diagnosis of the 1990 campaign which has proven to be of value to RSP at this young stage in its development and not the results of the trials per se.

This discussion will focus on agronomic tests conducted in one village, Thiougou, to illustrate RSP methodology. Thiougou is the southern-most research site in the central zone. In 1990, Thiougou experienced heavy early rains followed by drought, a pattern common in recent years (Fig. 1). Farmers held-off planting until late June when they were more confident of regular rainfall. In 1990, RSP trials, which farmers installed under the supervision of RSP technicians, were planted in July so that they would not compete with the labor requirements of food-security fields.

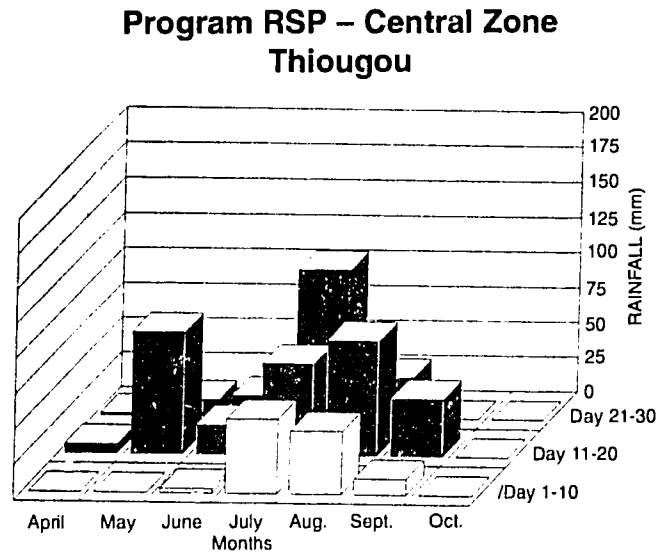

Figure 1. Rainfall Distribution in 1990.

The sorghum varietal trials evaluated the effects of organic compost and NPK on crop growth. Grain yield of local varieties was greater than both improved varieties at both fertility treatment levels (Fig. 2). ICSV 1049 is a short-statured variety with a compact panicle which the farmers

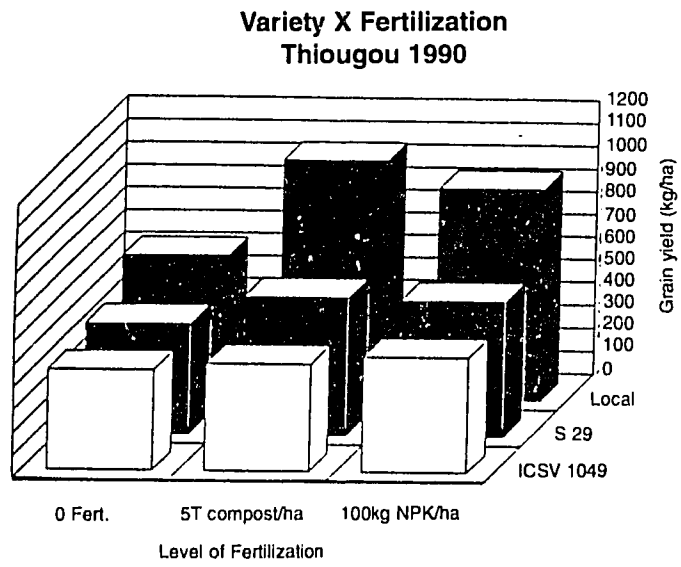

Figure 2. Sorghum Grain Yield.

did not like; they felt the panicles would not dry down properly for storage. S 29 is an improved local variety which resembles the local in growth habit but has a very short growth cycle and is drought resistant. Farmer interest in the two improved varieties centered on their forage characteristics (Fig. 3). The vegetative portions of the cereal and legume crops are the main feed sources for livestock during the long dry season. Farmers expressed preferences for ICSV 1049, which has a short yet very thick stalk, and S 29, which is tall. Animals were able to consume completely the entire plant compared to the woody local variety. It was assumed by the farmer that the improved varieties were sweeter in taste and therefore made a better feed source.

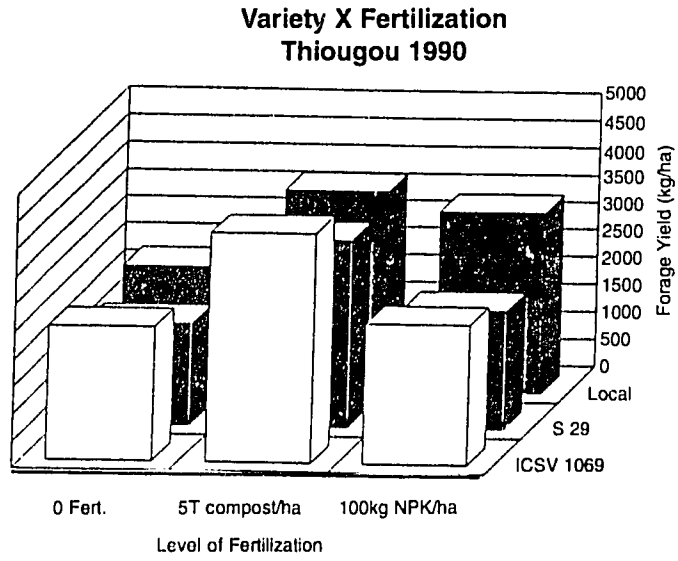

Figure 3. Sorghum Forage Yield.

The millet varietal trials were conducted with different soil preparation techniques: flat surface, simple ridging, and tied-ridging. Ridging treatments had demonstrated yield increases due to an improved soil moisture retention capability on-station and on-farm when associated with applications of 100 kg of NPK. Yield results have been erratic, however, and depend on favorable climatic conditions to be cost-effective. There were no grain or forage yield benefits due to either ridging treatment in 1990 (Fig. 4, Fig. 5). Local varieties responded better than both improved varieties at each treatment level. Farmers observed that ridging reduced the lodging of mature millet plants and conserved moisture (in the case of tied-ridges).

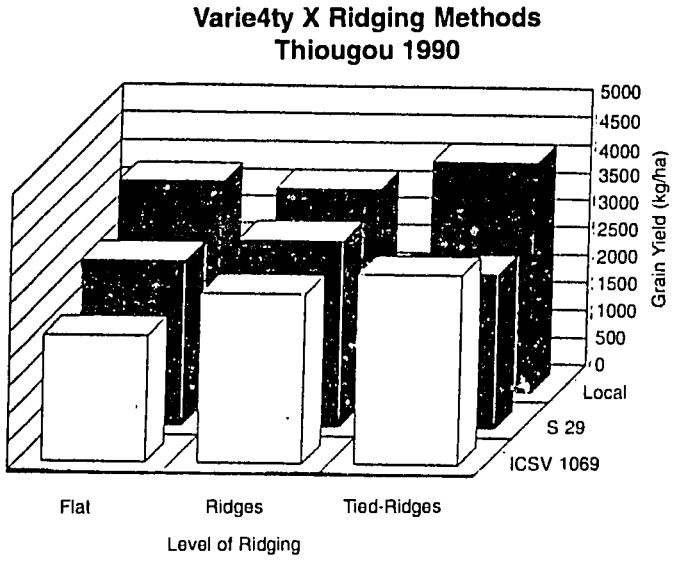

Figure 4. Millet Grain Yield.

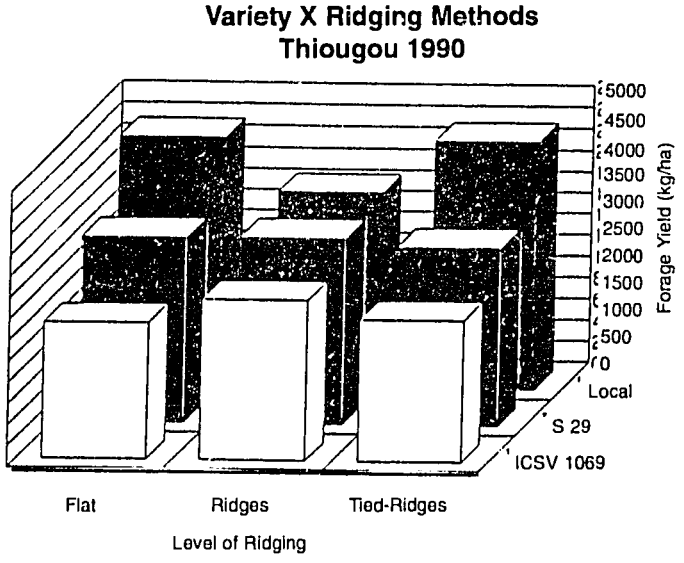

Figure 5. Millet Forage Yield.

The cowpea varietal trials were designed to evaluate the response to different levels of NPK. There were significant grain yield responses to each NPK treatment level (Fig. 6). The farmers' practice of intercropping cowpea with cereals complicates application of NPK under real conditions; an economic analysis would demonstrate whether or not it would be cost-effective to do so.

The upright growth habit of improved cowpea varieties make harvesting easier and, because of their determinant nature, all the pods mature at one time. They must be harvested immediately to avoid spoilage. Local varieties have a spreading growth habit and pods mature over a three to four week period. This allows for occasional harvesting as time and labor permit. There were no differences in forage production between cowpea treated with the lower and higher

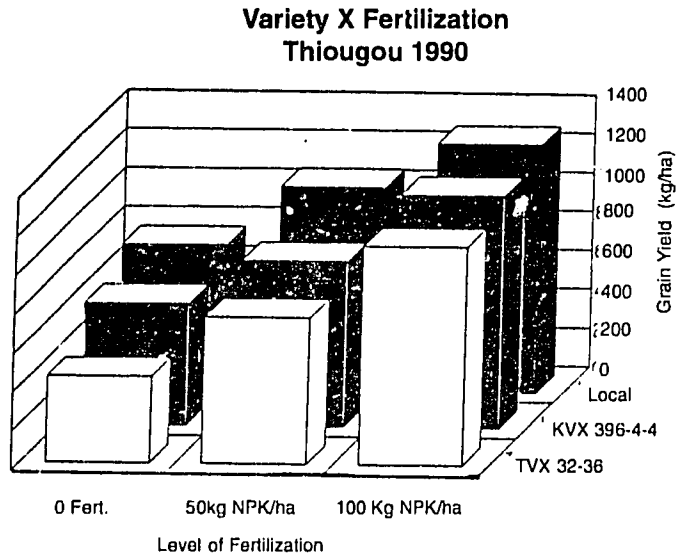

Figure 6. Cowpea Grain Yield.

rates of NPK, yet the lower rate resulted in a significant forage yield increase over the control (Fig. 7). The main problem with improved varieties, as identified by farmers, was handling and storing the great quantity of seed coming from the short, intense harvest.

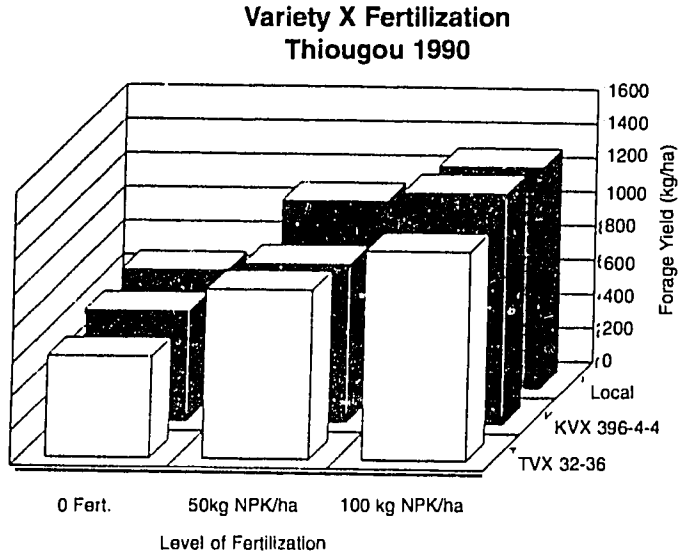

Figure 7. Cowpea Forage Yield.

Groundnut seed yield increases were achieved with increasing levels of NPK (Fig. 8). There were no seed yield differences between local and improved varieties at each treatment level. Improved varieties out-yielded local varieties in forage production at 100 kg NPK, which was important to farmers (Fig. 9). The vegetative portion of the groundnut plant is second to cereal crop residues as the most important source of forage for animal feed.

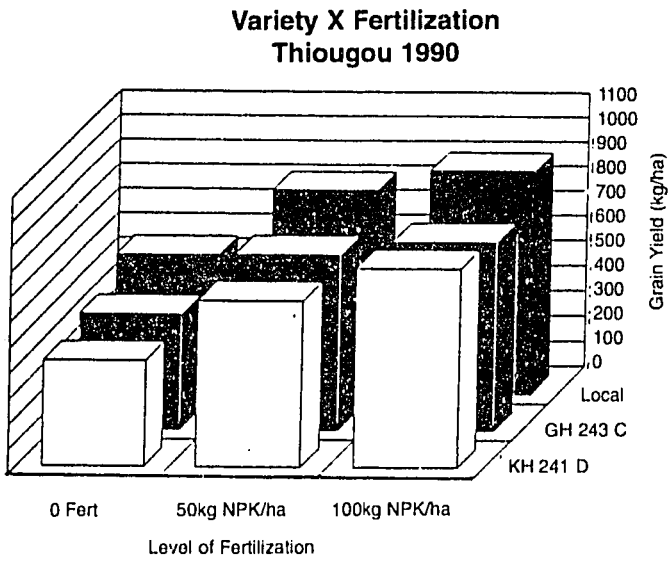

Figure 8. Groundnut Grain Yield.

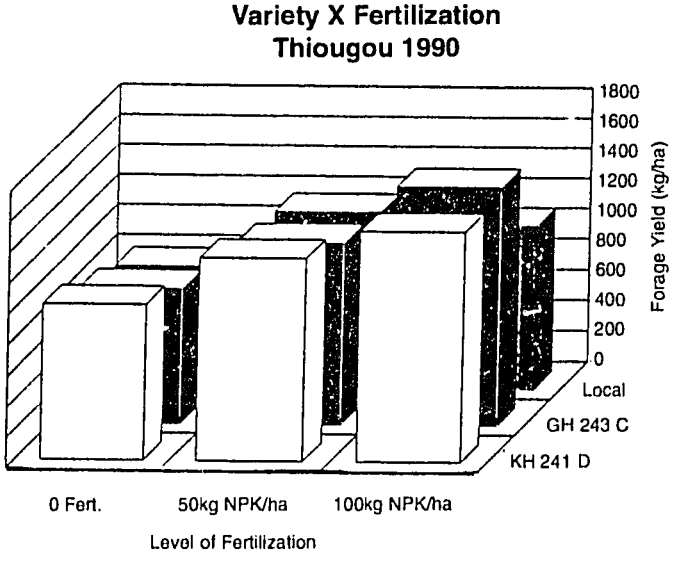

Figure 9. Groundnut Forage Yield.

Some farmers commented that NPK increased weed growth. Competition by weeds with groundnuts may occur, requiring more frequent weeding of groundnut fields. Customary practice is to weed once at six weeks. The question of whether NPK is cost-effective in legumes should be studied further. Commodity researchers at INERA recommend 100 kg/ha NPK be applied to improved varieties of both cowpea and groundnuts.

IV. FARMER OPINION SURVEY

The farmer opinion survey was conducted after the 1990 harvest to elicit evaluations of participating farmers on the agronomic tests. While quantitative analysis of the trials yielded an aggregate picture of performance, the opinion survey furnished a range of qualitative responses.

Through the survey, important information was also obtained on cropping patterns and varietal characteristics. An inventory of varieties grown on-farm was prepared. This information will be passed along to breeders in the hope that it will be incorporated into their breeding programs. Information exchange between farmers and researchers, and especially commodity researchers, is a key objective of the overall INERA program. It is recognized within INERA that few, if any, on-the-shelf technologies exist which have the potential to meet farmers' needs and interests. The opinion survey provided information on local varieties of sorghum, millet, maize, cowpea, and groundnuts, the characteristics of each, whether they are sown in pure culture or in association, and farmers' reasons for the cropping patterns they employ.

The survey served a training function, also. At the start of the 1990 campaign, the RSP program's approach was essentially top-down, fixed on instructing a sample of volunteer farmers in how to follow a research protocol — a kind of researcher-managed, farmer-labored approach. Through the opinion survey, RSP staff learned to identify farmers' views and knowledge of agriculture and to incorporate them into the research program.

Methodology

Sixty-two production units participated in the opinion survey. Each unit, consisting of one or more men and one or more women plus children, was interviewed one time at their compound. The head of the unit, a male, responded to the enumerator's questions. Women's assessements were sought on the processing qualities of improved varieties. An open-ended question format was used to facilitate unbiased responses.

A first draft questionnaire was developed at headquarters by RSP researchers. Field technicians and their supervisors were informed of the objectives of the survey and asked to modify the questionnaire. A second draft questionnaire was prepared. Technicians were called into headquarters to be trained in its application. The objective of each question was discussed, in french, in a group setting. Afterward, each technician presented his version of how to pose the question in Mooré (the language of the Mossi, the predominant ethnic group in the central plateau). The questionnaire was given different renditions by the technicians. The need to improve their communication skills was evident. Each question was discussed until the wording could be standardized.

The training lasted two days at headquarters and was followed by two more days of practical tests in the field. Researchers, supervisors, and technicians together conducted the field tests to verify the protocol followed and language employed by technicians.

During the week which followed, technicians conducted another four to five tests. Questionnaires were then returned to headquarters with comments. A final revision was made. Researchers and supervisors returned to the field to explain the changes to the technicians before the survey was implemented. The survey was conducted during the first two weeks of December, 1990, after all tests parcels had been harvested. The total number of respondents is noted in Table 2.

Table 2. Number of Respondents at Village-Sites by Type of Test

Village	Variety x Fertilization	Sorghum-Cowpea Association	Variety x Soil Management	TOTAL
Kamsi	15	05	00	20
Thiougou	18	05	08	31
Donsin	07	02	02	11
TOTAL	40	12	10	62

Data collected in the survey were processed using "LISA" (Logiciel Intégré des Systèmes Agraires), a data base management and statistical program. A training session was conducted in January 1991 in the application of LISA. For most of the Burkinabè participants, this training was their first exposure to micro-computers. The opinion survey was thus the first opportunity for several RSP staff to apply their new skills. A data processing group was formed, consisting of researchers, a senior technician (supervisor), and a data processor, to record and tabulate survey results. The raw data were collated and given initial interpretations by FSR sociologists, then distributed to other FSR researchers for their interpretations. The results, including the inventory of local varieties, were presented to the farmers in a village meeting.

Survey Results. The results of the survey were classed according to factors of acceptability and factors of production. Factors of acceptability described farmers' responses to trials: positive and negative comments by type of trial, interest in participating again next year in conducting trials, and opinions on the processing qualities of tested, improved varieties of sorghum, millet, maize, cowpea, and groundnuts.

Production factors described current farmer production practices and included an inventory of local varieties (varieties sown by local farmers) and their characteristics, a list of secondary characteristics (that is, aside from earliness and yield) sought by farmers in choosing varieties, a description of cropping patterns and the reasons for them, and a list of the sources of seed stocks by crop. This information had not been collected previously by RSP. Survey results are summarized below for all three village sites so that the complete range of responses may be presented.

Factors of Acceptability. Seventy-five percent of the comments on the tests were positive, generally citing the earliness and productivity of improved varieties and the positive effect of fertilizer treatments on production (local and improved varieties). Negative responses predominated in two trials: one in which the harvest of early sorghum was attacked by birds; and a second in which cowpea plants, when sown in association in the same pocket with sorghum, greatly reduced sorghum yields.

While most comments focused on the relative grain yields of different varieties, it was apparent that farmers were paying attention to other characteristics as well. The forage qualities of improved sorghums were appreciated, as were the drought-resistent qualities of improved

sorghums and groundnuts. On the other hand, some farmers noted that improved sorghums appeared vulnerable to infestation and did not withstand drought well.

Opinions on the processing qualities of improved varieties were varied and interesting. Some of the more drought-resistent varieties of sorghum, for example, such as IRAT 204 and ICSV 1049, were not appreciated for their taste and storability, respectively. The two improved varieties of millet were well-viewed for flour and tô (a porridge and food staple of the Mossi). All the maize varieties, whether eaten grilled or as tô, were preferred to local varieties. All the dishes prepared from improved groundnut varieties were well-liked. Only the 7/180-4-5 dual purpose (food/forage) variety of cowpea was judged not to have a good taste; opinion was mixed on the cooking qualities of other cowpea varieties.

Slightly more than one-half of the farmers expressed unqualified interest in participating again in next year's trials. Twenty-seven percent qualified their interest by expressing concern about the demands of trials on their time and resources. Some of these problems are attributable to research design: farmers were essentially laborers in researcher-managed trials. In other cases, labor-intensive technologies such as tied-ridging were cited as too demanding of labor to be considered for adoption.

Factors of Production. The inventory of local varieties was diverse. Some of the varieties have come from other agro-ecological regions of Burkina. Many varieties were described as drought-resistent and early-maturing. There was a wide range of growth cycles available from early to late. Farmers indicated that, in addition to yield and earliness, they also look for storability, performance in association, taste, multiple plant usage (animal feed) of cereals and grain legumes, and marketability of grain legumes.

Fewer than one-fourth of interviewed farmers sow more than one variety of a given crop. Generally, these are reported to be early and longer cycle varieties. Otherwise, lack of seed, land, and labor were cited as reasons for sowing a single variety only in any given field. Land and labor are limiting factors because some producers allocate available resources to varieties in which they have the most confidence. Lack of sufficient seed may be a major constraint as more than 90% of surveyed farmers use cereal seed which comes exclusively from their own stock.

Associations of two or more crops are common. Millet is sown with sorghum and/or cowpea, and sorghum is sown with cowpea or maize. Farmers indicated that crop association economizes on labor and reduces the risk of food insecurity from crop failure. Evidently, farmers recognize that multiple crops make more efficient use of soil moisture and nutrients, space and sunlight.

About one-half of the respondents purchase grain legume seed in the market.

V. THE OUTCOMES OF FARMER PARTICIPATION IN RESEARCH

The graphics presented in this paper represent average responses of crops to treatments across sites. They were an excellent means of portraying the results of the agronomic campaign to researchers, and especially to supervisors and technicians. Farmers also showed interest in the graphs during tests of the opinion survey. These visual representations of trial results were more effective than statistical presentations in communicating, to non-scientists, differences in varietal performance. Moreover, involving technicians and farmers in data analysis, an activity ordinarily reserved for researchers, helped to demonstrate RSP's commitment to the full participation of all members of the research team. The payback from this approach is evident in the 1991 campaign: farmers and technicians alike are offering unsolicited opinions on this year's agronomic tests and socio-economic studies.

The results of the opinion survey served to complement the graphs insofar as they evidenced the range rather than the *average* of responses. This provided researchers with important information on the characteristics of improved varieties. For example, discussions and survey results revealed that despite relatively lower grain yields in improved varieties, farmers still appreciated them for their secondary characteristics (such as palatability and forage). This information, along with the characteristics of the many "local" varieties sown by farmers, is valuable to breeding programs. Additionally, farmers remarked that organic compost seemed to have a greater effect on vegetative growth than NPK, especially for improved varieties. Given the low cation exchange capacity of the soils and the erratic rainfall, organic compost has a more beneficial effect on plant growth. This observation is also supported by agronomic data (Fig. 3).

Farmers found tied-ridging to be demanding of labor, mainly because it must be done at the first weeding when labor constraints are greatest. Tied-ridging is a classic example of a technology developed on-station which, given the necessary inputs (which most farmers do not have), can result in significant yield increases. Earlier economic analyses of tied-ridging showed the technology to be profitable. Tests for many years in farmers' fields in Burkina Faso, however, has evidenced little or no adoption. New economic analyses are called for to see if conditions have changed or if the earlier models contained specification errors.

Tied-ridging is a short-term solution to the long-term problems of erosion and soil moisture management. Grass and/or rock dikes, following the contour of the land against the slope for a terracing effect, is a better long-term solution. They can be constructed during the dry season when labor availability is less of a constraint.

Some farmers interviewed at the end of the 1990 growing season indicated that they were going to plant cowpea in pure stands rather than in association during the 1991 growing season to improve forage and seed yields, following the RSP demonstration. All farmers that requested seed stocks of the dual purpose (feed/forage) varieties tested in 1990 were given seed in 1991. None of these farmers applied NPK to their fields but most planted the improved varieties in pure stands. Potentially higher seed yields will underscore another problem with cowpea — storage. RSP is planning a study of traditional seed storage systems for the end of the 1991 growing season in an effort to identify potential interventions to alleviate the storage problem.

One of the valuable outcomes of the opinion survey was the inventory of local varieties. In addition to soliciting this technical information, RSP provided farmers with a public opportunity to review the inventories. This took place at village meetings at the start of the 1991 season. The discussion was animated, with farmers clarifying the precise characteristics of each variety. With researchers taking notes, the role of farmer-as-teacher was apparent.

Overall positive producer response to testing innovations was an encouraging sign for RSP. When volunteers were again sought for the 1991 campaign, fully three times as many producers volunteered as RSP believed it could accommodate (with limited human, material, and financial resources). We believe that the rate of volunteerism is one important indicator of RSP impact at the village level.

The agronomic research program in 1990 focused on preconceived solutions to on-farm problems. In 1991, the emphasis has been placed on collecting agronomic and socio-economic data on local production systems and comparing them to the management systems recommended for increasing the probability of better performance from improved varieties. Local and improved varieties are being tested under both farmer and researcher management. This will allow researchers to evaluate and characterize the numerous farmer-managed systems according to the performances of local and improved varieties. Farmer opinions of the recommended management systems will be obtained as well. An output of this research program will be a continuum of management systems used by farmers. These will include intermediate systems which may exhibit increased yields of both local and improved varieties at less than recommended input levels.

The information of varietal characteristics will be passed to breeders. Breeders and RSP researchers need to start a nursery of local varieties to evaluate as a source of germplasm. Additional research into the sources of these varieties is also desirable. Some of them are certainly "improved" local strains while others come from elsewhere in Burkina Faso. RSP hopes to interest commodity researchers in on-farm performance of varieties, improved and other, in order to encourage them to breed for on-farm conditions of limited-resource farmers.

Crop associations are widespread in Burkina and well-liked by farmers. Improved cowpea-cereal associations should be a RSP research priority for the central plateau.

The question of access to seed as a source of producer options and production strategies was raised by the 1990 research efforts. RSP hopes to do a seed/storage survey to understand better how producers are managing seed stocks. A census of seed stocks on the farm, well into the dry season (February-March), would reveal how successfully producers cope with the long period (over eight months) between harvests and plan cropping patterns for the coming season.

Finally, the results of the opinion survey suggest that a closer look be taken at potential policy issues. While producers generally responded favorably to the trials, many of them expressed doubt about their ability to implement those tested technologies which increased their need for labor, fertilizer, and cash. RSP needs to verify the extent to which limited human and cash resources constrain adoption of innovations. Caution, too, should be exercised in verifying that

the requirements of innovative actions are available locally. That minority of producers who indicated that they possessed sufficient labor and fertilizer to adopt tried technologies should also be studied further to identify why they are not, in fact, using more productive cultural practices and/or better technologies at this time.

VI. CONCLUSION

The agronomic results of the 1990 growing season portrayed the average responses of crops to treatments of fertility and soil management practices. The farmer opinion survey served as a valuable tool for involving farmers more in the research process by soliciting their individual perceptions of tested varieties and management practices. As these results become available, breeders will need to be informed of them.

Improved varieties which are developed under research station conditions and which receive all the necessary inputs to assure maximum performance are not well adapted to farmers' limited resource management systems. They are susceptible to the harsh conditions under which local varieties are grown. The factors which are important to the farmer concerning any given crop should always be identified. This information should then be incorporated into breeding programs. This is one of the feedback functions of an FSR system.

RSP and rural development programs will depend upon INERA to develop such improved varieties to test under farmer conditions. This process should take into consideration local varieties of the major food crops in Burkina Faso and other Sahelian countries as sources of germplasm in crop breeding programs. They have been selected by farmers under the harshest of growing conditions and represent a genetic base with tremendous potential. Yet the commodity research programs of INERA do not have seed multiplication programs. If INERA cannot provide seed for distribution, other sources will need to be developed.

Aggregating household level research results provides the means to develop village level recommendations to improve agricultural productivity. Such recommendations must be feasible in terms of the resource capabilities of farmers. Assessments of innovations applied at the village level will allow RSP to develop recommendations at yet more inclusive levels — for example, the sub-zone (or agro-ecological zone). Feedback from tests at this level is also important for breeding programs to establish criteria for developing varieties adapted to agro-climatic conditions.

Experience with many on-farm research programs has indicated that policy-induced constraints limit potential gains associated with technological change. Local policy constraints often result from a lack of appropriate technical information among decision makers. RSP is initiating research which uses farm-level data to identify policy constraints related to the introduction of interventions and to communicate this information to decision-makers in INERA and the Ministry of Agriculture.

RSP research activities in 1990 revealed a range of farmer interests in agricultural production. By using the tools of dialogue, meetings, graphic presentations, and opinion surveys, RSP will continue to identify the real concerns of farmers and assign them a major role in the research process.

Extending Agricultural Innovations in the Multi-Ethnic and Multi-Cultural Societies of Western Burkina Faso

D. Ilboudo and E. Robins

I. INTRODUCTION

Innovations can be defined, in our sense, as appropriate responses intended to overcome or relieve a constraint experienced by the farmer. This notion of innovation is preferred to that of technology which is more technicist and does not take into account the social and cultural constraints of the farming context.

As such, the acquisition of agricultural equipment (animal traction, carts, etc.), the purchase and use of agricultural inputs, the proficiency in new techniques, the provision in various supplies for meeting rural needs, and lastly the marketing of agricultural commodities, as well as socio-economic decisions based on profitability and rationality, are all necessary innovations for the modernization of agriculture and the upgrading of living standards of Burkinabé farmers.

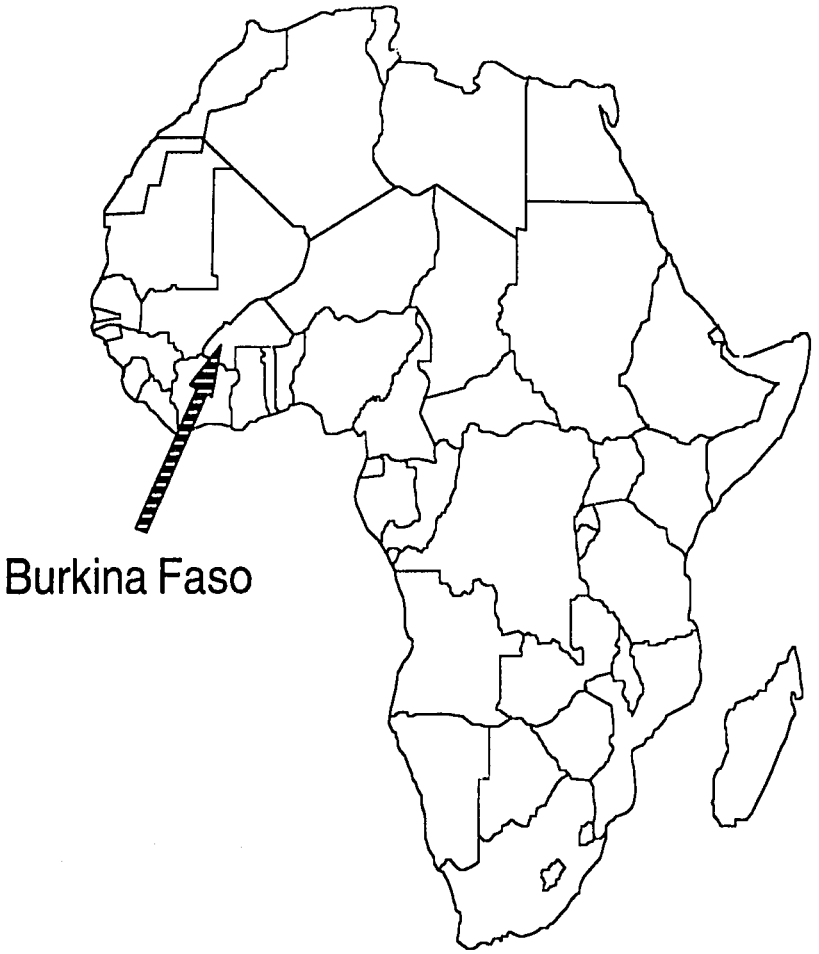

Figure 1.

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In the Western region of Burkina, there are many local partners of rural development:

1) Indigenous and migrant farmers, who according to their social positions pursue different strategies of consumption of self-produced cereals and production and marketing of commodities such as cotton.

2) Development structures, including the Centers for the Promotion of Agricultural Production (CRPA), both in the crop and livestock sectors, and SOFITEX, a textile company for the development mostly of cotton. Traditionally, these institutions have imposed their techniques on farmers with varied success.

3) Research institutes, which until recently have developed technologies which either do not correspond to farmers' needs or have not been adopted by them for numerous reasons.

4) The State, which organizes and stimulates all activities while attempting, not always overtly, to economize resources and maximize foreign currency through the marketing of agricultural goods.

In the present paper, some aspects of agricultural development that are crucial for the modernization of Burkinabe agriculture will not be discussed, for example, problems related to agricultural credit, technical themes, or farmer associations.

Can organizational issues dealing with a efficient extension system be left outside our current purview? Actually, our activities have not yet evolved to the stage where they can be extended. Yet developing innovations according to the needs and capabilities of agricultural producers is essential for increasing the appropriateness and adoption of innovation.

This paper discusses issues addressed by the Farming Systems Research Program (RSP) in Burkina Faso's Southwestern Zone. The RSP Program is one of eight research programs of the Institut d'Etudes et de Recherches Agricoles (I.N.E.R.A.) in Burkina Faso.

II. BRIEF OVERVIEW OF THE FARMING SYSTEMS RESEARCH PROGRAM (R.S.P.)

Originally designed for the whole of West Africa, agronomic research in Burkina used to be organized and conducted by French Institutes. Only in 1985 were national research programs organized to take-on more autonomy. Agronomic research was then reoriented to include all agriculture-related concerns.

The RSP Program was created during this period of change with the following three-fold mandate:

1) To adopt a holistic perspective on farms and their environment as the farm families themselves view it. RSP researchers work in multidisciplinary teams to promote this holistic approach.

2) To take local resources into account as local techniques are studied and improved. The RSP team works on the farm with effective farmer participation.

3) To identify problems of technology transfer by means of consultation between researchers, farmers and extensionists. The RSP team collaborates with development agencies and mainly with the "Centres Regionaux de Promotion Agricole" (C.R.P.A.), farmers (either individually or in groups), and with thematic researchers.

In a system-oriented, dynamic and iterative manner, farming systems research attempts to integrate the empirical knowledge of farmers and the scientific rationality of research and development actors.

Accordingly, a team originally made up of an animal scientist, an agronomist, an agricultural economist, a geographer, and a sociologist was appointed to the Southwestern zone of the country in order to study and improve the farming systems of the area. This team is assisted by three American researchers of the ARTS project (funded by USAID) including an agricultural economist, an agronomist, and a sociologist, as well as a socio-economist from CIRAD (France).

III. THE HISTORICAL AND HUMAN ENVIRONMENT OF THE WESTERN ZONE

Burkina Faso, once known as Upper Volta, is a landlocked country in West Africa. West Africa is a region in Africa which has been a cultural and economic theater of major world civilizations for more than ten centuries. Asia, through Arab traders, sought gold and slaves there. Europeans came later for the same and other reasons. These ventures resulted in major demographic, economic and cultural changes in West Africa which have weighed on regional development policies ever since.

Western Burkina is the area of the country where these events have been most concentrated.

Reasons for the settlement of existing populations in the villages of the Western Zone are related to the major historical phases and chronology of the region. Settlement history as reflected in the four village research sites of the Western Zone reveals that the vast majority of indigenous ethnic groups settled in the current sites during the last century. Moreover, throughout the nineteenth century (dates which correspond to the first village settlements), major events upset the balance of West African societies.

These include:

- The ongoing slave trade which kept pushing coastal populations further inland. It is said that this trade fostered tribalism and instability which led some chiefs to get rich byselling prisoners.

- Religious wars (Djihad) and/or conquest wars resulted in the out-migration of animist populations living nearby large Islamic Sahelian cities. The struggle for influence between

Tidjani and Kadiriya is one of those religious wars. Let us mention some famous warlords such as Cheikou Amadou and El Hadj Omar Tall (Ki Zerbo 1978).

- Besides these wars, there were those of the Dioula kingdom of Kong, the Senoufo kingdom of Sikasso and the wars of Almamy Samori Touré and his lieutenants (ibid.).
- Colonial penetration along with resistance movements and upheavals.
- The far-ranging, peaceful Dioula "revolution" which contributed to bond societies together and create some socio-political and economic dynamism. This "revolution" was responsible for the development of trade in places remote from roads.

Later, there were other events such as colonial violence, saturation of arable land in some overpopulated areas, and several droughts and other natural catastrophes, resulting in famines and other calamities and which led other groups to join the first settlers.

Immigration in the Western Zone of Burkina started a long time ago. According to some surveys (Remy 1977), immigration started during the French colonization with single runaways, but later entire families escaped the many demands of the administration (e.g. forced labor and heavy taxes)

Old refuge areas were then converted into settlement areas, while some other zones in the West underwent diffuse penetration (REMY 1977). While migrations were political in the past, current migrations for agricultural purposes are becoming more frequent as the degradation of Burkina Faso's Northern and Central Zones advances.

According to a recent survey by Alfred Schwartz (1991), among a total of 4,112 migrant heads of farming units surveyed in 1990 (extrapolating to 40,503 heads nationwide):

- 8.2% arrived during the 1960's,
- 28.7% arrived during the 1970's, and
- 48.7% arrived during the 1990's.

IV. SOCIO-ETHNIC AND CULTURAL DIVERSITY AND THE EXTENSION OF AGRICULTURAL INNOVATIONS IN WESTERN BURKINA FASO

The low population density per unit of arable surface area in the Western zone and consequently the low density on agricultural land have attracted agriculturalists and pastoralists originating from less fertile zones of the center and north of the country. (Table 1)

Table 1. Agricultural and population statistics for Western Burkina Faso

Statistics	Burkina Faso	Region Zone West	Dimolo	Kawara	Kayao	Yasso
Total Area	274,000. km^2	93,730. km^2	68 km^2 (6780 ha)	64 km^2 (6368 ha)	81 km^2 (8.050 ha)	46 km^2 (4.600 ha)
Total Arable Surface Area (ASA)	89,150 km^2 (33% of the territory)	35,600 km^2 (38% of the zone)	28 km^2 (40% of the total area)	26 km^2 (40% of the total area)	33 km^2 (40% of the total area)	37 km^2 (40% of the total area)
Area Cultivated	25,000 km^2 (28% of the national ASA)	7.950 km^2 (22% of the ASA of the zone)	11 km^2 (39% of the ASA)	25 km^2 (97% of the ASA)	10 km^2 (32% of the ASA)	28 km^2 (78% of the ASA)
Total Population	9,000,000	2,000,000	1002	1186	2262	2752
Population Density	33/km^2	28/km^2	15/km^2	19/km^2	28/km^2	60/km^2
Rural Population	8,280.000	1,840.000	1002	1186	2262	2752
Agricultural Density (pop/area cultivated)	331/km^2	251/km^2	95 km^2	48/km^2	218/km^2	96/km^2

The massive inflow of migrants of mostly Mossi and Peuhl origin in search of new cropping and grazing lands and numerous droughts have affected the conditions under which agriculture is practiced in many parts of the Western Zone.

All of the Western Zone bordering the Central and Northern parts of the country has undergone real population, economic and ecological changes due to migrant settlement. Extensive land clearing, modernization of agricultural techniques (causing yields to rise but also surface areas to grow), and the introduction of cotton are some factors which have transformed the farming systems in this subzone.

The current situation in the Western zone reflects the history of the region as discussed earlier. It is noteworthy that there is an acute ethnic segmentation in the area and a tendency toward a population equilibrium disadvantaging the indigenous community. (Table 2)

Out of 63 ethnic groups in the 1990 census in Burkina (7), 35 are considered indigenous to the Western Zone. In addition, there are migrant ethnic groups present in the area.

The Mossi ethnic group, originating from outside the area, has the greatest representation population-wise according to a recent 1991 survey by Alfred Schwartz (op. cit.).

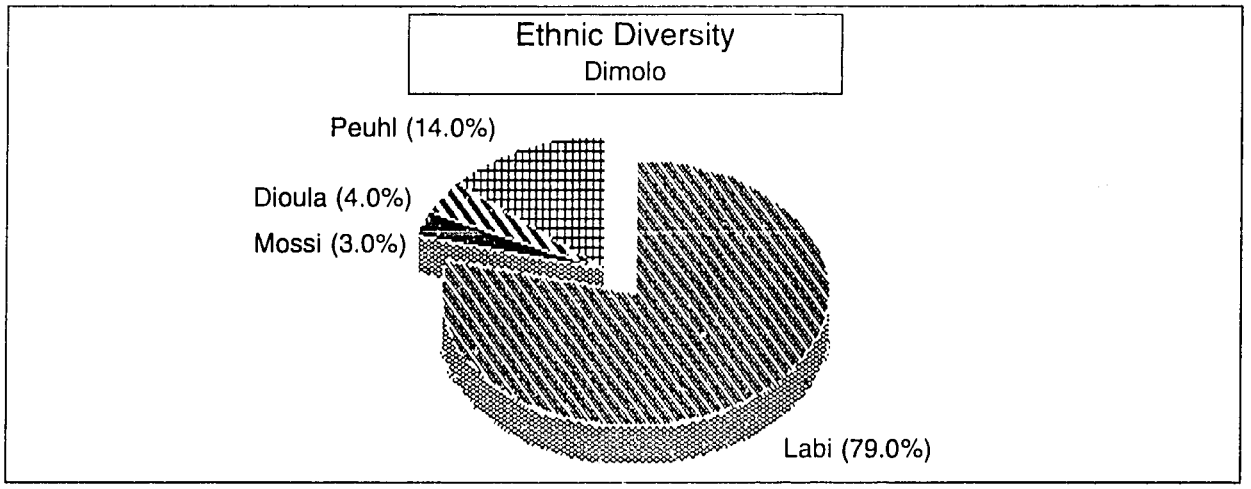
Table 2. Ethnic groups of Western Burkina Faso

Ethnic Group	National Population 1985 (%)	Population In The Western Zone 1991 (%)	Dimolo 1990	Kawara 1990	Kayao 1990	Yasso 1990
Mossi	49.0	22.3	03.0		58.0	21.0
Bwa	02.1	16.7			22.0	
Bobo	02.2	11.1				
Senoufo	01.4	07.1		30.0		
Dagara	03.0	07.8			08.0	
Peuhl	07.5	06.5	14.0	02.0	12.0	08.0
Marka (Dafing)	01.7	03.4				59.0
Samogho	00.1	02.2		14.0		
Dioula	00.5	01.4	04.0	34.0		
Dogon	00.3	00.3				11.0
Natioro	00.03	00.03		20.0		
Lobi	01.8	01.8	79.0			
Other	30.2	19.4				01.0
Total	7,965.000	1,184.935	1002	1186	2262	2752

Furthermore, agricultural migrations have often promoted local change. Migrants having left a degraded zone have shown themselves to be more open to change.

Agriculture in the Western Zone, in spite of its low labor and land productivity, is rather better off than the rest of Burkina Faso. Located in the Sudanian agro-climatic zone, the Western Zone has the highest annual rainfall in the country — ranging from 800mm to 1200mm.

These realities contribute to the demographic and cultural differences among villages. Apart from a few exceptions, agriculture in the West can or could provide self-sufficiency in food production to local populations. How can differences between self-sufficient and other villages be explained? How can we account for the fact that in a given village some farms perform well while other cannot organize their agricultural activities more efficiently?



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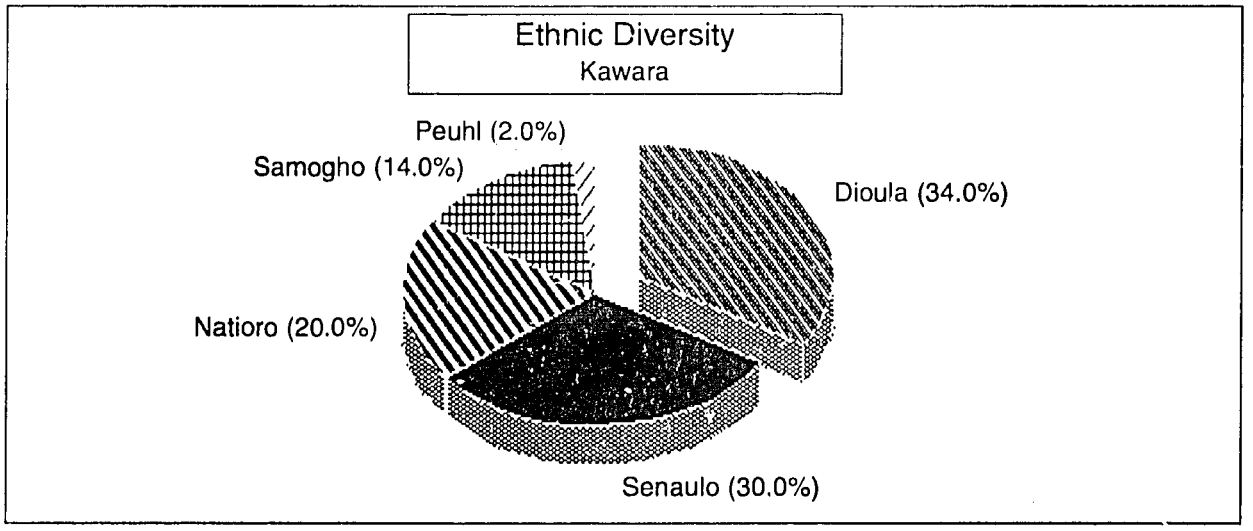

Figure 2

Explanations for inter- and intra-village differences raises another issue: How can the needs of diverse groups of farmers be fulfilled?

Diagnostic studies are designed to understand plant and livestock production systems in villages, and to identify potentials and constraints in their agro-socio-economic environment. This yields a global perspective on differences between and within villages. As this diversity is better known, chances are increased that specific needs will be met more appropriately.

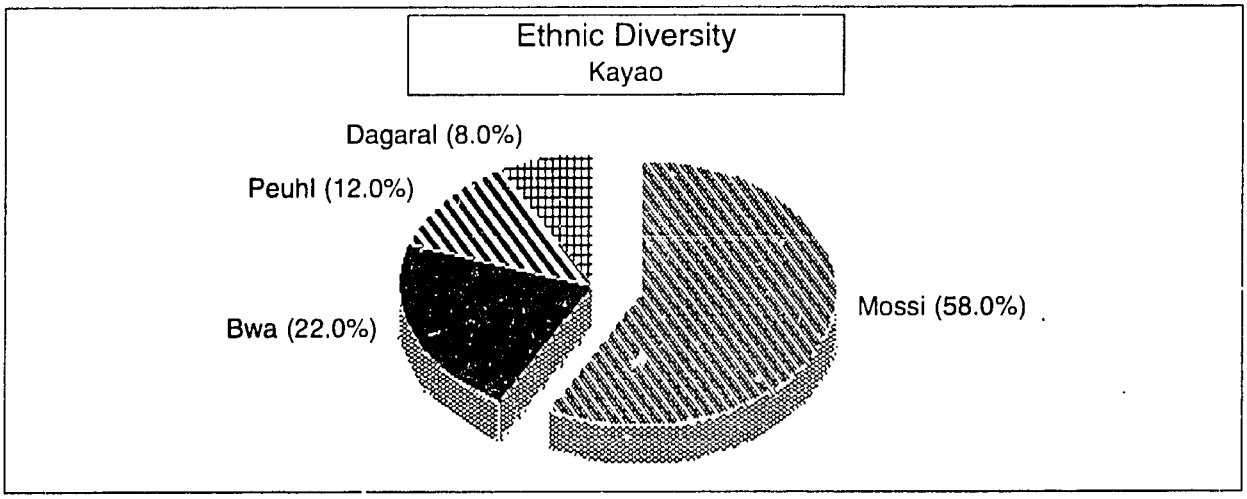

Figure 3

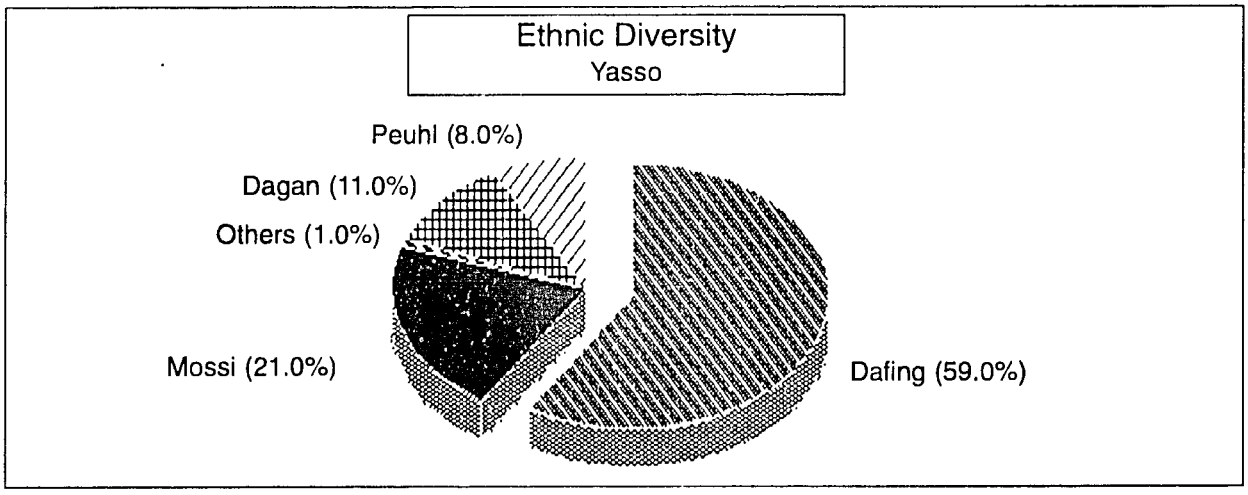

Figure 4

One of the difficulties in extending agricultural technologies in a rural environment is undoubtedly the identification of an appropriate approach.

In recent times, at least four extension systems have been implemented at a national scale and specifically in the Western Zone:

1) diffuse support with unplanned activities based on leading farmers;

2) close and highly individualized support, that is fairly similar to the above;

3) the "training and visit" system supported by the World Bank which encourages extensionists to work with groups and follow up activities in the field; and

4) the current Burkinabè extension system which combines the "training and visit" system and national realities as officially stated by the head of agricultural extension services and the Ministry of Agriculture and Livestock.

The operating principles of the Burkinabè extension system can be summarized in the following way:

- Support of farmer working groups to have them organized in village pre-cooperative groups.

- A clear program of activities which should include:
  - working group activities
  - farm follow-up and visits
  - management board meetings.

- Extension tasks thus include working in groups in on training in crop fields and on "training herds," and farm visits and follow-up.

How should extensionists go about transferring new know-how to a maximum number of farmers when they enter a village?

A common pitfall is that extensionists have failed to select adequately their partners. In several standard approaches their shortcomings are revealed:

- The extension agent chooses to work with older farmers in the hope that their wisdom will convince younger, more skeptical ones. In reality, these old farmers often are not open to new technical themes.

- The extension worker chooses to work with the younger farmers hoping their openness will spread to others. However, young farmers are often marginalized in the village level and within the household where they do not have much authority.

- Another approach has been to choose farmers according to the geographic location of their fields, which facilitates group formation. Nevertheless, farmers' interests fades as technical themes are proposed which do not concern them directly.

Therefore, a trend has been to work with ethnic groups which are "natural" groups.

Which is the best way? What type of groupings should be used to extend technologies?

V. THE RSP WESTERN ZONE APPROACH

Typology as a Tool of Extension. It should be noted that the RSP Program is not limited to merely extending agricultural innovations but rather to:

- studying farming systems and identifying development constraints according to environmental factors;

- designing and proposing innovations that will do away with or alleviate the identified constraints;
- assessing and improving these innovations in concert with thematic research; and
- providing a functional link between research, development and production.

As we have seen earlier, the extension of innovations is in itself a major constraint. Therefore, even though it does not represent a specific objective of the RSP Program, its failure ends up jeopardizing the entire RSP approach. Consequently, classifying zones, sub-zones, villages, and farms takes on a fundamental importance. One looks for similarities in the prospect of extending scientific results in the medium or long term. Classification or typology is, in this light, a particularly important extension tool.

Within the general approach of the RSP Program, moving from one level of knowledge to another always calls for some classification effort. First, the country was zoned in more or less homogenous regions in their physical, human and climatic characteristics.

Then, a sub-zonation was done which in the context of the Western Zone allowed for a sample of forty villages to be classified in four agro-climatic sub-zones and for the selection of four villages as research sites.

Farm classification (or typology) led to the classification of villages according to more precise criteria related to available resources and farming systems. This typology should give way to an efficient categorization of farmers for extension activities.

The objective of this classification is to sort farmers according to criteria which have particular significance at the village level. These classifications, which will inevitably gain in richness as knowledge of production constraints in the village expands, help to target activities adapted to each farmer group. As a result, it is believed that technical themes will be better understood because they will meet felt needs. At any rate, furnishing the results obtained at each stage to farmers and discussing with them the constraints and solutions to be adopted contribute to the development of the kind of trust that is necessary to the continuation of field activities.

Choice of Variables for the Typology: Village Level. Results of studies summarize a few major variables which differentiate the village sites (Table 3).

Table 3. Typology Of Villages In The Western Zone

Variable	Type "A"	Type "B"
Population density	low	high
Presence of migrants	low	high
Cultural setting	domination by a single cultural group	multicultural with a competitive style
Cotton production	absent	present
Integration of livestock and agriculture	weak	strong
Market orientation	internal	external
Most important factor of production	work measured by labor	capital and work measured by animal traction
Variable for differentiating production units	ratio of workers to the population of the production unit	use of equipment for animal traction
Secondary variable for differentiating production units	number of head of cattle	status of production unit head (migrant/indigenous)

Criteria for grouping villages include:

1) Population size: It was noted that the size of the village population is a determining factor in its social and economic dynamism.

2) Settlement type: The existence or absence of relatively recent migrants accounts for this dynamism. Migrants are often very dynamic and population size and make-up is related to settlement type.

3) Evolution of traditional institutions: Whether traditions are conservative or not is essential in the understanding of each village's dynamism. Generally, the existence of imported religions (Islam or Christianity) and their degree of adoption make it possible to measure conservatism or the extent to which local traditions have changed.

4) Crop type: Whether cotton is present or not in the cropping system indicates the level of extension of agricultural technical themes in general.

5) Integration of livestock and agriculture: The integration of livestock and agriculture (as evidenced by animal traction or/and the use of manure) is an indication of the level of technical and economic change.

6) Economic dynamism: The existence of internal vs. external market orientation is a meaningful indicator of the village's development potential.

Choice of Variables for the Typology: Production Unit Level. After characterizing villages into two types, A and B, knowledge was gathered on individual family farms of each type. In each village type, the most discriminating variables were identified.

In villages of type A, the animal traction criterion is not yet discriminating. Farms in each village type are characterized according to other variables in order to respect local contexts. In the future, it is hoped that the same variables may be used in all villages as type A villages evolve toward type B villages (Tables 4 and 5).

Table 4. Typology Of Production Units Type "A"

Type of Production Unit	Dimolo N=94	Kawara N=106
Type 1: Favorable ratio (labor force:population of the production unit) and important role of livestock production	06%	05%
Type 2: Weak ratio and important role of livestock production	03%	06%
Type 3: Favorable ratio and minor role of livestock production	1%	07%
Type 4: Weak ratio and minor role of livestock production	11%	07%
Type 5: Favorable ratio and the absence of cattle	44%	47%
Type 6: Weak ratio and the absence of cattle	43%	16%

Table 5. Typology Of Production Units Type "B"

Type of Production Unit	Kayao N=71	Yasso N=86
Type 1: Indigenous with animal traction	13%	33%
Type 2: Migrant with animal traction	25%	25%
Type 3: Indigenous, partially equipped for animal traction	—	04%
Type 4: Migrant, partially equipped for animal traction	04%	05%
Type 5: Indigenous without equipment	15%	17%
Type 6: Migrant without equipment	43%	16%

Using the Typologies in Research. The village and production unit typologies have served the program well for three years. For example, the village typology was used to understand differences in the answers given by heads of production units on their aspirations and needs. Thus, aspirations and needs vary by village type. A major need identified by producers in type A villages, for example, is "cash." In type B, by contract, producers identify "animal traction equipment" as a primary need (Table 6).

Table 6. Stated Priority Needs Of Heads Of Production Units

Need	Dimolo N=43	Kawara N=43	Kayao N=67	Yasso N=71
Money	68	51	09	15
Agricultural Equipment	02	21	52	54
Means of Transportation	02	19	07	13
Food	07	05	10	03
Lodging	—	—	05	04
Medical Care	05	02	02	03
Improved Crop Varieties	—	02	—	—
Water	05	—	06	—
Training	—	—	—	—
New Lands	—	—	02	—
Wife	—	—	—	03
Cattle	02	—	—	01
No Response	09	—	07	04

It has also been determined that there is a clear difference between the types of villages in their daily consumption of cereals (Table 7).

Table 7. Daily Consumption of Cereals (in Grammes)

Quantity	Dimolo	Kawara	Kayao	Yasso
Average	592	400 (without rice)	744	714
Minimum	182	118	318	137
Maximum	971	1000	2100	1400

Tests of Agricultural Innovations. The use of the farm typology has proved most useful in the trials of agricultural innovations in the two village types.

In type A villages, innovations proposed included:

- trials of agricultural intensification, for cut and clear cultivation still prevails in this area of land abundance and low population pressure;
- trials preparing for the introduction of animal traction, e.g., seeding in line;
- mineral fertilizer and pest control trials; and

- short cycle improved varietal trials.

In type B villages, new maize, sorghum and rainfed rice varieties were proposed to some farmers according to constraints and potentials encountered. Fodder plots and fodder supplementation trials were proposed to some pastoralists. Soil fertilization, improved fallow, and cotton/cereal crop rotation trials as well as trials for the optimal use of traction equipment were proposed to some farmers.

Farmer participation in the decision-making process occurs in "feedback sessions" (restitutions) in which innovations intended to alleviate identified constraints are proposed according to farm type. These propositions are then discussed with farmers who volunteer to test them. The "feedback sessions" are important occasions in the RSP approach because they are a time for researchers and farmers to discuss results of the past agricultural campaign and to make decisions for the next one.

VI. ROLE OF SOCIOLOGY

One of the weaknesses attributed to the sociological study of change is its inability to predict events (Rocher 1973). Is it a methodological inability which precludes the identification of rules of change? Or is it a lack of proper reasoning about individuals' behavior which nevertheless is central to social change?

Is the meaning that individuals assign to their actions not important for understanding social change, as Max Weber argued? Does one need to support Weber's conception or that of Talcott Parsons in the Chicago School (school of social actions) who emphasize man's role in social change? Or should one rather go by the evolutionist theories of A. Gunderfranck and many others who regard the world as a sequence of societies which precede each other and in whose opinion economic development follows a series of stages.

According to Crozier and Frieberg (1977), "organizational analysis of roles has an important limitation which lies in the unique problem of adaptation. Individuals are therefore spokesmen of structures and are conditioned by their roles. Any form of "deviance" is abnormal, even pathological. It is due to a misconception or a poor understanding of the role, that is, in short, a malfunctioning of the whole: conditioning is the rule."

So it is for any macro-sociological analysis of social change. To avoid these difficulties which belong to the realm of reason and to provide individuals with the status of autonomous actors whose behavior is the product of their freedom, as limited as it may be, one needs to shift the problem toward the concept of play. Game, as writers say, is the instrument people have established to regulate their cooperation. It is an essential instrument of organized action.

Game reconciles freedom and restraint. The player remains free, but if he wants to win, he has to adopt a rational strategy according to the nature of the game and has to respect its rules. This means he has to accept the imposed constraints to pursue his own interests.

Within the definition of strategic analysis presented by the authors of "l'Acteur et le Systeme" (Crozier, et. al. ibid.), it should be noted that:

- Evolutionism and determinism are rejected. This means that, in their sense, there is no outside principle in the action of change.

- The idea that change is the result of an enlightened outside power is also rejected.

- They also discredit the conception that change is the natural result of social struggle, social struggle being an element of change but not a one-way relationship (linear causality) for change. Social struggle, in this perspective, does not consist in one of the actors having all the power. Rather, there are power conflicts which indicate to various degrees the idea of competition for winning the social game.

Furthermore, acknowledging the fact with G. Balandier or else A. Gunderfranck that there has been an abundant yet sterile literature on development — with many critics but few propositions — and that it was characterized by Western ethnocentric and evolutionist patterns, we have attempted to understand social relations between individuals, social, and other interest groups through strategic analysis as a sociological approach.

In this approach, the understanding of social actors who are empirical realities will help in the analysis of operational systems defined by the frames, structures and rules of the game acknowledged by the players.

This implies that strategic analysis is part of a larger reasoning framework, that is a system-oriented way of reasoning which relies on a sort of system causality, whose causes and effects are inextricably linked. A sound knowledge of all aspects of a social system is always necessary to understand and predict social actions.

VII. GENERAL CONCLUSION

It is claimed that the approach consisting of knowing farmers' objectives, in understanding their strategies, and in analyzing them according to the physical, socio-political, and socio-economic environment in an iterative manner is a valid extension methodology to present local development agencies vith in spite of its heaviness.

During the three years of research on farming systems in the Western zone of Burkina Faso, our program has used several methodological tools to understand farmer strategies and objectives, their aspirations and objectives, and to propose small scale innovations.

Extension of agricultural innovations in Burkina Faso's Western zone should take into account available results from systems research as well as specific characteristics of the zone.

The regionalization of the extension system captures human potentials and constraints in the area; for, as it has been said, social and human diversity calls for diverse measures.

Therefore, the extension system will become more dynamic through the combination of:

- Village diagnostics leading to a farmer typology. In turn, this will allow technical themes that are built around the specific needs of each group to be better adapted to various environments.

- Effective participation of all farmers: young, resource-poor or rich, male or female, to take into account all the cultural and socio-economic factors of the farm.

- Effective link between extension and agricultural research in the Western Zone to bring about solutions to diagnosed constraints.

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Collaborative Agricultural Systems Research in Burkina Faso 1992

E. Robins, P. Sanou, S. Ouédraogo, and D. Ilboudo

I. INTRODUCTION

The principle of collaborative research is widely recognized in Burkina Faso's Institute of Agricultural Research and Studies (*l'Institut d'Etudes et de Recherches Agricoles* or *INERA*). A limited number of collaborative actions have been realized between the Production Systems Unit (RSP) and other research programs and development entities. Thematic and systems researchers especially hold different points of view about how research should be conducted.

Part of the mission of the RSP program, one of eight programs within INERA[1], is to collaborate effectively with thematic research programs. RSP was established in 1985 to orient other research programs to the realities of the village milieu. RSP adopts a *systems* approach which integrates the sectorial approaches of thematic research. RSP's integrative role is revealed by its position in the INERA structure: it is a "horizontal" program, traversing each thematic ("vertical") program.

RSP is also expected to play a major role in interacting with development entities, particularly the agricultural extension service and NGOs. RSP serves both *research* and *development* functions. Each year RSP organizes in-country training for senior technicians (*TS*) of the extension service based on a needs assessment prepared by the service itself. These short courses may involve a researcher from any INERA program who, over a 2-3 day period, covers a selected topic (such as diagnostic methods, water and soil conservation, or cereal pathogens). This arrangement permits RSP to influence the way extension conducts itself vis-a-vis the rural producer. However, follow-up with extension personnel only sometimes occurs. Also, extension follows the *Training and Visit* method which conflicts in some important ways with RSP's methodology.

This paper discusses the recent efforts of the two largest RSP programs (Center and West) to collaborate with thematic research and development. Some of the problems encountered and possible solutions to them are discussed.

II. RSP AND THEMATIC RESEARCH

Different conceptions of how to adapt technology and conduct research have blocked collaboration between thematic researchers and RSP. Thematic research typically views RSP as a means of validating in producers' fields innovations developed on-station. Thus viewed, RSP serves thematic research. When innovations perform poorly on-farm, thematic researchers frequently hold the producer responsible (i.e., failure to devote the necessary resources -- labor or capital -- to the

[1] The eight INERA programs are: RSP; ESFIMA (Water, Soils, Fertility, and Machinery); SOMIMA (Sorghum, Millet, Maize); rice; cotton; market crops; animal production; and grain legumes.

technology). In this perspective, RSP should change producers' attitudes and practices to remove the "producer-constraint."

In contrast, RSP itself emphasizes diagnosis of the real milieu and informing thematic researchers of producer priorities and constraints. Innovations developed by thematic research should, to some extent, respond to the conditions of the real milieu and be tested in it. RSP monitors the performance and impact of tested innovations and feeds back results to thematic research for further refinement on-station or on-farm.

The disagreement about the organization of research is also revealed in different perceptions about the researcher-producer relationship. Thematic researchers generally begin with the knowledge and priorities of researchers. By contrast, RSP begins research planning with diagnostic studies. It identifies problems and solutions with producer families and communities based on the experiences and knowledge of villagers themselves.

How can RSP implement its role within INERA given this state of affairs? Two approaches are being taken by RSP at the present time: 1) to collaborate with thematic researchers who are interested in an applied problem; and 2) to contract with thematic programs on a project. Through this process, RSP intends to increase the appreciation among collaborating thematic researchers of on-farm conditions and constraints and to implement the farmer-first research dynamic. By the same token, RSP may learn to feed back information more effectively to thematic research while listening more carefully to their interests and concerns. Successful collaboration should encourage yet more collaborative research with thematic programs.

Among the collaborative efforts underway in 1992 are: an on-farm test of cultural techniques and varietal resistance to mildew on millet (with SOMIMA); a study of the conditions for the development and transfer of short cycle rainfed and irrigated rice in zones where declining rainfall has witnessed the cessation of rice cultivation (with RICE); a survey of the extent and uses of animal traction in the cotton zone of western Burkina (with ESFIMA); a study of the uses of fallow and the effects of bush fire on fertilization (with ESFIMA); a watershed management study (with ESFIMA); and a diagnostic survey of on-farm trees and their uses (with IRBET, a sister institute of INERA under the umbrella of the National Institute of Scientific Research). In each case one or more RSP researchers works with one or more researchers outside the RSP program. These efforts will include collaborative analysis, interpretation, and reporting of research results. These projects will illustrate the benefits of addressing applied problems in a collaborative manner.

One example of the results of collaborative research is between geographers of the remote sensing unit of INERA and RSP scientists. The products of this effort -- maps portraying lineage occupation and use, and the character of village land -- is proving to be of value to researchers with diverse research interests. This successful demonstration of multidisciplinary collaboration should stimulate other collaborative work within INERA.

III. RSP AND EXTENSION

Two elements predominate in the conception of this linkage: training and the widespread testing of promising innovations. RSP is mandated to manage a training program for senior technicians of the extension service. Courses are offered by INERA researchers in response to a list of subject areas prepared by the extension service. RSP is responsible for conducting courses on methods of diagnosing constraints to production systems. The technicians' competency in this regard is currently in need of further development. Experience has shown that the skills levels of *TS* are extremely varied -- some require instruction in fundamental calculations (such as computing averages) while others are more capable and ready to learn computer applications. A thorough, objective assessment of the skills of these agents has not been undertaken.

Training programs have had an ad hoc character. They are often announced late and trainer preparation for them is insufficient. Trainers rarely conduct follow-up sessions in the classroom. Follow-up in the field is infrequent. Complicating this situation is the hierarchical manner in which extension relates to the producer according to the *T and V* method. *TS* are poorly prepared to value farmers' technical knowledge or engage them in open dialogue.

Widespread testing of innovations which issue from RSP research sites, the second element in this collaboration, has not yet occurred. RSP has identified innovations to submit to extension. However, poor communication between RSP and extension and logistical problems limiting the movement of researchers and agents has seriously impeded development of the research-development linkage. This deserves the attention of both RSP and the extension service so that the liaison between research and development will be more effective.

RSP has asked INERA to reexamine its contract with the extension service as a first step in improving the working relationship between the two structures. In particular, RSP must join extension in a review of training needs of *TS* and prepare a more targeted program to address them.

Some effort is already being made by the RSP-West team to strengthen the RSP-extension link through instruction in diagnostic methods and joint visits to field sites at the start of the campaign (to review the previous year's results and the research program for the coming year) and again later in the year to see what progress has been made. It is this kind of action which is needed on a larger scale to correct existing weaknesses in the RSP-extension relationship.

IV. RSP AND NON-GOVERNMENTAL ORGANIZATIONS

RSP is expected to play a role in both research and development. RSP should assist development entities in monitoring and evaluating their activities in the rural milieu. RSP should also use the experiences of NGOs in better diagnosing the local milieu. At present, the relationship with NGOs is superficial.

There are basic actions which RSP could take at the present time to work more closely with NGOs. RSP can distribute annual reports to NGOs active at RSP research sites. RSP can prepare and

distribute technical manuals (e.g. "How to Conduct an Evaluation Survey"). RSP can meet periodically with NGOs to review current experiences at research sites. A recent example concerns Foster Parent Plan (PPIB) at Boulsa.

PPIB has been operating small projects in literacy, health, and resource management for 10 years at Donsin, an RSP village research site in the eastern Central Plateau. By their own assessment, PPIB claims these projects have not been as successful as hoped for because local populations have not taken charge of them. PPIB has not conducted formal evaluations of their activities at Donsin, according to their Acting Director, because they "lack the knowledge" of how to do so. Nonetheless they continue to operate programs in Donsin and would like to improve their effectiveness.

The experience of PPIB is instructive for RSP. RSP has experience in evaluating its own activities in the field and has prepared technical reports describing methods and results. The reports have not yet been distributed, however, so that others might benefit from adapting RSP's methods.

RSP is currently assisting PPIB at Donsin in monitoring the results of erosion and water control dikes built in producers' fields. RSP researchers pass by the test sites to witness what is happening and to discuss results with producers. This is an effective collaboration insofar as PPIB gains input from research scientists and RSP has the opportunity to follow innovations being tested at their village sites.

V. CONCLUSION

Collaboration among research and development entities is generally regarded as desirable and necessary in Burkina Faso. Yet concrete cases of productive collaborations are rare. RSP is a program squarely at the crossroads of collaboration, interacting as it does with thematic research, agricultural extension, and local non-governmental organizations. Moreover, RSP's approach is multidisciplinary and holistic, necessarily requiring collaboration among a diverse group of actors. Thus, RSP must play the principal role in seeing that collaboration between research and development takes place.

RSP has begun to take initiatives to see that this occurs. Currently underway are joint field research activities with thematic researchers, an improved dialogue with NGOs, and a review of the relationship with extension. If these activities accomplish their goals, agricultural research and development in Burkina Faso will move more toward a "farmer first" approach. This has the potential to empower local populations and reverse the record of past agricultural research. By working from an existing base of producer knowledge, positive change and development can be realized.

Definition of New Intervention Zones of the R.S.P. Program with Geographical Information Systems (GIS)

Bakary Djaby, Michael Bertelsen and Souleymane Quédraogo

I. INTRODUCTION

G.I.S. systems are very powerful decision-making tools. They are based on indexed data on well-defined information layers. This very dynamic tool analyzes information by superimposing various layers. It is used in several areas to determine geographical zones based on common characteristics.

II. OBJECTIVE

The objective of the present study is to define new intervention zones of the RSP Program according to agroclimatic and socioeconomic criteria. To the extent possible, these zones have to be homogeneous in order to achieve better extension of research results.

III. METHOD

Criteria used in this study include:

- Rainfall
- Soil productivity
- Main crops: Cereals and cash crops
- Animal density
- Population density

Value classes for each factor correspond to observed realities.

Bio-physical factors. They are differentiated based on agroclimatic zones. The country is divided in 4 sub-zones of increasing annual rainfall from north to south (Figure 2).

Soil distribution data was based on soil productivity results for rice and cowpea. There is a low and a medium productivity zone including a particular situation in the Kénédougou Province (Figure 3). The superimposition of soils and rainfall divides the southern zone II within rainfall classes.

Farm factors included cropping systems and animal density.

Cereal and cash crops. The cotton and peanut zones as well as the small millet zone are presented (Figure 4). Other regions including the central region are characterized by the association of several crops.

Animal density. Based on this factor, the country is divided in two main areas. These include the central zone with very high bovine stocking density (density of 20 bovines and 38 small ruminants per km2 in over half of this area) and other regions with a low bovine and small ruminant density (Figure 5).

Population density is the only socio-economic factor taken into account in this study. Based on this factor, a zone of high density on the Central Plateau, a zone of medium density to the south and a zone of low density to the north and east (Figure 6) are identified.

IV. RESULTS

There are 4 intervention zones of the RSP program, namely the Sahelian, Central, Northwestern and Western Zones (Figure 7).

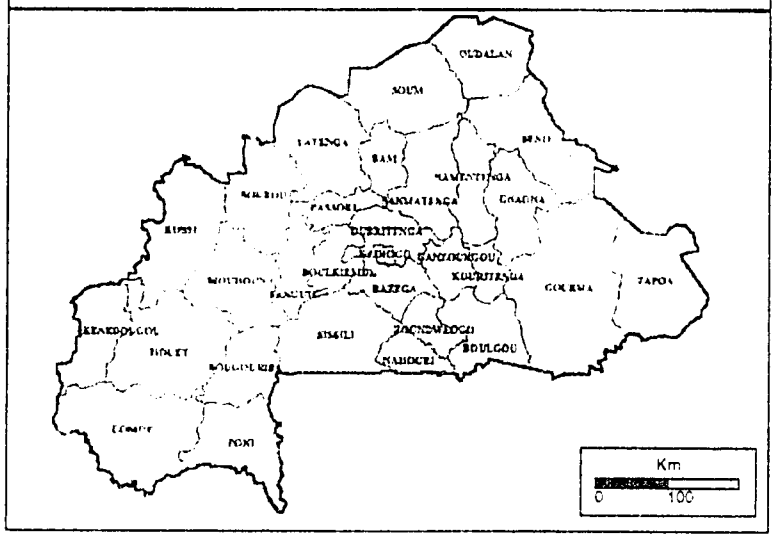
These identified zones, especially the Central Zone, remain heterogeneous for several factors (Figures 8 to 12).

Thus, the study identified the following 5 new zones and characteristics (Figures 13 to 18):

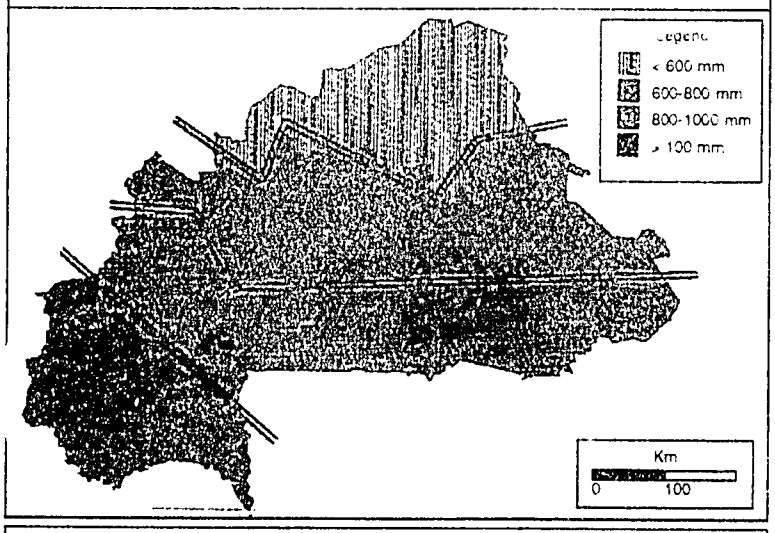
- Sahelian zone: Low rainfall and millet as the only cereal crop.
- Central zone: Very high animal and human densities and low rainfall.
- Eastern zone: Peanut as a cash crop and medium soil productivity. Low animal and human densities.
- Southern zone: This zone has better soils and higher rainfall than the Central zone of which it is traditionally part. Very high animal and human densities.
- Southwestern zone: Large cotton zone, good soils and high rainfall. Low human and animal densities.

1. Administration Map of Burkina Faso

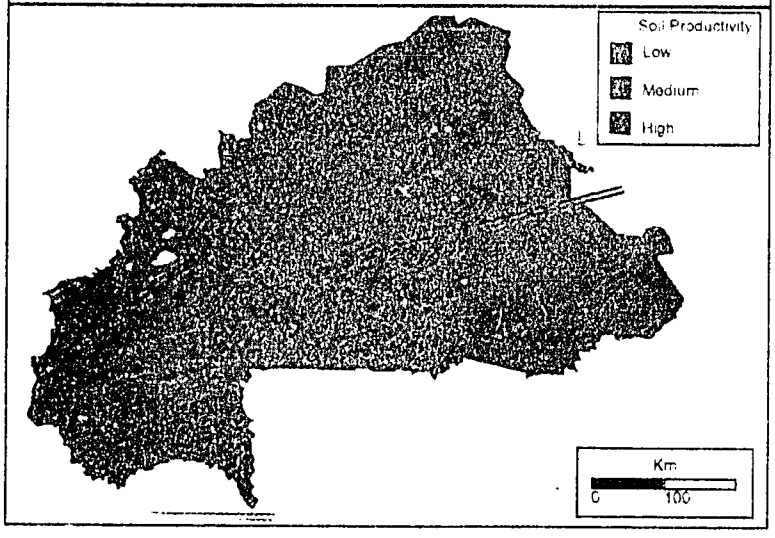
The 30 Provinces



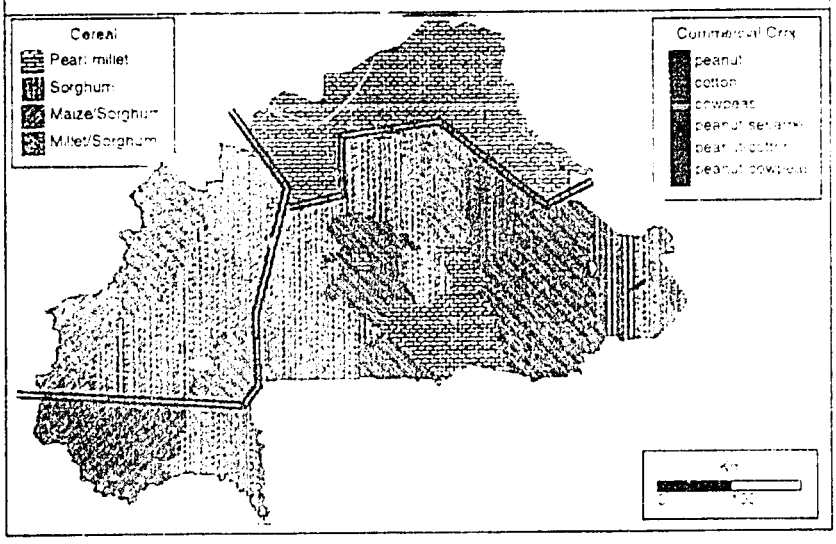
2. Annual Rainfall



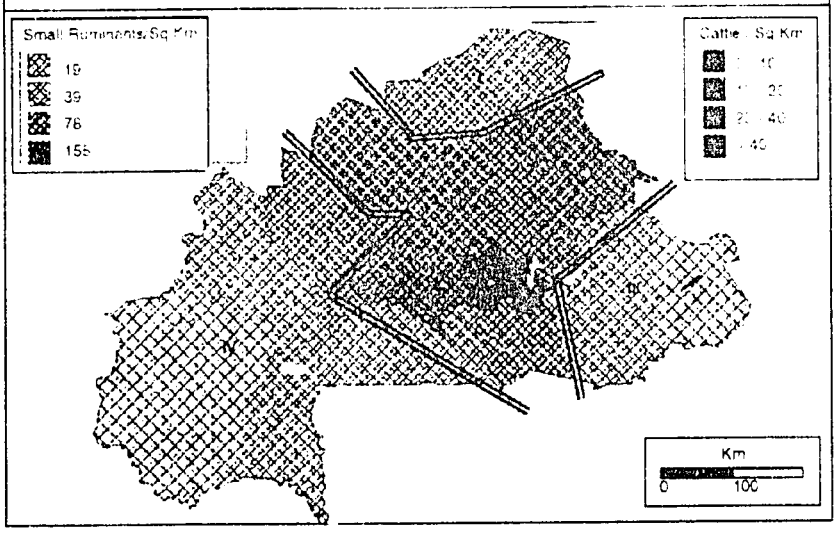
3. Soil Productivity



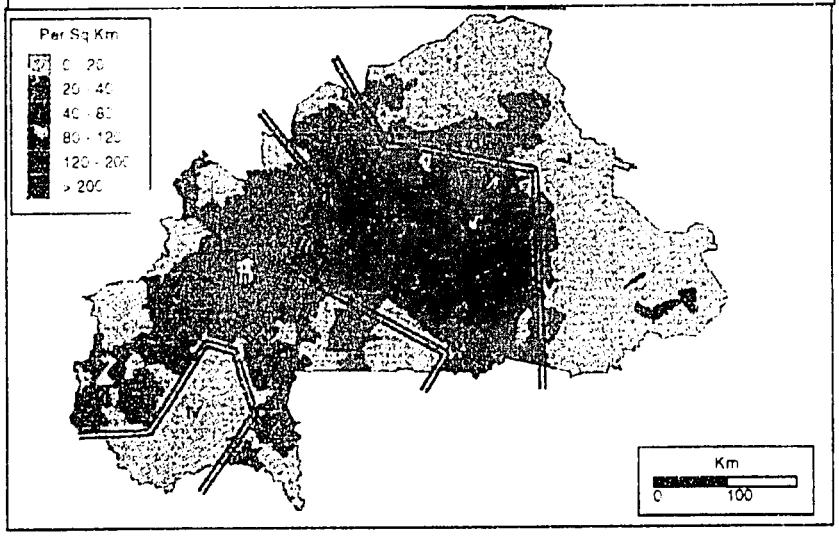
4. Dominant Cropping System



5. Animal Densities

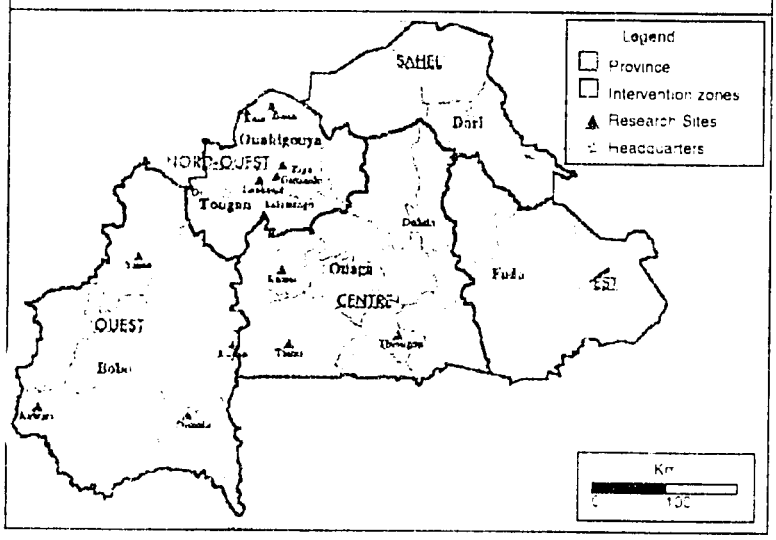


6. Population Density



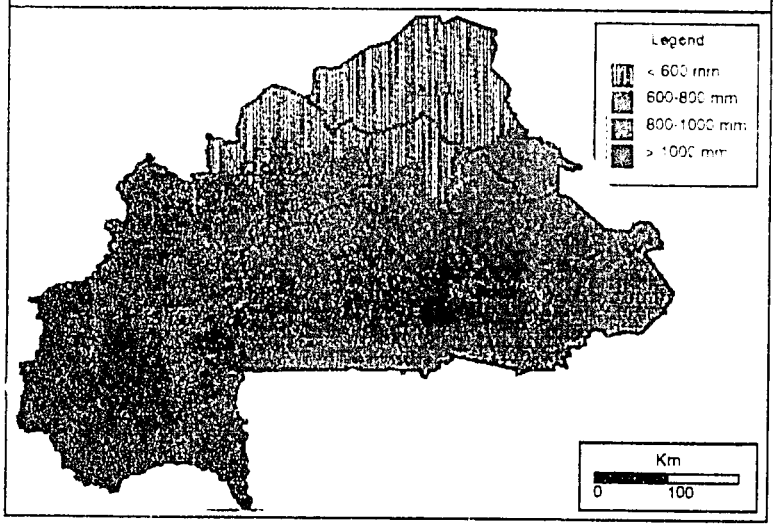
7. FSR Intervention Zones

Research Sites



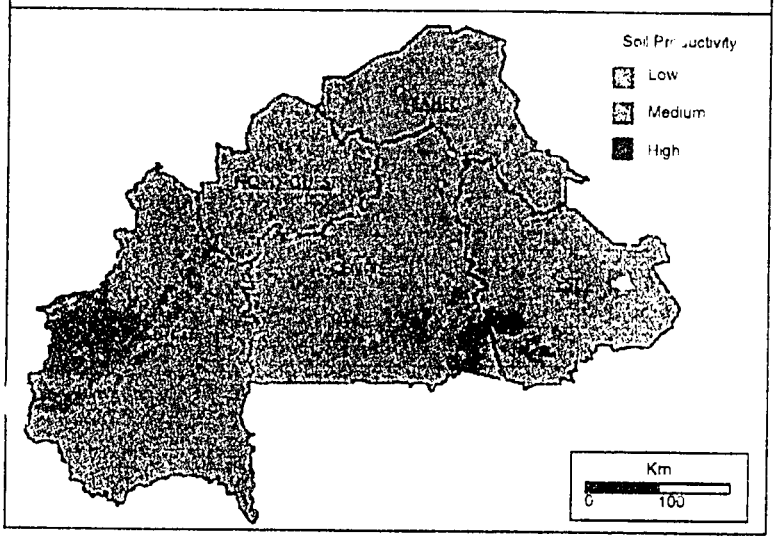
8. Annual Rainfall

Zones



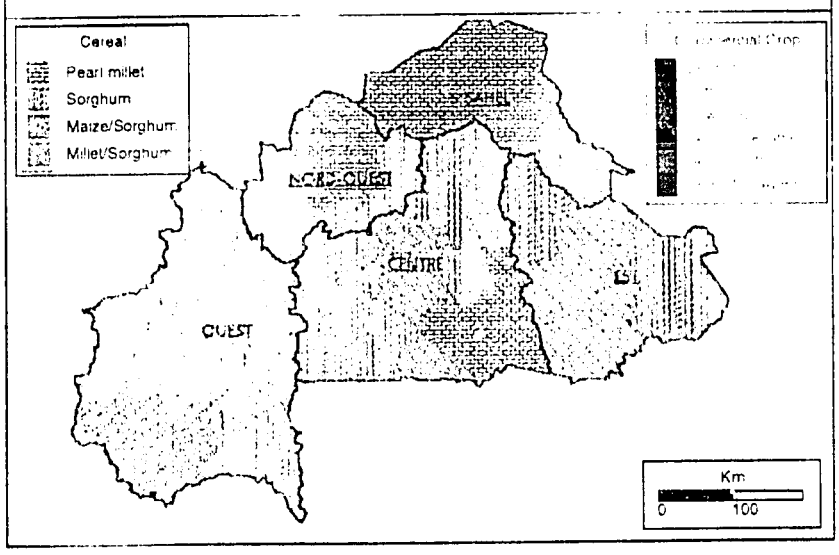
9. Soil Productivity

In the Present Intervention Zones



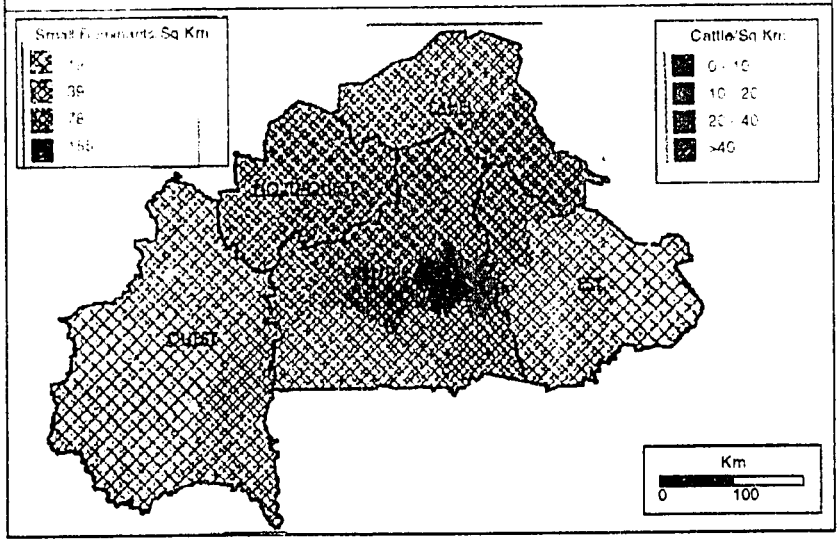
10. Dominant Cropping System

In the Present Intervention Zones



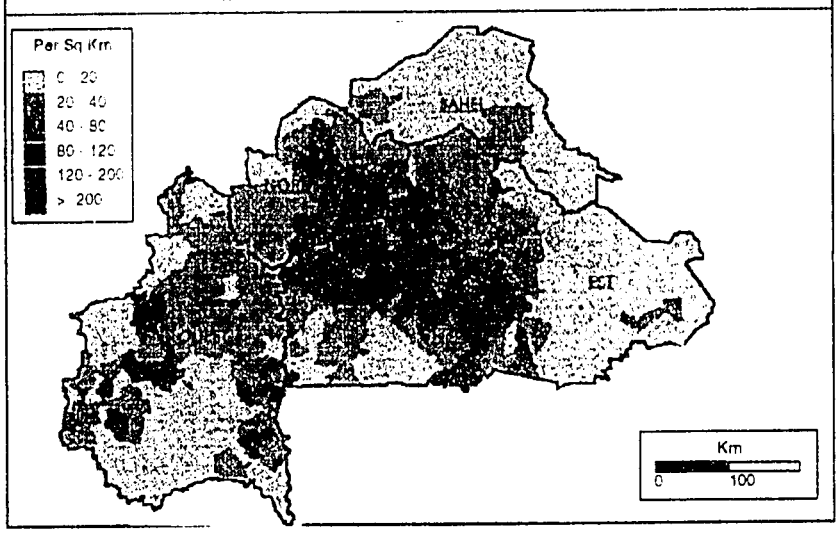
11. Animal Densities

In the Present Intervention Zones



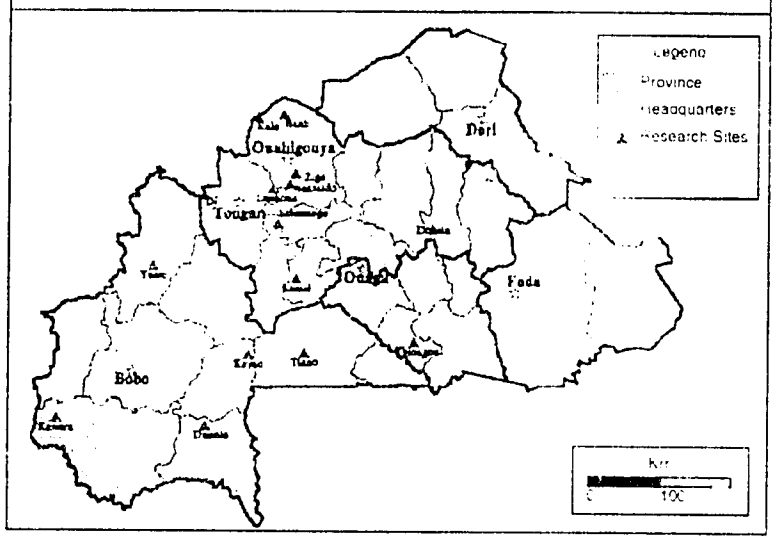
12. Population Density

in the Present Intervention Zones



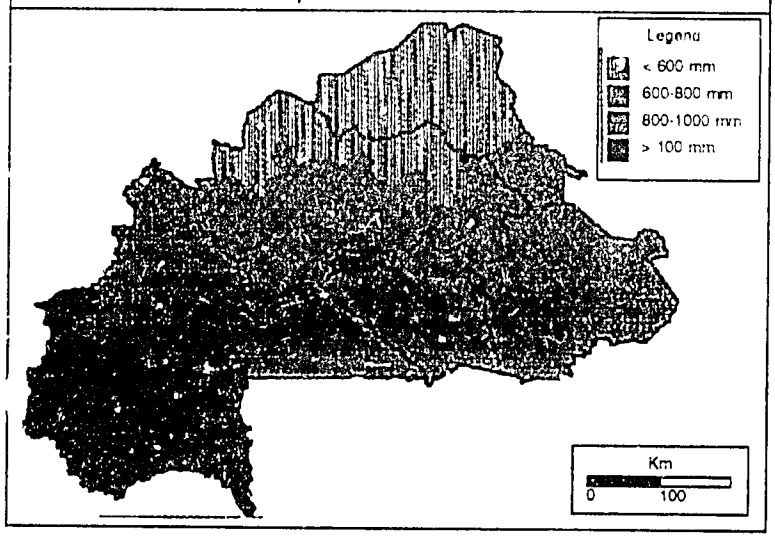
13. Proposed Intervention Zones

Research Sites



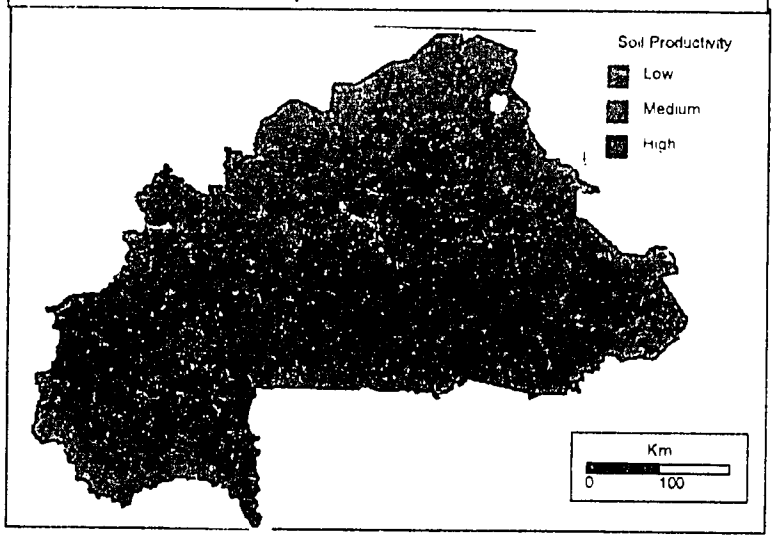
14. Annual Rainfall

In the Proposed Intervention Zones



15. Soil Productivity

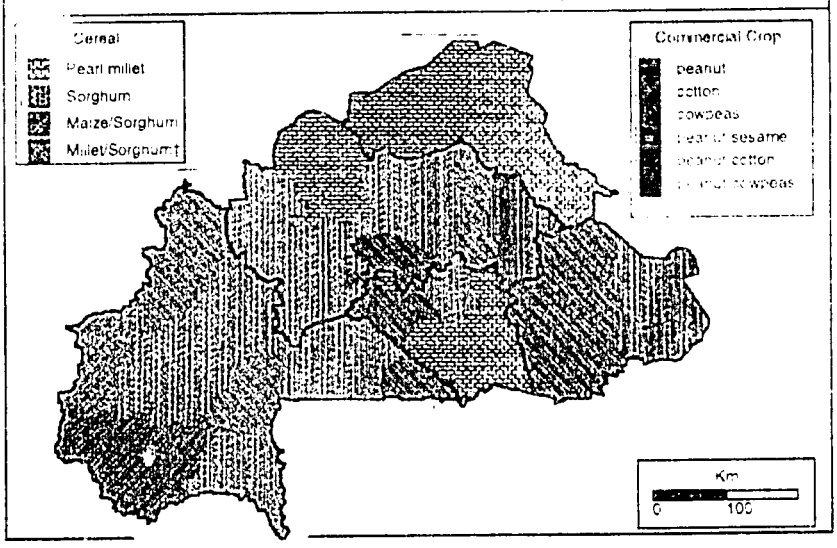
In the Proposed Intervention Zones



16. Dominant Cropping System

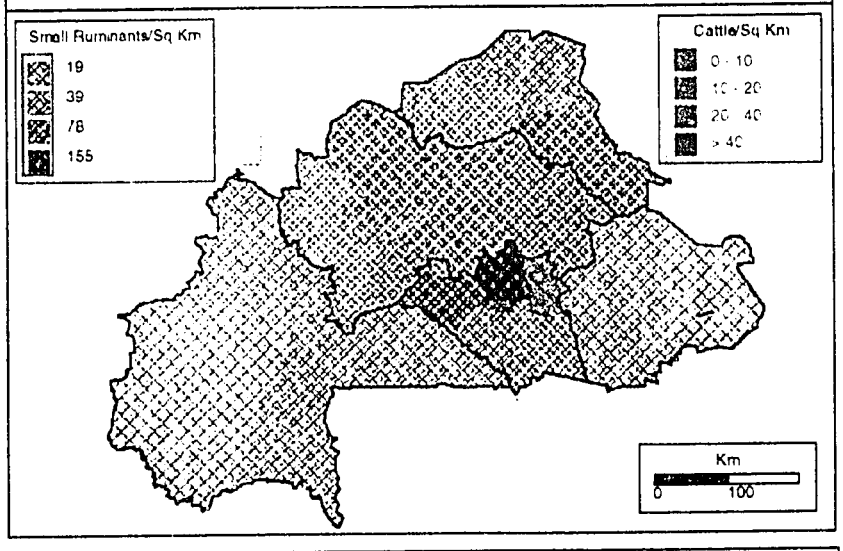
In the Proposed Intervention Zone

Grain and Commercial Crops



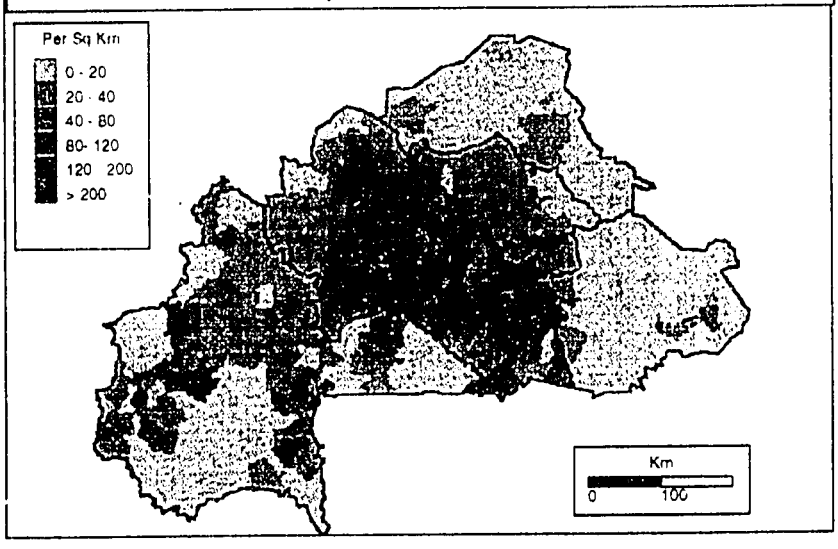
17. Animal Densities

In the Proposed Intervention Zone



18. Population Density

In the Proposed Intervention Zones



Section VI
Agricultural Policy and Land Tenure

Land Tenure and Farm Productivity in Western Burkina Faso

S. Ouédraogo

ABSTRACT

The objective of this study is to determine to what extent land tenure affects farm productivity in the Western zone of Burkina Faso. For this purpose, a Cobb-Douglas production function is used to test the hypothesis that farm productivity changes according to land tenure using data on three main crops, namely sorghum, corn and cotton.

Data were collected in Séguéré and Djigouéma, two villages in the Western zone during the 1989-1990 agricultural season. The analysis shows that there is no significant evidence to conclude that farm productivity in sorghum and corn is dependent on land tenure. That is not so for cotton, however.

I. INTRODUCTION

Background. Historically, land has not been a limiting factor in agricultural production in Burkina Faso. Agricultural activity was considered as a use of land in the village territory. Social norms regulated access to land and reduced land use insecurity. Land availability and needs within and between social groups were kept in balance through several loan practices. The issue of loan precariousness and permanence was totally secondary. Use rights generally turned into permanent rights over time. This adjustment system enabled those who did not have large landholdings to have access to sufficient land. As long as population density was low, land use regulations were flexible and after some time spent in the village, a newcomer would take on the same rights as the indigenous population; he could then have free access to village land resources.

With population increases and the development of cash crops, the land borrowing system has become associated with the problem of use right long term security. As land resources become scarcer, loans are increasingly difficult to obtain and loaned fields can be recalled.

In Western Burkina Faso, settlement rights that migrants are given cannot be formally inherited. Fields remain an integral part of the indigenous fallow system and the various procedures allowing a farmer to cultivate land are built into the local tenure. Under these conditions, the precariousness of use rights can be a constraint to investment and increasing farm productivity.

Traditional principles governing land access and ownership have often been criticized by economists. However, no consensus has yet emerged on the topic. For some researchers such as Adegboye (1964), Oluwasamni (1966), Fabiyi (1974), Famorio and Adéniyi[1] (1986), Bruce (1985), Curie (1981), Boutillier (1964), and Mellor (1966), the traditional land tenure system

[1] Quoted by Francis, 1986 in "bulletin du CIPEA 24, March 1986 pp 2-7.

deters manpower and capital mobilization, especially among young farmers. Furthermore, this system impedes land access to farmer groups originating from outside land-owning groups. They attribute inefficiency to the problem of the 'Commons' and the traditional land use system. Modernization of agriculture has to involve the creation of viable economic units and farm investment. But investment and a search for profitability requires that farmers feel responsibity for their land resources. These authors believe that this cannot be the case for traditional land use practices based on periodic land redistribution. The rigidities in traditional land tenure, sharecropping and agricultural credit are blockages to productivity increases per hectare and per farm. For Adegboye (1964), sharecropping is such an insecure condition that the sharecropper does not dare invest capital or manpower in his farm. Therefore, according to these authors, consolidation of tenure rights is a necessary condition for investment and land improvement. Wild (1968) showed that the results of such a consolidation process were successful in Kenya where the consolidation of land rights, fencing and land registration have boosted crop expansion and the creation of a profitable milk industry.

For other researchers such as Francis (1977), the traditional land tenure system is flexible enough and is no barrier to land access and to efficient resource allocation. For Francis the contention that traditional practices impede land access is based on a misunderstanding of the local traditional law and that it is false to state that farmers are handicapped by defects and inconsistencies of a rigid customary land tenure system. He thinks that land tenure does not affect innovation or investment. He also showed that in Nigeria, lineages who controlled land not only granted it preferably to outsiders, but that for the next generation, they also did not keep migrants from having permanent crops on fields they were using. Likewise, Bennech[2] (3) mentions that a newcomer will keep use rights as long as his behavior toward society is satisfactory. This debate has remained on a theoretical level in the absence of empirical results on relations between land access and farm productivity.

Study Objectives. The objective of this study is to determine whether in Western Burkina Faso, where there are three major ways of gaining access to land (Ouédraogo 1991), farm productivity varies with land tenure. If indigenous farms whose land is inherited are more productive than migrant farms whose land is allocated customarily, any policy for the leveling of land right inequalities would lead to an increase in agricultural productivity. In order to test this hypothesis, a Cobb-Douglas production function is estimated using ordinary least squares estimation procedures on farm data collected from two villages in Western Burkina Faso for sorghum, corn and cotton, the three main crops of the area.

[2] Bennech quoted by Berthelot (1977).

II. METHODOLOGY

Village selection. This study utilized the results of a survey carried out in two Wester Burkina Faso villages, Djigouéma and Séguéré. Village selection was guided by the fact that both villages are destination points for migrants coming from the North, whose settlement flow reached full speed in the 1970's. The populations of Séguéré and Djigouéma were 498 and 338 respectively in 1975, increasing to 3955 and 3397 respectively in 1985, an annual rate of increase of 23 and 25 %.

These villages are also interesting because they include several ethnic groups (Bobo, Mossi, Samo, Peuhl) and because of local crop diversity. There is also more available agricultural land in Séguéré than in Djigouéma where most of it is appropriated and cropped. Because Séguéré has a larger village land area with a similar sized population, degraded land that is unsuitable for agriculture is more extensive in Djigouéma. Finally, Djigouéma uses more inputs than Séguéré. For example, in the agricultural campaign of 1989-90, the amount of fertilizer used in Séguéré was 45 tons (NPK fertilizer and urea) as opposed to 76 tons in Djigouéma. This results from the fact that Djigouéma is a large cotton producer.

Sample selection. In order to collect primary data, a stratified random sample of 28 and 25 farms were selected in Séguéré and Djigouéma, respectively. The resultant survey covered all productive resources and activities of the various farms.

Empirical Model. A Cobb-Douglas production function was selected for estimation because of its desirable properties (it directly measures elasticities and facilitates economic analysis), but mainly because it gave an adequate fit to the collected data[3]. The algebraic form of the Cobb-Douglas production function is as follows:

$$Y_i = AW^{a_1}K^{a_2}e^{a_3LGT + a_4LTL + a_5STL + a_6LP + a_7T + a_8PC} + U.$$

which reduces to the linear form:

$$\log Y_i = A + a_1 \log W + a_2 \log K + a_3GT + a_4LTL + a_5STL + a_6LP + a_7T + a_8PC + U$$

Y_i = Yield per hectare of crop i;
W = Work (man-days) per hectare of crop i;
K = Capital per hectare(fertilizers and pesticides measured in CFA per hectare).
LGT = Land gifts;
LTL = Long term loans;
STL = Short term loans;
LP = Land Purchase;
T = Technology used in production (animal traction or hand cultivation);
PC = Cotton cropping history.

[3] Other equations including linear and quadratic forms were tried but their fit to the data was poor.

U = error term

Access to land (GT, LTL, STL, LP) is incorporated in the model as a dummy with a value of 0 or 1. Inherited tenure which is the comparison variable is confounded in the intercept term. Being the reference variable, the basic assumption is that farms which inherit land will have a higher productivity than farms in other tenure types. Should this situation prove correct, signs of the other tenure coefficients (GT, LTL, STL, LP) will be negative.
T and PC are dummy variables which take on the value of 1 if animal traction was used and if the past crop was cotton, and 0 otherwise. Animal traction and a cotton crop in the past may have a positive influence on yields.

The efficiency of tenure as compared to inherited tenure will be assessed by their respective coefficients a3, a4, a5, et a6. If these are statistically different from zero and whether signs are positive or negative, it will be concluded that the specific land access type is more productive than inherited tenure.

The a1 and a2 coefficients are a measure of the yield elasticity with respect to labor and capital respectively. a7 and a8 measure the effect of technology and cotton crop history respectively on yield.

III. RESULTS AND DISCUSSION

Table 1 presents the results of the estimate. R-square (R^2) coefficients and associated F Fisher statistics indicate the model is statistically significant. The R^2 values indicate the proportion of variance in the dependent variable accounted for by explanatory variables. The fact that R^2 values are not very high is due to the omission of some variables which would be significant in yield determination, but that have not been identified. The descussion of regression coefficients will proceed by crop.

Sorghum. Regression coefficients show that labor contributes to sorghum yields in both villages. Yield elasticity with respect to labor is 0.15 in Séguéré and 0.11 in Djigouéma. This suggests that a 10% increase in labor time results in a 1.5% and 1.1% yield increase in Séguéré and Djigouéma respectively.

Table1. Cobb-Douglas production function regression coefficients (with yield as dependent variable).

	Séguéré			Djigouéma			Ensemble Village		
	Sorgho	Maïs	Coton	Sorgho	Mais	Coton	Sorgho	Mais	Coton
Constant	6.58	6.95	7.35	5.88	5.36	7.09	6.88	6.43	7.81
Labor (Man days per ha)	0.15* (1.96)	0.54*** (4.04)	0.25* (2.10)	0.11* (1.80)	0.40** (3.17)	0.98** (3.20)	0.03* (0.10)	0.55*** (4.26)	0.40** (2.34)
Capital (CFA)	- -	0.01 (1.71)	0.13* (1.78)	- -	0.02** (1.46)	0.16** (2.47)	- -	0.008 (0.59)	0.12** (2.42)
Agricultural materials (0/1)	0.035 (0.24)	- -	0.08 (0.14)	- -	- -	- -	0.08 (1.11)	0.04 (0.28)	0.08 (0.36)
Previous crop (0/1)	0.29**	0.04	-	0.32**	0.001	0.25	0.11*	0.06	0.003
Inheritance	-	-	-	-	-	-	-	-	-
Gift (0/1)	0.012 (0.78)	0.07 (0.40)	-0.07 (0.41)	-0.09 (0.50)	-0.03 (0.17)	-0.68* (2.07)	0.18* (1.77)	-0.076 (0.50)	-0.33* (1.73)
Long-term loan (0/1)	-0.02 (0.14)	-0.20 (1.28)	-0.35** (2.32)	-0,34** (2.01)	-0,15 (0.79)	-0.48** (1.73)	-0.05 (0.50)	0.066 (0.37)	-0.51** (2.75)
Short term loan (0/1)	-0.21 (1.34)	-0.36* (2.01)	-0.39 (1.79)	-0.11 (0.51)	-0.007 (0.03)	-0.01 (0.00)	-0.10 (0.00)	-0.14 (0.70)	-0.50* (1.83)
Purchase (0/1) Djigouéma	0.055 (0.72)	-0.21 (1.26)	-	-	-	-	-	-0.07 (0.48)	-0.02 (0.10)
Séguéré (0/1)	-	-	-	-	-	-	-0.11 (1.36)	-0.35** (3.15)	-0.33** (1.87)
R^2	0.56	0.76	0.56	0.72	0.51	0.75	0.35	0.54	0.52
R^2 adjusted	0.43	0.66	0.41	0.66	0.34	0.61	0.22	0.49	0.42
F	3.54**	7.25***	2.80*	9.82***	2.99**	4.11**	2.91**	4.95***	3.53***
DF	19	16	13	19	17	8	43	38	26

Source : Survey

( ) = t Statistic.
*** Significant at 1% level.
** Significant at 5% level.
* Significant at 10% level.
- = eliminated variable (due to its not being used for specific crop or too few cases).

Animal traction is not a significant variable of sorghum yields. However, past cotton crop history contributes to yield increase in both villages. It amounts to 34% in Séguéré and 38%[4] in Djigouéma.

Concerning land tenure types, besides the coefficient for long term land loans which is significant and negative, coefficients for other tenure types are not significant. This makes problematic the

[4] The production function being a Log function, land tenure and previous crop history coefficients were converted in percentage with the following calculation: EXP(B)-1, where B is the regression coefficient and EXP, the exponential function.

interpretation of their signs. When regression coefficients of the estimate are considered together, the land gift tenure type is the only positive and significant coefficient. Its productivity would be higher than that of inherited lands by 19.7%. Generally speaking, results do not suggest there is an important difference in productivity among sorghum fields.

Maize. Labor is responsible for yield increases in both villages. A 10% labor increase results in a 5.4% and 4% yield increase in Séguéré and Djigouéma respectively. Capital is a significant variable for yield in Djigouéma, even though its elasticity of 0.02 is low.

The crop history coefficient is not significantly different from zero in both villages. Thus it does not help account for yield. This may seem to conflict with agronomic observations which show that maize makes profitable use of the residual fertilizer effect of a previous cotton crop. In reality, several factors including rainfall should be taken into account. In good rainfall years, the residual effect of fertilizers causes a maize yield increase; conversely, when rainfall is not evenly spread with prolonged drought periods (as was the case during the 1989-90 agricultural season), the residual fertilizing effect may not result in any yield effect.

Maize is a crop that is very intolerant to drought, which causes yields to decline. Tenure coefficients are not significantly different from zero, except for that of long term loans. Consequently, there is not sufficient evidence to conclude that land access type influences maize yields, even when data from both villages are combined.

Cotton. Labor helps account for cotton yields. The elasticity is 0.25 in Séguéré and 0.98 in Djigouéma. In the latter case, labor is a very important variable.

Capital is also an important variable for yield in both villages, but its elasticities are low; 0.16 in Séguéré and 0.13 in Djigouéma.

Tenure types contribute in accounting for yields. In fact, all estimated coefficients are negative, and four out of six coefficients are positive over the two villages. When data from both villages is combined, all estimated coefficients of tenure types are negative and statistically different from zero. This implies that tenure influences cotton productivity. Table 1 shows that farms which have access to land through gifts and long term loans have a 32% and 29% lower productivity respectively than farms which have inherited land in Séguéré. In Djigouéma, farms which acquired land through gifts and long term loans have a 49% and 38% lower productivity than farms on inherited land.

IV. CONCLUSIONS

This study indicates that there is not enough evidence to conclude that farms having inherited land are more productive than other farm types for sorghum and maize producers. In fact, in the majority of cases, tenure coefficients are not significantly different from zero. In contrast, results for cotton show that farms having inherited land are more productive than other farm types. These results show that in the conditions of traditional agriculture where the primary objective is to meet subsistence needs, land tenure is not a constraint to farm productivity. However, as the modernization of agriculture proceeds, along with a quest for profits, land tenure can become a limiting factor to farm productivity. These results support those of Shem et al. (1991) in Ghana, Kenya and Rwanda. These authors also contend that when new technologies and means for their appropriation become available, a link emerges between land tenure and farm productivity.

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The Challenge to Create a Durable Agriculture: The Experience of Burkina Faso

S. Ouédraogo

ABSTRACT

Burkina Faso is facing a deepening agrarian and land crisis linked to the degradation of natural resources which seriously threatens the sustainability of its agriculture. However, the problem is not uniform throughout the country, but varies according to region.

The Burkinabé government has developed a new agricultural policy whose objective is to respond effectively to curb the crisis, while at the same time boosting agricultural production. This policy focuses on the reorganization of land tenure and agriculture, and on the national program for soil management.

I. INTRODUCTION

Burkina Faso is a landlocked country of 274 000 km^2 with a population of approximately 9 million inhabitants. Agriculture plays a fundamental role in the country's economy, indeed, It employs more than 90% of the Burkinabé population. Its contribution to the GDP in 1992 was around 30%. Land and labor constitute the principal production factors. Since independence, agriculture has been given the priority it is due, given its vital role in the national economy. An examination of the country's various development plans (1972-6; 1986-90) reveals the common objectives of rural development strategies from 1967 to the present day. These objectives have been:

- to increase both food and export production,
- to diversify crops, and
- to reduce isolation of rural areas.

The 1986-1990 development plan devotes 20% of public expenditure to investment in the agricultural sector, which represents 62% of the budget allocated to production sectors. In spite of this special emphasis, the country is still not self-sufficient in cereal products. According to Lecaillonet Morisson (1985), the degree of national food self-sufficiency dropped from an estimated 90% in the years before 1970, to 80% in the 1980s.

The Burkinabé environment has been subject to serious degradation, which jeopardizes the whole future of production. This degradation is the consequence of the combined effects of climate and of population growth with its resultant pressure on natural resources, particularly on agricultural land. Faced with this situation, the government has developed an agricultural policy that aims to find solutions to the problem of promoting a sustainable agriculture, while it conserves natural resources.

This paper aims to show the very real challenge facing Burkina Faso: to promote and preserve a lasting agriculture. The study will be presented in the following manner:

- Exposition of the problem
- The current context of Burkinabé agriculture
- Governmental action to promote a sustainable agriculture.

II. FACTORS STANDING IN THE WAY OF A SUSTAINABLE AGRICULTURE

Context: Agro-economic environment. In the Burkinabé population it is estimated that there are 85% producers for a "clientèle" of about 15%. These figures correspond approximately to the population distribution between rural and urban areas. This means that the clientèle for agricultural production is to be found in the city. Based on these figures, one can deduce there are six producers to feed every consumer. In spite of this, the country continues to have a food deficit, only meeting the food demands of its population by relying on food aid and imports. According to the World Bank (1992), the level of food aid in the form of cereals, for the period 1989 to 1990, amounted to around 44,000 tons.

Burkinabé farmers are, therefore, unable to achieve food self-sufficiency or to release a marketable surplus to meet the food needs of its urban populations. For many of them, farming remains principally the means of providing for their own families, and they rely more on secondary activities (e.g. crafts and breeding livestock) to increase their income.

Incomes have generally remained low throughout the country. In 1980, the average national income, per capita, was in the order of 50,000 F CFA. This can be compared with 58,000 F CFA in 1988. The incomes of agricultural and non agricultural sectors were in a 1 to 11 ratio between 1970 and 1981. In 1978, for example, the average income in the agricultural sector was around 20,799 F CFA (constant price for the 1970-1974 period), as opposed to 409,401 F CFA in the non agricultural sector, (I.L.O., 1982[2]). This difference demonstrates the unequal distribution of income.

Due to the lack of capital, which stems directly from the mediocre level of agricultural incomes, investment in modern production methods is very slight throughout most of the country.

One reaches the conclusion that, in spite of its predominant role within the country, agriculture is not able to finance development. The truth of this is brought home especially when one considers that even though 85% of Burkinabé's population are producers, they are unable to feed adequately the remainder of the population.

Natural resources: capacity and degradation. Today, Burkina Faso can be divided into three large agro-ecological zones. Firstly, the Southern Sudanian zone, with rainfall levels above 900 mm. This is the zone which enjoys the most rainfall, and covers about 36% of the country, with an

average population density of 20 inhabitants per square kilometer. It is also the zone which absorbs Mossi and Peul ethnic groups.

The environment is in the midst of great change, under the combined pressures of emigration and extensive production systems. With less than 30% of the national population in 1985, the Western zone includes about 35% of the nation's arable land. The population density in this area is low, as is the crop intensity coefficient (cf. Table 1). The area under cultivation per inhabitant varies between 1.5 and 4 hectares.

Table 1. Land Distribution and population density, by region

	Arable Land (1000) [1]ha	CIC[2]	Land area farmed/person	Population Density (persons/km^2)
Sahel	980	14	2.8	36
Yatenga	350	70	0.7	141
North Center	615	39	1	103
East Central	325	43	0.8	124
Central	740	56	1	103
West Central	805	38	1.1	92
East Mouhoun	1550 930	13 29	3.8. 1.5	26 68
Hauts Bassins	1150	17	4.3	23
Comoé	760	12	4.1	24
Bougouriba	720	18	2	50
	8925			

Source: Adapted from Sanou (1986)

The abundance of land in this area is one of the motivating factors for emigration from the Central plateau into the Western zone. This has resulted in an increase in surface area under cultivation, a reduction in fallow, a decline in soil quality, and a change in behavior of the native people, in relation to the farming of their land. Indeed, a veritable "race" for land has been provoked by competition from emigrants. In some villages, the critical agro-demographic threshold[3] has already been reached. The Sudano-Sahelian zone covers the middle section of the country, with rainfall of between 600 to 900 mm. This zone represents 53% of Burkina Faso's surface area, and sustains 55% of the population, although only 32% of the land is arable. The population density ranges between 70, to more than 100 people per square kilometer. The crop intensity coefficient varies from 39% to 70%. Farmland per person living in this zone is around 0,7 hectare to 1 hectare. In this part of the country, the agro-demographic threshold[3] for land use has been overstepped, initiating a seemingly inexorable process of natural resource degradation. It has been estimated that, under current circumstances, the Central plateau should not have a population density above 40 inhabitants per square kilometer. This situation, together with an

[1] *ha = hectare, or 2.47 acres*

[2] *CIC = crop intensity coefficient = area cultivated /arable land.*

[3] Agro-demographic threshold = relation between area under fallow and area cultivated, beneath which soil under extensive cultivation no longer regains its fertility.

ancient land tenure structure, are negative factors for agricultural production. Young people do not have easy access to the land, and therefore see their income restricted. For them, in order to take some economic initiative, the only alternative is to emigrate. This explains why 82% of agricultural immigrants from the West are young people migrating from the Central plateau. (Boutillier et al, 1977).

Given that most producers have only limited funds to invest in inputs, fallow has long been the most common way of maintaining fertility and of restoring the soil. Fallow used to be the key to ensuring the sustainability of the production system. A good fallow does however, require sufficient space.

This space is simply not available at the present time, given the demographic pressures that have led to fallow being abandoned and to the reduction of pastureland, thereby creating conflicts between crop farmers and livestock raisers. Monocropping of cereals without use of fertilizer has also sapped the fertility of the soil.

The Sahelian zone corresponds to the northern part of the country, which has a rainfall of under 650 mm, and which represents 11% of Burkinabé territory. Population density is around 5 inhabitants per square kilometer. It is a prime area for rearing livestock. The production system has evolved towards agro-pastoralism with a sedentary tendency even though seasonal movement of the livestock is still practiced.

This zone is characterized by a significant loss of woody and herbaceous plants. There has been a marked drop in rainfall and the ponds are rapidly drying up. The biomass deficit has been estimated at 1.2 million tons, equivalent to the annual fodder for 175,000 head of cattle. The low productivity of grain crops has induced potential losses equivalent to the needs of 100,000 people.

The early drying up of ponds takes away the water supplies from the animals, so that certain pastureland is no longer used, while other pastures become excessively burdened. The reduction in productivity has led to the farming moving into the lowlands which further limits available grazing land for livestock. Moreover, as land is cleared for crops, erosion is exacerbated by the quick disappearance of woody resources.

As one can see, the degradation of natural resources in Burkina Faso poses a very real problem and dangerously threatens the sustainability of the production systems, although this varies from region to region. In the Central zone, for example, the problem is essentially one of adequate natural resources for the considerable size of population concentrated there. In the Western zone, natural resource availability is not the major issue, but instead the principal problem is the security of land use. These differences explain why the problems of natural resource management are among the priorities that have been chosen by the political powers-that-be, (cf. the law on agricultural and land tenure reorganization (RAF).

<u>The agricultural crisis and the degradation of natural resources</u>. The degradation of natural resources in Burkina Faso can be traced back to the crisis facing the land tenure system. The traditional land tenure system in Burkina Faso was based on the principle that each man, whether

or not he belonged to a community, had a natural right to the land in order to support himself. The appropriation of land was collective, and the control of the community over the resources was overseen by the land chief. On the cultivated portions of the village territory, the agricultural equilibrium used to be maintained by the fallow system, which permitted the regeneration of soil fertility. This system of farming was compatible with sustainable agriculture, but could only continue in conditions of sparsely populated, abundant land and a subsistence economy. The system met the needs of a given socio-political milieu.

With the profound transformations that the rural communities have undergone over the last few years, the scale of traditional values has been shattered. Customs are no longer respected, the land chief has lost his authority, and, with the development of new economic needs and the growth in population, individualism has displaced the old collective values. Faced by all these changes, traditional means are no longer able to regulate the management of productive resources. The consequences have been devastating: today we are confronted with massive deforestation, and the impoverishment and inadequacy of agricultural land. Traditional land management now leaves the land to the mercy of cultural practices which do not regenerate the soil, thereby posing a very real threat to the existence of a sustainable agriculture.

The consequences of a degraded environment. The degradation and lack of fertile land lead producers to react in one of the following three ways: either they clear marginal areas and lowlands, or they turn to lucrative, non-agricultural activities, or, as a last resort, they emigrate. For the last two decades, in order to cope with the grain deficit and low incomes, certain producers have opted for seasonal emigration to towns and coastal countries, or have turned to gold mining , or even to breeding of small ruminants where conditions permit. Others have chosen to emigrate permanently.

III. FACTORS FAVORING THE IMPLEMENTATION OF A SUSTAINABLE AGRICULTURE: NATIONAL AGRICULTURAL POLICY

The major challenge which Burkina Faso must face is the promotion of a sustainable agriculture. The principle obstacle to this being the persistence of itinerant agriculture throughout most of the country. The Burkinabé Government has therefore taken a number of measures since 1980 which target the conservation of natural resources. This was translated into texts published on agricultural and land tenure reorganization (RAF) in 1984, and the launching of three campaigns in 1985. These two texts mentioned above demonstrate the determination of the Burkinabé Government to search for solutions to the problems of land tenure and to the degradation of natural resources engendered by the demographic growth and the increase in livestock. To tackle these problems, the government has set up a national program of land management (PNGT), strengthened national extension and agricultural research programs, and then moved on to make institutional reforms.

The reorganization of land tenure and agriculture. The land tenure system in Burkina Faso is governed by a number of regulations which are not enforced. The government, through the RAF has taken steps towards giving more tenure security to producers. In fact, while appropriating

the whole of Burkinabé land for the nation, at the same time, the government recognizes the producers' rights to long-term use.

In effect, a producer whose production is secure will be more likely to make the investments necessary to develop and conserve resources. It is therefore a matter of promoting the investment necessary for production, maintenance and restoration of soil fertility. The RAF aims to change drastically the management structures that have been in place for too long, and which are now judged to be incompatible with the need for development of truly sustainable agriculture. This may lead to a more rational management of natural resources.

The National Program for Community Land Management (PNGT). The National Program for Community Land Management aims to do the following:

1. Organize the use of rural land with a view to better management of natural resources
2. Provide producers with adequate land tenure to enable them to develop their activities, while at the same time preserving the environment
3. Settle the farms in fixed locations, in order to intensify and diversify crops
4. Restore the potential productivity of natural resources (PNGT 1993).

Community land management is a new approach to rural development. It is based on the rural communities participating in, and sharing the responsibilities for resource management of their own territory. In fact, it involves engaging and encouraging rural populations to reflect on the problems, in order to help them manage their potential productivity and meet the challenge of their socio-economic needs. In other words, this involves making producers responsible for their own destinies. The document on the main trends in land management define community land as a rural area managed by a community which claims and exercises the right to farm and occupy the land within a defined socio-economic framework. The originality of this approach derives from the fact that it is:

- participative and bottom-up: decisions are taken by the grass-roots communities, the technicians act as advisers; and it is also
- global: it takes into account all the economic and social sectors of the communities concerned.

The notion of the community land management contains at once the idea of developing and of protecting natural resources. In its philosophy, the community land management approach closely associates the actions of developing the land, the agriculture, forestry and livestock activities, together with the setting up of socio-economic infrastructures. For this are envisaged the division of the community land into an agricultural zone, a breeding zone, and a forestry zone.

The aims of community land management is to ensure the harmonious development of the Nation's land, by improving the distribution of its population and their activities. It aims at sustainability through intensification of agricultural productivity; in order to achieve this it takes into account the constraints and potential of the natural milieu, the capacities of human and technical resources, as well as considerations of national economic imperatives and specific regional socio-economic inter-action. All this is done through development plans.

Agricultural research and extension work. To attain the desired sustainability, it is essential to set up production systems that are effective and reproducible. This is the role of agricultural researchers and extensionists. It involves creating or finding innovations, eliminating technical and economic constraints which limit the intensification of agriculture and "agro-sylvo-pastoral" integration which is essential to a rational management of natural resources. To attain these goals, the Government has set up a national program of agricultural research and gone ahead with its regionalization. The regionalization involves:

- bringing research and development closer together. Proximity would enable research to be better informed of, and to work on the problems of development;
- creating innovations which are adapted to the different agro-ecological zones of the country;
- reinforcing the links between the extension services and research, in order to facilitate the transfer of innovations and better to respond to the training needs of development agents.

There are also twelve (12) Regional Centers for Agro-Pastoral Promotion (CRPA) whose essential role is the training of farmers, and the extension of technologies developed by research.

Institutional reform. The problem of resource degradation is also linked to institutional failures, such as the difficulties in distributing grain products, and government pricing policies. For decades, the government has maintained grain prices at levels that are unprofitable for producers.

These two elements are firmly underlined in the CILSS report (1977) on the marketing policies of pricing and stockpiling in the Sahel countries.

With the policy of structural adjustment that has been operative since 1989, the government has progressively passed on the responsibility for certain aspects of agricultural policy (pricing, subsidies etc.). This disengagement aims at eliminating the distortions created by government intervention in order to direct productive resources towards the most profitable sectors. Nevertheless, the government still keeps control and definition of research policies, of extension work and of the development of rural areas. Marketing and production policies have been transferred to pre-cooperative structures, to cooperatives and to economic operators. Only in the case of import and export products will autonomous quality control structures be created. This is done to maintain quality control standards. As for prices, the easing of restrictions on prices is being done to a varying extent, according to the type of production. For local agricultural products (millet, sorghum, corn etc..) price controls have been relaxed, but this does not include cotton, for which the stabilization mechanism is still in place.

For agricultural imports, the relaxing of controls was accompanied by tariff protection which will evolve in time in order to motivate domestic production. This applies to rice, sugar and wheat imports.

As far as credit policy is concerned, credit institutions should facilitate access to loans for producers and for others involved in the various rural activities. The government envisages pulling out, favoring instead the participation of producers and business people in the financing of

agriculture. Such financing will involve their participation in the capital of existing credit institutions and the promotion of various forms of decentralized credit with legal and financial guidelines.

To better manage its withdrawal from direct involvement, the government favors the development of socio-professional structures that would help manage the new tasks that have been passed on to the producers.

IV. CONCLUSION

Changes in climate, coupled with increasing demographic pressure, and recent economic transformations have led to profound modifications in the management of natural resources. Rural communities are increasingly convinced that the traditional mechanisms of management are no longer capable of regulating the rational use of resources, and hence, believe it necessary to find new forms of management. The latter need not, however, reject traditional values outright, but should instead, modify and develop them in a way that adapts them to the new socio-political and socio-economic context.

SECTION VII
BASELINE SOCIO-ECONOMIC STUDIES

Farmer Participation in Generating Village Socio-Economic Profiles

E. Robins, M. Bertelsen, and D. Kaboré

ABSTRACT

Establishing recommendation domains is fundamental in Farming Systems Research. Farm families which have similar characteristics are expected to have similar production problems and to be responsive to similar solutions. The National Institute of Agricultural Research (IN.E.R.A) of Burkina Faso, through its farming systems research program, conducts agricultural research which is responsive to the needs of rural households. One important step in the research process requires classifying household production units according to relative wealth. Farmer participation in generating socio-economic profiles was sought to obtain criteria meaningful to villagers themselves. This paper reports an RSP exercise with village resource persons to classify household production units. Each resource person generated a set of criteria by which households could be differentiated and proceeded to evaluate a sample of households in three villages. A typology consisting of three or four socio-economic classes resulted. Discriminant analysis was performed on traditional wealth variables to compare the results of the profiles with a more "traditional" method of classification. It is concluded that traditional recommendation domain indicators such as wealth and family size yield a classification similar to the results of the profile exercise. The method tried and validated is an "enabling" intervention and represents an important shift in collaboration with farmers, a shift from farmer testing to farmer analysis. An additional benefit of the method is its simplicity. It can be employed by extension agents and others and thus has the potential to increase the impact of research by multiplying the number of sites where research intervenes.

I. INTRODUCTION

Grouping relatively homogeneous production units into classes or types is fundamental in Farming Systems research and extension. Farm families which have similar characteristics are expected to have similar production problems. It is reasoned that they should be responsive to similar solutions as well. Households which share the same circumstances may be said to constitute a *recommendation domain*, for it is the relevance of recommendations to the needs and capabilities of farm families which is the ultimate test of their adoptability (see, for example, Byerlee and Collinson 1980; Shaner, Philipps, and Schmehl 1982; Gilbert, Norman, and Winch 1980; Farming Systems Research and Extension Training Manual 1987).

FSR/E devotes attention to the goals of rural households and their individual members. Such goals, while diverse, are expected to be conditioned by circumstances which households or individuals share. Households at a village site which are of similar size, have similar incomes, and practice farming in similar ways may be expected to benefit from similar innovations. Other households elsewhere with similar technicity and resource endowment may also find such innovations appropriate for their needs

and circumstances. This may be equally true of individuals of the same age or sex in different households.

The National Institute of Agricultural Research (IN.E.R.A) of Burkina Faso, through its farming systems research program (*RSP* or *Recherche sur les Systèmes de Production*), conducts agricultural research which is responsive to the needs of rural households. Annual research plans are prepared in response to villagers' evaluations of the previous agricultural campaign. RSP's research program is also evaluated by villagers for its pertinence to their circumstances.

Farmer participation in generating socio-economic profiles of production units was seen as a logical step in the process of increasing farmer input into the research program. The profiles themselves are needed to differentiate production systems according to resource endowment. Having farmers rather than researchers generate the profiles is a novel way of elucidating criteria which indicate wealth and success. It serves also as a reality check on researchers and their hypotheses regarding the interests and values of villagers. The two key questions tested by the socio-economic profile exercise were: Would the method work? Would it be corroborated by more traditional measures of wealth?

This paper reports an RSP exercise with village resource persons to generate classifications of village production units. In the first section below the farmer-participation method is presented. There follows a summary review of how it was applied at three village-research sites in the Central Plateau of Burkina Faso. In the conclusion of this section the experience is evaluated.

The second section of this paper describes the results of discriminant analysis of village census data, identifying conventional wealth variables which differentiate household production units. This classification is compared to the ones generated by village resource persons.

The potential importance of this research is discussed in the conclusion.

II. FARMER-GENERATED CLASSIFICATIONS OF VILLAGE PRODUCTION UNITS

Methodology: A typical method for generating recommendation domains is described in a classic text (Shaner, et al., 1982). Numerous agro-economic variables are used to reveal cropping pattern, cultural practices, biological and labor inputs, income streams, and so on. Turnaround time is estimated at about 2 months for 100 enumeration units.

An approach which introduces a qualitative/evaluative aspect to this process was recently described by Franzel (1992). He argues that an informal survey of extension agents can be quickly conducted at low cost to yield a rough assessment of farm households and, in conjunction with more formal surveys, increase coverage of a geographical area. He notes that extension agents were poorly informed about the conditions of low income households, however.

The method employed by RSP is a form of *Rapid Rural Appraisal* or *MARP (Méthode Accélérée de Recherche Participative)* and is more qualitative yet. Two RSP researchers were trained in *MARP* in 1992. The method requires that a minimum of three resource persons be identified in a village to

evaluate a sample of production units (Gueye and Freudenberger 1991). Three is thought to be the minimum number of persons needed to neutralize bias.

Resource persons were selected by RSP technicians living in village research sites on the basis of their knowledge of the village population and their openness to discussion with researchers. Each resource person met individually with researchers and was asked in *Mooré*, the language of the Mossi villagers, to differentiate households according to a set of criteria which they themselves were to generate. In discussing the exercise with these villagers, terms specifically denoting *richness* or *wealth* were avoided. Instead, households were compared to *birds in the sky* or *fingers of the hand* which are different, one from the other. In this fashion most resource persons came to appreciate the objective of the exercise.

The sample of households was randomly selected from a list of all production units in the village. Every third head was chosen, resulting in a sample of 51-69 households per village. Two to three hours per resource person was needed to complete the exercise.

After having generated a set of criteria by which households could be differentiated, each resource person proceeded to evaluate the households in the sample. Some households were not known to a particular resource person; others were no longer in the village (usually the disintegration of the household after the death of the head). The final number of households evaluated by at least three resource persons varied between 20%-30% of the total number of village households.

Each household was ranked in a class by each resource person. A final ranking was computed by averaging the weighted scores of each resource person for a particular household. For example, a rank of *1* out of *3* classes was assigned a weight of *1/3* or *.33*; a rank of *2* out of *3* classes was *.67*, and so on. Cut-offs were determined to assure that the class most heavily represented in the evaluations would prevail. A final breakdown into 3 classes was made by researchers, with cut-offs set at <.35 for class 1, .35 - .78 for class two, and >.78 for class 3.

Conducting the Exercise at Three Village Research Sites: The three research villages all are located in the Central Plateau. Thiougou is found in the south-Sudanian zone where average annual rainfall historically is between 800-900 mm. Donsin is at the northern limit of the Sudanian zone; annual rainfall is between 600-700 mm. Kamsi is between the two with rainfall averaging 700-800 mm. The most degraded soils and precarious agro-climatic conditions are found at Donsin. It is also the most isolated of the villages, being some 20 km from the nearest regional town via bush track. Kamsi is close to a major town and is 90 km from the capital, Ouagadougou. Thiougou has a long experience with development projects and is 17 km on a good earth road from an important regional center.

Thiougou: The first attempt at using the method was in Thiougou village. A sample of 69 households was selected; three evaluations were obtained for 51 of them or 22% of the households in the village. A relatively large number of households were not known to the three resource persons initially identified; thus another two were identified.

Criteria for differentiating households resulted from the evaluations of the five resource persons. Those families most "at ease" (*à l'aise*) shared some of the characteristics noted below and were ranked in the first class. Those others placed in classes two or three lacked some or all of the resources or attitudes of the first group.

- He can send his children to school or pay medical costs without financial risk.
- He can feed his family.
- He's dynamic; he has a good attitude.
- He uses animal traction.
- He possesses livestock (which can be sold to solve a financial problem).
- He's in business.

In sum, households in which food security is assured, there is liquidity (usually indicated by livestock or commerce), and the household head is ardent and dynamic are differentiated from others less well-off.

The results of the evaluations of five resource persons are presented in Table 1. All five used a 3-part classification: well-to-do, average, poor.

Table 1. Classification of Households in Thiougou

Household Ranking n=51	Percent
class 1 (15)	29
class 2 (7)	14
class 3 (29)	57
TOTAL (51)	100

More than one-half the sample is placed in the "poor" category, a result somewhat surprising for researchers in a village where 70% of the population uses animal traction.

Donsin: Four resource persons were used to evaluate a sample of 59 households (32% of the households in the village). The criteria they cited for families well-off are noted below.

- At least 12 head of cattle and pasture.
- 15-20 sheep and goats.
- Food self-sufficiency.
- Wherewithal to help the needy.
- Sale of surplus crops.
- Hard-working; a good outlook.
- Involved in commerce; has cash to resolve problems.

By contrast, poorer families are said to:

- lack enough to eat;
- lack correct clothing for celebrations;
- have permanent difficulties;
- count on the generosity of others.

One of the four resource persons classed households into 3 groups. Two others used four groups, distinguishing between households with cattle, those with small ruminants, and those who succeed at agriculture but possess no animals (the lowest class consisting of those who are destitute). The other person used six groups, adding cash liquidity (i.e., commerce) to the top of the list and distinguishing between good and average crop production. Table 2 presents the classification for Donsin in 4 classes.

Table 2. Classification of Households in Donsin

Household Ranking n=59	Percent
class 1 (7)	12
class 2 (7)	12
class 3 (14)	24
class 4 (31)	52
TOTAL (59)	100

More than one-half the sample is found in the two poorest classes. Classes 1 and 2, distinguished by the presence of cattle in addition to sheep and goats, together account for one-fourth the sample. This compares roughly with Thiougou (29%).

Kamsi: Three resource persons were used to evaluate 48 of 153 (31%) households. Two of the three used four classes; the other used six.

The principal criteria retained include:

- self-sufficiency in food production;
- ability to help others;
- possession of livestock;
- relatives in Ivory Coast (from which remittances are derived);
- relatives in town (either Koudougou, a major regional town or Ouagadougou, the capital).

Table 3 presents the results at Kamsi, notable for the high percentage of households placed in the first class. This, we believe, is a function of the large number of families receiving remittances. There has been an important out-migration from Kamsi. Land is severely degraded and villagers have sought alternatives to agriculture to meet their income needs. According to the RSP census, 51% of the population of Kamsi is "absent." (This compares to 23% at Donsin and 18% at Thiougou.) Many of these villagers are working in nearby towns and in Ivory Coast.

Table 3. Classification of Households at Kamsi

Household Ranking n=48	Percent
class 1 (31)	65
class 2 (12)	25
class 3 (3)	6
class 4 (2)	4
TOTAL (48)	100

Conclusion: The method tested by RSP at three village research sites succeeded in yielding socio-economic classifications of household production units. In most cases the exercise was completed in two days at minimal cost. Data processing was simple. Turnaround time for a single village was about one week.

Village resource persons grasped the objective of the exercise. They offered interesting and important observations on the socio-economic condition of households in the sample. The profiles constitute the population from which stratified samples of households in each village have been selected for further research.

In the cases of Thiougou and Donsin villages, more than one-half the population is situated in the poorest class. Precarious rainfall in Burkina Faso's Central Plateau and the dependence of the population on agriculture put populations at risk.

The case of Kamsi appears to be different. Its proximity to Ouagadougou and its high level of out-migration -- one result of the failure of agriculture to provide sufficiently for family subsistence -- have, paradoxically, resulted in a relatively high proportion of well-off families.

While class characteristics and boundaries are clearly based on the circumstances of each village, it may be hypothesized that villagers' conception of well-being does not vary greatly from one village to another. This is studied below by looking at traditional wealth variables in the three villages research-sites.

III. A TRADITIONAL METHOD FOR EVALUATING SOCIO-ECONOMIC STATUS

The ability to compare the results of the profiles developed through the collaborative efforts of farmers and researchers with a more "traditional" classification approach can serve to validate both methods. To the extent that they yield the same results, practitioners of either method can feel confident that they would have arrived at the same conclusions had they used the other. The "right" method to use is the one which furthers researchers' other goals.

A comprehensive RSP census conducted in each village during the 1991 campaign provides the traditional data necessary to make such a comparison. Discriminant analysis (DA) was selected as the multivariate technique to analyze the results of the two methods.

Discriminant analysis allows the researcher to pursue either of two objectives: classification or analysis. In both cases, known groups are forced through statistical analysis to be as distinct from each other as possible. The resulting discriminant functions are composed of linearly combined weights developed from the set of independent variables available for the analysis. For example, if[1]

X_{Ji} = the ith observation of the Jth independent (discriminating) variable,
b_J = the discriminant coefficient for the Jth variable,
D_i = the ith observation's discriminant score, and
D_{cr} = the critical value for the discriminant score,

DA procedures develop a discriminant score for each observation which is a linear function of the discriminating variables:

$$D_i = b_0 + b_1 X_{1i} + \ldots + b_n X_{ni}.$$

An observation is classified in group 1 if $D_i > D_{cr}$ and in group 2 if $D_i < D_{cr}$. The classification boundary becomes the locus of points where:

$$b_0 + b_1 X_{1i} + \ldots + b_n X_{ni} = D_{cr}.$$

When n groups are present in the analysis, the classification boundary is a (n-1)-dimensional plane in n-dimension space.

As a classification tool, DA provides criteria (the b_Js above) which allow the researcher to classify group membership of new cases or observations. As a tool of analysis, DA allows the researcher to investigate the degree to which different groups may be differentiated and the importance of variables in achieving this differentiation[2]. Discriminant analysis has been used extensively in economics and

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[1] This general exposition follows closely that of Morrison (1969), p. 156.

[2] This interpretation is correct if it can be assumed that the discriminating variables are distributed in a multivariate normal manner and that the variance-covariance matrices of these variables for each group are equal.

sociology as a tool of analysis (see, for example, Ladd (1967), Currin (1970), Gram (1973), Hallberg(1971), Kaiser (1968)).

In the present case, DA allows us to analyze the variables taken from the census data which best explain group membership determined by the farmer-researcher collaboration. Group membership was determined by averaging rankings for each farmer given by the resource persons. Farmers were put into one of three groups: high (< 0.35), medium (0.35 - 0.77), and low (> 0.78). Data for the independent variables in the analysis were taken from 1991 census conducted in each village. We hypothesized that wealth variables and other traditional indicators of recommendation domains would be identified by the analysis as important discriminating variables among profile groups. The results of the discriminant analysis are presented in Table 4.

Discussion: In Table 4, the analysis is divided into five sections. The first section (A) presents a list demonstrating the order in which the variables entered into the discriminant functions. A step-wise process using critical values of Wilks' Lambda determined the order and the number of variables which entered (and in the case of number of residents, was removed from) the functions. Thus, although number of residents was initially the most important discriminating variable, after taking into account the influence of other factors it became insignificant and was removed from the analysis. In general, the list and order of variables in Part A indicates a predominance of wealth and other, traditional recommendation domain indicators.

Table 4. Results of Discriminant Analysis (Pooled Data)[3]

A. Summary Table

Step	Action	Vars In.	Wilks' Lambda	Sig.
1	Number Residents	1	.77099	.0000
2	Oxen	2	.71202	.0000
3	Cattle	3	.66894	.0000
4	Members Absent	4	.62842	.0000
5	Fowl	5	.59600	.0000
6	Goats	6	.57568	.0000
7	*Houe Manga*	7	.55936	.0000
8	Cart	8	.53978	.0000
9	Sheep	9	.52696	.0000
10	Number Actives	10	.51561	.0000
11	Residents	9	.52186	.0000
12	Moslem Religion	10	.51049	.0000
13	Pigs	11	.50226	.0000

[3] Detailed analyses done on data from each site gave results similar to those being reported here.

B. Canonical Discriminant Functions

Eigen Fcn value	Pct of Variance	Cum Pct	Canonical Corr	After Fcn	Wilks' Lambda	Chi square	DF	Sig
1	.6924	79.69	79.69	.6396:	22.0000	0.5023	10	97.786
2	.1764	20.31	100.00	.3873:	1.8500	23.073	10	.0105

C. Standardized Canonical Discriminant Function Coefficients

	FUNC 1	FUNC 2
Houe Manga	-.37053	-.34655
Cart	.42914	.33264
Cattle	.40015	-.59180
Oxen	.27601	-.14049
Fowl	.25592	-.56749
Sheep	.24409	-.25262
Goat	-.13943	.77280
Pig	.17172	.22781
Family Members Absent	.42879	.28633
Family Actives	.24269	.15893
Moslem Religion	.24447	.25663

D. Canonical Discriminant Functions evaluated at Group Means (Group Centroids)

	FUNC 1	FUNC 2
1	1.31728	-.35491
2	.08668	.56915
3	-.80337	-.27261

E. Percentage of Cases Correctly Classified = 68.2%

The second section of analysis (Table 4B) presents relevant statistics for the derived discriminant functions. The right hand side of the table gives the Wilks's Lambda and associated Chi-square for each function. For example, for function 0 (before the analysis) the Wilks' Lambda is low (and Chi-square high) indicating the presence of a great deal of discriminating power within the variables. After the variation accounted for in the first function is determined, a lesser (though still significant) amount of discriminating power exists. The implications of this for the analysis are made apparent on the left side of the table where it is indicated that the first function explains over 79% of the variance, and the second, less than 21%.

The third section of the analysis (Table 4C) presents the standardized canonical discriminant function coefficients. These coefficients represent the relative importance of the variables in discriminating among the groups. When considered together with the Group Centroids (fourth section; Table 4D), the group to which the variable contributes can be determined. Thus, possession of a cart, the number of members absent, and the number of cattle are the most important discriminating variables contributing to a group 1 or 2 classification (high and medium) due to their positive signs in Function 1 and the positive signs for the centroids of groups 1 and 2 (also for Function 1). Oxen, fowl, sheep, number of actives, the moslem religion of the family head, and

the ownership of pigs contributed respectively less to a group 1 or 2 classification in Function 1. Alternatively, the *houe manga* and ownership of goats makes it more likely the farmer will be classified in group 3 (low).

The secondary Function 2 is useful for clarifying the contributions of discriminating variables to the various groups. The Centroids indicate that Function 2 is useful for unambiguously discriminating group 2. Consequently, the variables carts, pigs, number of members absent, number of actives and moslem religion which were classed as either group 1 or 2 in function 1, now appear to be more associated with group 2. The interpretation of the negative coefficients for cattle, oxen, fowl and sheep is straightforward: since function 1 indicated either group 1 or group 2 membership and function 2 indicates either group 1 or group 3 membership, these variables must be highly associated with group 1.

The last section of Table 4 contains the "Percentage of cases correctly classified", a measure of the relative strength of the discriminant functions. 68.2% indicates a fairly robust discriminant analysis but this figure should be interpreted with caution since it is well known that a substantial upward bias in this measure will exist when the same data is used to develop and test the same functions.

In summary, the discriminant analysis of the pooled data indicates that cattle, oxen, fowl and sheep are unambiguously associated with group 1. Possession of carts, pigs, the number of members absent, the number of actives and the Moslem religion are also associated with group 1 but more so with group 2. The *houe manga* is unambiguously associated with group 3; goats are also associated with this group.

There is reason to suppose that possession of cattle or small ruminants is a benchmark for level of wealth. Typically, small ruminants are acquired with cash from crop sales or other sources. They may be sold to purchase cattle. In the economic evolution of a family, cattle represent accumulated wealth.

Given these results, it is concluded that traditional, recommendation domain indicators such as wealth (animals, animal traction, etc.) and family size (number of actives) yield a classification similar to the results of the profile exercise.

IV. GENERAL CONCLUSIONS

It is said that FSR gives a "voice" to small farmers (Norman 1982, for example). Certainly in recent years farmer participation in research and development is seen as a necessary condition of success (Chambers 1989; Cernea 1991; Gatter 1993; Fairhead 1993). Chambers (1992:2) argues that farmers' own *analysis* of their farming systems is essential, so that *we* (researchers) do not "investigate, analyze, and prescribe" for *them* (farmers).

The method tried by RSP is an "enabling" intervention. It permits rural people to organize and share information with researchers. It also demonstrates how farmers see themselves. The method represents an important shift in "collaboration" with farmers, a shift from farmer "testing" to farmer "analysis." As such it is likely to improve research by improving the understanding researchers have of farmers and farming systems. It is likely, too, to enlist greater commitments from farmers to the research process, making research seem less like something imposed from the exterior and more akin to farmers' own experiments in resource management.

An additional benefit of this method is its simplicity. It can be employed by development workers, e.g., extension agents, to classify households in villages where research has yet to arrive. Households which appear to be included in a *recommendation domain* established elsewhere may thus receive innovations developed elsewhere. This "appropriate" method thus has the potential to increase the impact of research by multiplying the number of sites where research intervenes.

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The Settling of Western Burkina: Future Trends for Village Societies

D. Ilboudo

I. INTRODUCTION

As its name implies, the history of settlement chronicles a society's history by systematically taking into account all elements pertaining to the distribution of groups, and the modalities through which these groups become established (migration, socio-political and economic changes, formation of factions). (Izard in Samtouma, 1990)

The history of settlement allows one to create a chronology and hierarchy of events which explain the founding of current populations at national and local levels as well as in villages. The history of settlement thus implies a knowledge of migratory events, and in this sense current migrations thus represent the history of settlement in action. The settlement of a country or region is a dynamic process which must be contextualized in order to grasp the various paths it (will) undertakes.

The type of settlement currently under way in western Burkina, if carefully studied, suggests: either a multicultural society, i.e., a society in which each ethnic group possesses a distinct cultural value system; or cultural monolithism, in which a single ethnic group culturally influences all the other groups; moreover, a new form of collective living is borne out of a society experiencing cultural diffusion[1].

Is it not possible that a new society is shaped by present competition amongst cultural patterns, i.e., ethnic groups?

The more we understand this diversity, and the present trends, the more we have the opportunity to respond to the specific needs of societal development. One of the pitfalls of popularizing agricultural innovations, e.g. in a rural area, is without dispute the establishment of a method which takes into account the needs and constraints of communities and individuals. These needs and constraints, however, are often expressed through the goals of the "great societies", international or national, and by state agendas, and don't always take into account consumer trends or local markets.

[1]In 1882, Frederick Ratzel (considered the father of the diffusionist school) had already announced the principle by which, in the majority of cases, the migrations or interactions of peoples were the source of similarities amongst cultures, and that similiar cultural traits were rarely due to independent developments (Creswell, 1975).

II. ETHNIC FRAGMENTATION IN THE WESTERN ZONE

Thirty five out of sixty three ethnic groups censused in Burkina in 1990 [2](i.e., over half) are considered western zone natives.

Approximately four major ethnic families are recognized which, together, form the native core of western Burkina. Together these are: The Bobo group, the closely related Senoufo group, the closely related Lobi, and the homogeneous or mixed ethnicities.

The Bobo group consists of: the Bobo Mandare[3] (or Bobofing in the Dioula language), and the Bwa (or Bobo Oule in Dioula).

The closely related Lobi group consists of: the Teese or Lorhon, the Gaan, the K_l_go, the Lobi, the Dagara, the Birifor, the Dj_an, the Wala, and the Pwa or Puguli.

The buffer ethnicities, homogeneous or mixed comprise: the Bolon, the Sembla, the Dioula, the Bobo-Dioula, and the Marka.

The native core is characterized by its use of the Dioula language except in its southern portion, the rare village or two, and certain elderly people. This has conferred a certain cultural identity to the area which has allowed the zone's population to oppose itself to certain cultural values[4] brought by recent migrants, notably Mossi, whose socio-political structure has influenced the cultures of other native ethnic groups in the past, especially in the central plateau and in the north: the fact is that ever since they moved into the central plateau during the fifteenth century, and later in the northern part of the country, the Mossi have been influenced by the natives and by other local peoples, as much as they have, in turn, influenced the peoples around them.

Thus, for example, if the Dagomb-Nakomse influenced others on the strong use of female work in agriculture; it is the Yarse who converted the rest of the Mossi to Islam and commerce; or still, the Peulh transmitted their knowledge of husbandry to the Mossi (Orstom, 1975; Riesman, 1968; Ilboudo, 1966; Samtouma, 1990; Kouanda, 1984).

The Mossi, non-native in the western zone, according to a recent study (1991) by Alfred Schwartz, these days constitute the most demographically represented ethnic group.

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[2] Cf. J. Vaugelade and G. Kedrebeogo "A list of Burkina's ethnicities sorted by region" (Orstom, IRSSH; 1990).

[3] One generally adds the Bobo Dioula to the Bobo Mandare who are the 'true' Bobo of Sya to distinguish the Bobo-Fing.

[4] Whereas, for example, the woman's role in agricultural activities is very limited amongst the natives, it is preponderant in the Mossi culture; or from a religious perspective the natives are mostly animists whereas the Mossi are primarily muslim.

Table 1. Demographic and ethnic data at the rational level in the western zone and four villages

Ethnic Group	National Population (%) 1985	West Zone Population 1991 (%)	Dimolo 1990	Kawara 1990	Kayao 1990	Yasso 1990
Mossi	49.0	22.3	03.0	0	58.0	21.0
Bwa	02.1	16.7	0	0	22.0	0
Bobo	02.2	11.1	0	0	0	0
Senoufo	01.4	07.1	0	30.0	0	0
Dagara	03.0	07.8	0	0	08.0	0
Peuhl	07.5	06.5	14.0	02.0	12.0	08.0
Marka (Dafing)	01.7	03.4	0	0	0	49.5
Samogho	00.1	02.2	0	14.0	0	0
Dioula	00.5	01.4	04.0	34.0	0	10.5
Dogon	00.3	00.3	0	0	0	11.0
Nations	00.03	00.03	0	20.0	0	0
Lobi	01.8	01.8	79.0	0	0	0
Others (of which Samo)	30.2	19.4	0	0	0	0
Total	7,965.000	1,184.935	1,002.00	1,186.00	2,262.00	2,752.00

[1] Sources: Recensement National 1985, Ministère du Plan, Burkina; A. Schwartz, ORSTOM, Ouagadougou, 1991; Recensement des Villages-Sites, Programme RSP, Zone Ouest, 1990.

Table 2. Agricultural and demographic data at the national, regional and village levels

Data	Burkina Faso	West Zone Region	Dimola	Kawara	Kayao	Yasso
Total area	274,000 km^2	93.730 km^2	67.8 km^2	63.6 km^2	80.05 km^2	46 km^2
Usable Crop land (UCL)	89,150 km^2 (33% of the land)	35,600 (38% of the zone)	28 km^2 (40% of the total surface area)	26 km^2 (40% of the total surface area)	33 km^2 (40% of the total surface area)	37 km^2 (80% of the total)
Cultivated Area	25,000 km^2 (28% of the nat'l UCL)	7.950 km^2 (22% of the UCL)	11 km^2 (39% of the UCL)	25 km^2 (97% of the UCL)	10 km^2 (32% of the UCL)	28 km^2 (78% of the UCL)
Total Population	9,000,000	2,000,000	1002	1186	2262	2752
Demographic density	33 inhab/km^2	28 inhab/km^2	15 inhab/km^2	19 inhab/km^2	28 inhab/km^2	60 inhab/km^2
Rural Population	8,280,000	1,840,000	1002	1186	2262	2752
Agricultural Density Pop/cultivated area	331/km^2	251/km^2	95/km^2	48/km^2	218/km^2	98/km^2

Sources: Adapted from general data of the 1985 census, of the RSP Program census of 1990 and data (reports) *of the* four west zone CRPA: High basins, Sourth West, Mouhoun and Comoe belt.

Out of four village-sites[5] for research by the RSP program in the western zone, the 1990 census shows the presence of these in three villages, even if, in Dimolo, the Mossi penetration is just beginning.

The Peulh are represented in all four of these villages, albeit their numbers are much smaller in general with respect to the other ethnic groups.

In addition to the Mossi and the Peulh who are frequently encountered in the villages of the zone, there are the Dioula who despite pronounced cultural intermarriage these days, remind one of a certain regional to subregional dynamism. The Dioula from the RSP program's three village-sites, all originally from Manding, settled there during different time periods (19th century and recently) and for different reasons (wars, commerce and agriculture). Thus, in certain cases (Comoe), the Dioula are not considered migrants such as the Mossi and the Peulh, who recently settled.

Immigration in the western zone of Burkina is certainly ancient. since according to several investigations, it began during the French colonization, through escapes of individuals, but also of entire families to escape the multiple harassments of the administration (forced labor, heavy taxes...).

It is apparent that the migratory phenomenon, especially where exterior migration is concerned, was instituted if not made official through French colonial administration.

Forced or voluntary emigration towards the Ivory Coast and towards the Gold Coast eventually convinced people that good salaries and a better standard of living could be found to the south and west. With the freedom of movement borne out of a certain liberalization after World War Two and following the Independances, internal migration expanded. "The evolution of needs and of society 'institutionalizes' migrations, once the reasons that brought them into being are extinguished (Marchal, 1975)".

Thus, the refuge areas evolved into agricultural immigration areas, to which inhabitants of economically depressed areas now immigrate (by drought, by demographic and land tenure pressure, and by socio-cultural causes...) from all over the country.

This situation causes a dichotomy in the western zone between traditional-monocultural[6] villages and new style-multicultural villages that are expanding, with culturally distanced ethnic groups.

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[5] The villages of Dimolo, Kawara, Kayao and Yasso were chosen by the RSP interdisciplinary team of the western zone, as agricultural research sites to represent more or less homogeneous agricutlural sub-zones.

[6] A 'monocultural' village means that in this village, there exists only one dominating culture; but this does not necessarily mean that only one ethnic group can be found there. There exist villages with several ethnic groups, as is the case in Comoe, where one nevertheless finds a certain cultural homogeneity given the overall life expectancy of these groups.

This frequent presence of certain ethnic groups in the zone, which have added themselves to the first one, already very diversified, undoubtedly creates a tendency towards greater demographic density and socio-cultural intensity.

III. THE PROCESS OF SOCIO-CULTURAL INTENSIFICATION

The low demographic density per available cropland (S.A.U.) in the western zone. and consequently the low agricultural intensity coefficient (i.e.. the level of crop-land use)[7] have since (with better physical potential that elsewhere) attracted farmers and livestock farmers from disinherited zones from the north and central parts of the country. The massive arrival of migrants, mostly Mossi and Peuhl, in search of new land to cultivate and to use for grazing, especially since multiple droughts, has done little to change the agricultural situation in many areas of the western zone.

As a baseline figure, the total area is always the physical and historic fingerprint of the locality. The area of the western zone, slightly over a third of the national land area (thus 93730 sq. km. versus 274000 sq. km.), accounts for less than a quarter of the current national population thus 2,000,000 inhab. versus 9,000,000 inhab.

The available crop-land as with the total area, also represents a baseline figure, which together with other figures, allows one to grasp the zone's potential.

The level of available crop-land over the total area will determine, according to the village or the region, the agricultural tendencies and notably the evolution of production systems. Thus, the average available crop-land in the western zone[8] which is greater than the national average, also indicates the greater agricultural potential and the possibility of rapidly evolving production systems with respect to other zones.

The general agricultural situation of the western zone remains homogeneous as indicated by the data concerning available crop-land of the three other villages and the zone's average (around 40% of the total area). above the national average (which is 33%).

But it is the total agricultural surface area, which indicates the level of occupation of lands by cultures at a given time, which gives more information concerning the gap between usable crop-land and human occupation. It is thus noted that at Kawara and at Yasso, 97% and 78% of the available crop-land is cultivated, respectively.

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[7] cf. annexed table on the classification of the ORD (current CRPA) by SAU and distribution of the agricultural population in 1975.

[8] In this case western zone means the four collective CRPA: the Mouhoun belt, the Comoe, the High-Basins and the southwest where the eight provinces are: the Mouhoun, the Kossi, the Sourou, the Comoe, the the Houet, Kenedougou, the Bougouriba and the Poni.

It helps to know that Kawara is a village where women and men are full-time farmers. The women of Kawara, on top of helping their husbands with traditional agriculture, are involved with rice production in the lowlands. It is therefore easier to understand why landspace is more heavily used than in other areas.

Where Yasso is concerned, situated in flooded catch-basins, and where the available crop-land is almost equal to the total land area, one can better understand the agricultural pressures exerted on this village, which is measured by the level of the cultivated area over the available crop-land.

If the demographic density is relatively low in Burkina and more still in the western zone, one nevertheless notes that nowadays there is a tendency towards differentiation inside the zone. Villages which have received migrants and have simultaneously undergone a change in their agricultural production systems, as in Kayao and Yasso, have an evolving population density.

A narrow correlation is noted between agricultural immigration, high population density and local changes.

Having left a degraded zone the migrants often bring a spirit more open to change, especially where efforts to increase agricultural revenues are concerned.

Despite the low productivity of agriculture in the western zone is relatively richer than in the rest of Burkina. Situated in the Soudanian zone it receives the highest rainfall with a pluviometry varying between 800 to more than 1200mm. With some exceptions this agriculture is or could reach sustainable levels for the zone's population. However, not all villages are self-sufficient.

What explains this differentiation between self-sufficient villages and the others? And what explains the fact that in one village, some individuals get their agriculture off the ground while others struggle their agricultural activities?

Do these realities not express demographic, economic and cultural differences between villages?

If these diagnostic investigations aim to understand crop and livestock production systems in the villages, and then to identify the potentialities and constraints of the agro-socio-economic setting, according to us their goal is to help understand the process of social and cultural change. This allows one to have a global vision of differences between villages and within villages[9] .

All of the western zone adjacent to the center and north of the country has already undergone true demographic, economic and ecological changes due to the settling there of migrants. Largescale clear-cutting of the land, the modernization of agricultural techniques has increased production as well as available surface, the introduction of cotton cultivation and the use of animals in agriculture are factors that have transformed the agricultural production system in this zone. The

[9] i.e. the four research village-sites of the R.S.P. program of the western zone and the INERA. The interdisciplinary team of the R.S.P./western zone program, to which we belong, has since 1990 conducted several research projects in these villages.

present situation of the western zone reflects this past very recent turbulent history already described.

One notable change is, without doubt, the process of cultural transformation, which is currently operating in the field through socio-cultural exchanges establishing themselves between two communities living together as a whole in village societies: the natives and non-natives. Thus, for example, out of thirty six villages researched in the western zone[10] during 1990, we were able to note that thirty two villages (i.e., 89% of the villages) were inhabited by at least two communities of distinct status: the natives and the non-natives or migrants, and more precisely by at least two culturally distant ethnic groups. What will come of these different ways of life more or less specialized by such diverse environments?

This is what we seek to understand through the example of the historic and cultural situation of one of the four village-sites of RSP/western zone.

The example of the Yasso village settlement. Autonomous agrarian and social entity. Yasso is a Dafing village located in the Balave department of the Kossi province. Accessible during all seasons, today it is really a cosmopolitan village with an economically dynamic population. Yasso was chosen to represent the cotton-producing sub-zone strongly equipped following the sub-zoning and the reconnaissance investigation undertaken by the RSP/west zone team from July 1989 to June 1990.

Yasso, as are most of the villages of the western zone of Burkina, is a village undergoing changes. If, nowadays, the economic changes seem more visible, it is good to underline that the changes were first ethno-demographic, and this continues to operate.

In this village of Yasso, one can presently count five ethnic groups each with its own relatively important community. There are, by decreasing order of importance in Yasso: the Dafing, the Dioula, the Mossi, the Kaado and the Peulhs.

One must, before describing the settlement of these different ethnic groups in Yasso, underline the inherent difficulties in breaking down the ethnic groups through assertions made by the natives and the non-natives. By natives or aborigines according to some, one means inhabitants whose origins are the said location and whose ancestors have always lived there, and this without other reference, we will attribute this qualifier solely to the Bwaba who are the most ancient in the region, who do not live on the Yasso land as such, but always been in the area, as we are in the middle of Bwaba country.

If, on the other hand we speak of non-natives as inhabitants whose ascendants are the first to have invested themselves in the area, one may affirm that the Dafing are the non-natives of Yasso. One

[10] Reconnaissance investigation carried out by the multidisciplinary research team throughout the entire west zone of the country, in order to determine homogeneous sub-zones previously clustered and to choose the research village sites.

must also emphasize that even in this assertion all the Dafing of Yasso are not non-natives. There exist Dafing migrants called Dioula.

Similarly, if by migrants or allogenous peoples we speak of: inhabitants from other areas, we will encounter difficulties when breaking down the different ethnic groups since certain heads of enterprise in Yasso are of the second, or of the third generation of migrants.

Thus, in Yasso, we will see migrants in the Dafing who constitute the native ethnic group and we will see in the migrants, individuals considered natives and who, for example, participate in ritual ceremonies. But in reality, the situation is more trenched as no migrant son or grandson claims native status, no matter what ethnic group he belongs to.

To understand these particular situations, it helps to know how all these ethnic groups present in Yasso became established.

The Dafing of Yasso. The ancestors of the Yasso Dafing probably settled there during the establishment of the Macina Peulh kingdom by Cheikou Amadou. Just a reminder that Cheikou Amadou[11] constructed the new capital in 1819, Hamdallayi (praise to God) which created the Bani between he and a possible attack by the Bambara. As of 1825, he extended his conquests and engulfed Tombouctou this empire centered on the Mesopotamia of Bani and the interior Nigerian Delta which extends from the confluence of the Sourou and the Volta-Noire and south to Tombouctou in the north.

As everywhere else, the chronicles concerning the arrival of the first occupants are much varied and more or less mythological. We bring here a few selected accounts regarding the settlement of the Dafing and the creation of Yasso which developed next to the site of a previous village named Konney.

Konney. The Konate arrived first followed by the Peulhs from the north. This wave consisted of two brothers, their respective families and their men[12]. The older brother felt weakened and declared to his brother "N'DESSERA". Thus he invited the younger brother to continue with the men to flee the enemy. Some men chose to remain with the older brother to defend him in case of an attack, and in this manner Desse was born. In turn, the little brother chose to settle between two water ways to wait for his older brother. With the fear of the Peulhs catching up to them gone, the younger brother allowed the men to build their houses. They named their village "HEN KAA KON" which means 'let us await him', which, by transformation became Konney. It is told that Konney later conquered the whole area by war and imposed its domination by forcing all the surrounding villages to pay an offering.

This Konney village, after its apogee fell into a period of decadence which, in the end, brought about the dispersion of its inhabitants throughout the whole region. A war was provoked by the

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[11] cf. Ki Zerbo, J. "Histoire de l'Afrique Noire, d'hier a demain". Hatier press, Paris 1978 (p.258)

[12] i.e. probably their slaves or paid warriors.

Peulhs against Konney and the neighboring villages of which Desse and Yasso would play the lead role in Konney's fall.

Having chased the Bwaba from Dokuy, the village they occupied, the Peulhs now sought out means to vanquish the Konate of Konney and occupy all the neighboring villages of which Yasso, then a very small village. Where Konney's fall is concerned two versions have been proposed to explain it:

1) An epidemic would have brought about a high infant mortality. This situation shed panic throughout Konney's population and caused a dispersion throughout the region.

2) By way of black magic, the 'Mougouti' or 'the powder war' i.e. by occult science the Peulhs succeeded in vanquishing the population of Konney, because of their inability to conquer them with weapons. A bad spell would have been cast on the village as well as on Desse which was also destroyed. One morning, the population of Konney woke up to find a cat with a boa on its head perched on the rim of the well. The population was terrified: from then on nobody dared go to the well or even go out at night. The Peulhs enemies succeeded and the village decayed very quickly; the men having fled to take refuge in other villages more or less distant of which Dira was one.

Yasso. If for the existence of Konney (which has not existed for a long time) one can only come up with one realistic explanation, such is not the case for the birth of Yasso which has two versions with varying amounts of mysticism depending on the version's source. According to the Tyonou version, Tyonou 'Wakari' or 'Lassoun' of Mande or more precisely of Bonflan, was a great hunter in search of good game areas. When he got to a marsh (next to present Yasso), he settled in a clearing from where he later discovered the Konate village of Konney. He returned to Bonflan to prepare himself and with the permission from his village leader returned to settle to the north of Konney in the depth of the forest (impenetrable because of ferocious animals). The Tyonou ancestor came against a lion who was the master of the area. The lion fell and there the ancestor built an oven to dry the meat, and thus was later born in that spot the 'heart', even today, of Yasso.

After having killed the lion, the Tyonou ancestor entered the Konney village and abducted children to increase his world. The konate had thus named the area "Diarraw-Ya-so" which means 'house of lions' or 'retreat of the lions', and they were afraid to venture there. The pronunciation of this name in Dafing was later transformed into Yasso. Before returning to Bonflan to bring his family and settle for good, he dug out a tree trunk and placed a stone in it as a symbol of his staked claim.

According to the Konate version, the Tyonou ancestor and his kin built bricks out of banco upon their arrival to build their houses with. But as they moved to Desse the children of the Konney village destroyed the bricks as they were made. As this happened a second wave of Tyonou (Tyonou II) arrived after the fall of their first village 'Bonflan'.

Upon their arrival the Tyonnou II brought with them new ways of building houses: they erected walls without making bricks. On their way to Desse, the children of Konney saw the rapidly built house came back with friends from Desse to destroy the house. The leader of the Tyonou II (the second Tyonou wave) instigated an attack on the Konney villagers. The leader of Konney informed of this fact, asked his people not to provoke the Tyonou as he was astonished at the audacity of this little group of men who dared attack the most feared village in the area. The children of Konney and Desse are said to have baptized the Tyonnou area "Nan maw-ya-so" which means 'house of idiots'. This expression was transformed and later became Yasso.

A third version, less credible, would have it that the inhabitants of Konney were the ones making the bricks to build their homes. And the construction never saw the light of day because the Tyonou ancestor and his kin destroyed the bricks. In this version the Konate would have then fled and taken refuge in Desse which in Dafing means "they were unable". In return the inhabitants of Desse called the Tyonou Ya-so which, in Dafing, means 'inhabitants of the ignorants.'

The Mossi of Yasso. The Mossi of Yasso are distributed amongst two group according to their arrival wave and settlement.

The first arrival wave corresponds to escape migrations to escape the forced taking of men for labor imposed until the end of the Second World War. The arrival and settlement of the first Mossi in Yasso occurred in between the two world wars.

Thus we were able to encounter some Mossi born in Yasso and almost sixty years old, therefore born before 1935. There remains only a few lineages making up the first wave of arrivals in Yasso, are still in Yasso, and notably in Lawarankuy a neighborhood founded by one of the first lineages.

The second wave of settlement corresponds to Mossi migrations towards 'new lands' of western Burkina. According to the AGRAR[13] report of November 1979 "... The proportion of emigrants migrating out of the Mossi country was 7% from 1960 to 1966, 20% in 1966-1969, and 53% in 1969-1973.

According to a recent investigation by A. Swartz[14] , of the total 4112 farmers migrating out of Mossi country polled in 1990 in the western zone (by extrapolating this makes 40503 farmers):

- 8.2% arrived in the 60's,
- 28.7% arrived in the 70's and,
- 48.7% arrived in the 80's.

[13] Preparation des deux projets Koudougou et Bougouriba II Partie Bougouriba, Annexe 5. P. 22, AGRAR UND HYDROTECHNIE GMBH ESSEN, nov. 1979.

[14] A. Schwartz "L'exploitation agricole de l'aire cotonniere Burkinabe: caracterisitiques sociologiques, demographiques, economiques." (doc. de travail, Ouagadougou, Oct. 1991).

In Yasso the greatest number of migrants from the Ouahigouya region and the Yako region, arrived for the most part after 1970 during the drought most felt in the center and the north. Innumerable and diverse lineages are thus settled in Mossikin (traditional neighborhood of Yasso) or in Lawarankuy.

The Dioula of Yasso. These days the only difference between the Dioula and the Dafing natives is that, precisely, they are migrants.

When they settled in Yasso, two fundamental differences separated them. Whereas the natives were sedentary farmers, the newcomers were traders. Secondly, the first Dioula were coranic masters come to convert the animist natives.

Some of these first Dioula came from Mali (Sonan) or other villages more or less distant from Yasso, more than seventy five years ago. The Dioula migration would have continued until the 60's, before stabilizing itself.

The Dioula or Dafing migration, contrary, for example, with that of the Mossi, was never massive. These days, the Dioula still have a strong hold on the trading business in the village, but more totally the monopoly of the islamic children. As migrants, they feel the same constraints in lack of good soils for agriculture.

The Kaado (Dogons) of Yasso. The Kaado or Tomon or yet Kibsi are Dogons whose roots are located in the cliffs of Bandiagara. Their ancestors left the cliffs a long time ago following destruction of their area by locusts and the famine that followed. Kaado would thus be a Peulh designation, that which was adopted by the Dafing. The Mossi usually call them the Kibsi. Tomon or Dogons are the names they give themselves, they are autonyms. Following the departure from the cliffs of Bandiagara, the Dogons of Yasso's ancestors settled in Djena which means 'on the hill'. Djena is situated in a Bobo area (Bwaba) next to Djibasso. The soil of Djena was thus given to the Dogon ancestors at their arrival towards the end of the 18th century (according to an approximate calculation of generations according to the present Dogons of Yasso). A portion of the Dogons of Djena found itself in Boule next to Barani, the Peulh enclave situated in the middle of Bwaba and Marka lands.

A realistic hypothesis is that this reconciling with the Peulhs of Barani must have been violent. The name give the Dogons by the Peulhs is, as it were, symptomatic of the domineering nature of the relationship which have brought together these two communities in the past. Kaado and Peulh would signify 'follow me'. We also know that Barani was back then a small kingdom very powerful and rich even if nowadays the majority of Peulhs left with their flocks towards other areas.

Today a fair number of Dogons still live in small villages around Barani: Were they slaves or descendants of slaves recently liberated? The present study did not allow the solving of this enigma. In any case, the first wave of Dogon Migrants to arrive in Yasso came from Boule (Barani) or from Senekadougou d'Aourena again next to Barani, less than 20 years ago. Contrary

to past massive migrations the present migration of Dogons into Yasso is less massive even individual.

A second wave of Dogons is in the middle of settling in Yasso and this wave directly from Djena where the Dogons remain still.

The Peulhs of Yasso. In this northern part of the western zone, the strong presence of Peulhs livestock farmers can be explained undoubtedly by the troubled regional history and the proximity of ancient Peulhs enclaves such as Barani[15] or Dokuy, (cf. the Islamic holy wars: Djihad and other wars of conquest of Ousman Dan Fodio, d'El Hadj Omar Tall, of Cheikou Amadou... during the 19th century.).

Still, in Yasso, the presence of the present Peulh community seems very recent. Considering their nomadic way of life other communities could have gone through in the past. Considering the historical domination of the Peulhs in the area, it is not impossible that certain communities could have lived in Yasso before the present ones. Besides, the present Peulh presence does not correspond to a religious deployment, but to the search for good pasturage. This present Peulh presence corresponds as everywhere else in the western zone to a more individual migration than a collective one. This Peulh migration is most often characterized by several stages in such a way that the recent origin does not often say much concerning the origin of the first lineage.

One thus notes that the lineage segments come from the Barani, Bomborokuy or Djibasso surroundings. Some claim to have come directly from Dokuy without us knowing the previous stages.

One must recall the Peulh husbandry system, to understand this systematic progression from north to south: the transhumance and the semi-transhumance, which consist in following the pasturage and water whenever they can be found. This search for pasturage brought about moving during the dry season towards fallow lands of the interior; and during the rainy season towards their own permanent or semi-permanent installations.

The cultural and social confrontation. And the human adventure continues in Yasso! One must imagine these diverse communities each with their own different experiences, finding themselves on land 46 sq. km. in order to construct their future.

In the beginning, everything brought together the first Dafing groups who all came from the same area and were fleeing a common enemy. Cultural integration was facilitated by the need to stay grouped to defend themselves against the outside elements.

The Dafing at that moment were still animists, and it is indeed to save their beliefs that were forced to escape. Hunting and gathering allowed, together with a very extensive agriculture, and certainly reduced to a few crops to produce (if not to collect!) for their own subsistence.

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[15] cf Diallo Youssouf "Les Fulbe du Boobala, Genese et evolution de L'Etat de Barani (Burkina-Faso), EHESS, Paris, 1993.

If these days the Dioula (or rather the Dafing muslims and traders at their arrival), are still foreigners; is it not that the collective conscience of the natives still reproaching them for having brought with them what they (their parents) once fled from, i.e., Islam? This would explain why despite a great knowledge of Islam by the Dioula, the muslim chiefs are still chosen from natives who often went elsewhere to be trained; whilst great Dioula coranic masters receive students from the whole area and even beyond.

The occurrence of the catholic missionary penetration in Yasso after World War II, was necessary to speed up the massive conversion to Islam; certainly through the same reaction that those who were able to observe elsewhere in Burkina and in the Sahelian sub-region: in the face of two monotheistic religions. Islam was preferred as it does not deny traditional values. It must be emphasized that in Yasso, the catholic mission was a success at first, as shown by the construction of the church and the big property of the mission.

The first Mossi would have arrived in Yasso animists. The conversion to Islam or to catholicism intervened later, even though some remain animists even today. The Mossi of the second wave, who arrived during 1972, were already muslim upon arrival. It is good to remind one that historically the Mossi also remained animists for a long time, and that the Yarse settlement in Mossi land (cousins of the Dioula); and also by the same reaction against the mission, assimilated to the colonization that they massively converted to Islam.

The Peulh and Dogons, also arrived muslim at Yasso, since they came from Islamic centers such as the Peulh enclave of Barani.

The data of the 1990 census by the RSP team indicate the percentages for the entire 283 heads of farms of Yasso: 65% muslim, 27.5% catholic, 7% animist and .5% protestant.

What these figures hide is the continuity and quasi-universal animist practice0 beyond religious declarations. In Yasso as is often the case in Burkina and in Africa. one is animist before any other religion.

Thus, management of soils and wilderness, human health and many other aspects of daily life, are managed by a traditional legislation which the customary chiefs and wizards attempt to perpetuate.

What is singular in Yasso and in this western zone today, are less the ethnic particularities than the present trend towards a certain cultural unification. This is what we call cultural "densification", i.e., an intensification of cultural life with the onset of different cultural models already set up.

The organization of space in the villages of the zone for example, demonstrate three fundamental dimensions of these present village societies, that is:

- A historic dimension which defines these villages through indelible prints left by the presence of different ethnic groups with their specific cultures.

- A basic sociological dimension which defines every village by a gradual integration; this from the types of habitat and the realty gamble. The integration process is an historic step in the life of the Communities and also a subjective will of the ethnic groups concerned.

- A third structural dimension, defines the villages by the organizational differences of the ethnic groups. The social organization of the native group is often the norm accepted by all or simply respected by all.

In general the dwellings these days tend to be clustered. In large villages, the Migrant groups are brought to occupy increasingly restrained spaces. One must also note that even in villages where the traditional dwelling of the natives was dispersed, one notices that a certain grouping together is occurring in front of our very eyes. Is this through 'the softening of the traditions' taking into account the 'pax' colonial or post-colonial which allows these villages to live in peace and change their habits as some authors believe? It seems that a certain socio-economic and demographic evolution changes habits as rapidly as any other socio-political consideration.

Thus one notes in Yasso, which is a big village where economic case brings more the disintegration of the traditional village in which dwellings are clustered tightly together. We are witnessing a shattering of dwellings and the richer of the young farmers are building further away, veritable mansions; whereas the mossi migrants for example, who have traditionally dispersed dwellings, are here developing a progressively tighter knit living area: probably for more security, but certainly also because space devoted to living areas is reduced.

Changes are thus observed at all levels in the value systems of different communities, and this through coexistence. More than religion which tends to restructure itself in certain cases, or changes in living space; one notes the generalized adoption of a language, in this case Dioula.

There is also the growing technical knowledge bank, of which the most visible is without question, the integration of cattle raising and agriculture: the use of draft cattle for the adoption of draft culture and the use of organic manure.

Where this is concerned, one may notice that a certain agricultural 'revolution is operating in the zone with the adoption of agriculture by the Peulhs who were not farmers when they arrived, who thus have become very skilled agro-shepherds.

All these changes remain nonetheless limited as the important traditional institutions like marriage, are not charged by inter ethnic alliances.

More constraining in poorly populated villages the traditional institutions are undergoing a certain relaxing in the more heavily populated villages in which several cultures are brought together without one becoming exclusively dominant.

Thus collective institutions such as the Djoro (initiating institution) or the "tons" (work associations according to ethnic group, age and gender), in the monocultural villages of Poni or of Comoe are social realities from which few individuals escape. On the other hand in open villages such as Yasso (in a difficult but tendencial way) one notes that traditional institutions are no longer what they were and are confined to one increasingly restrained group of people, who by being conservative wish to perpetuate these traditions.

To complete this analysis, one must bring up the field of social conflicts which bear much meaning where the future of the villages is concerned. These conflicts convey different interests of the groups; and the ways in which these are solved symbolizes the level of consensus achieved or projected.

In general, one encounters mostly land tenure conflicts, bearing on:

1) property shared by close ancestry;
2) property between neighboring villages;
3) land occupied by migrants. The borrowing is carried out generally by young natives more sensitive to the dangers of appropriation of land by migrants.

Up to now, the solving of these conflicts goes through a traditional or administrative legislation according to the nature of the conflict. Where the collective conflicts amongst villages or lineages are concerned the customary authorities, the elders, witnesses of the past, are summoned.

For more individual conflicts (usually between a migrant and a native owner of the land), the local representative of the administration, the delegate, is summoned[16] .

To this one must add that from now on the efforts (of the administrative authorities and the development organizations) fuse in order to find solutions to these conflicts within permanent official and structural frameworks and with the effective involvement of the populations: this is land management as such, which implies an improved management of natural resources, i.e., all that is needed to foster a durable social life. But until such time as the populations understand these activities and say what they really feel, we shall pursue the effort which consists in understanding their social dynamics.

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16 The delegate. borne out of the structures of the 'Revolution'. even though the said structures were abolished. remains a reality in the rural setting. In the village. for example. as much as one does not create a structure automatically by a text. as much as one does not dissolve this as is done in town by a law. Moreover. the delegate in these cosmopolitan villages of the west zone. is often the result of consensus. if he is not a direct representative of the customary authorities.

VI. CONCLUSION

The current discussion concerning participatory development, brings to light the fact that rural masses in our areas were not accustomed to administering themselves. Without trying to imply that malign orientations are brought in from outside the rural world, after an analysis of population trends one may think that the present multi-cultural village societies of western Burkina gather within themselves an internal dynamism and mechanisms capable of bringing about positive innovations.

This important social game in the zone is perceived by different human groups. We were able notice that, historically, cultural values which were assimilated were ones which initiated a debate which takes into account local values.

Thus the non-natives know more than anyone, the price of coexistence which allows one to benefit from a new rural life and all its attributes.

The natives know that with foreigners (rural) in their village, they can 'benefit from the richness of the world without leaving the village' (as was confirmed to us by the Bwaba patriarch of Kayo). Thus they know that the current melting pot is a condition which favors the continued changes in their society. Must we absolutely direct the social body, (to be assured of a homogeneous and standardized society) or rather must we initiate a debate concerning the possible innovations, by favoring the access to diverse and modern tools and then let each village society takes its own course towards its own identity?

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Women's Activities in the Village Research Sites of the RSP Western Zone

D. Ilboudo and P. Lingani

I. INTRODUCTION

"Women are the true actors in development", said J. MADJI in his editorial, published in CESAO's journal "Construire ensemble" (Constructing Together), n° 34, "They participate in the economic and social development of the community by performing the multiple tasks that fill their days". Women are indeed responsible for all kinds of work: from growing and preparing food, educating the children, housekeeping, the chores of drawing water and hauling wood, to small-scale commerce (henceforth referred to as 'trading'). The contribution of women to the task of improving living conditions in our societies is inestimable.

From the very beginning, up until the present day, the RSP team has worked directly only with the men who are heads of housholds and hence responsible for family farming activities. The production systems research team (RSP) has paid little attention to the contribution made by women to the development process.

The study of the main, specific activities of women, which was initiated by the RSP's Western Zone team, is set within the context of a first hand knowledge of women's activities and roles in the development process, as directly observed in the RSP villages.

This study will provide information and insights into women's activities which will help guide action to improve the productivity of women in these village research sites.

The present report concentrates mainly on diagnosing constraints to the main activities of the women in these villages. It will be structured around two principal points. As a first stage, we will inventory the activities of women living on these sites. As a second stage, we will bring out the specific details of these activities, noting especially what constraints they represent for women.

II. THE OBJECTIVES OF THE STUDY

This study should enable us to achieve the following:

General goals

- Inventory the activities that involve women throughout the agricultural year as a whole.
- Analyze women's activities in the context of the dominant and specific social and cultural characteristics of each village site.
- Determine the real potentialities which would favor or limit the contribution of women to economic and agricultural development.

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Specific goals

- Survey the principal and secondary activities of women on each village site, by ethnic group and by season.
- Identify the women socially by activity.
- Investigate the socio-economic and cultural milieu of the women.
- Determine, in dialogue with the women, which activities are the most demanding, and which are the most profitable.
- Understand the history of women's activities.
- Learn the attitudes, opinions and aspirations of the women, as far as their activities are concerned
- Determine how the income from women's activities is spent.
- Identify which factors promote or limit the development of women's activities.

III. DEFINITIONS OF CONCEPTS

To improve the focus of our study, it seems necessary to define some concepts designating "women's activities" and "activities performed by women".

"Women's activities". Women's activities are those activities which are performed by women, but which could also be performed by men. Women's activities are activities which are linked to the women's status, which means that these are activities traditionally associated with women but which, with today's more modern outlook, are being undertaken by men too. Examples of this category of women's activities include: domestic tasks, such as cooking, collecting wood and providing child care.

"Activities performed by women". These are activities that are ones which women undertake, but which are not necessarily traditionally "women's work". Certain tasks done by women are reserved in traditional society for men, for example, when the plastering of the walls of their homes is done by a woman, it is an activity "performed by a woman", in spite of the fact that this task is socially reserved for men.

"Specific activities". The activities are called "specific" when they are exclusive in themselves, both in their nature and in the laws peculiar to them. When one speaks of specific activities of a given group, this means the activities exclusively performed by, or linked with that group. In this manner, one can refer to the specific activities of Sénoufo and Fulani women, to designate the activities exclusively performed by those women who belong to the Sénoufo and Fulani ethnic groups.

IV. HYPOTHESES

For the purposes of the present study, the following hypotheses are retained:

- The women in our villages have very diversified activities depending on their ethnic group.
- Women's activities change depending on the season and the economic situation.
- The women's activities in the villages depend on certain social and cultural considerations, such as age, marital status, etc. They also depend on the socio-economic standing of the farm with which the woman is associated with.
- Generally, the cultural traditions are the key to establishing the framework for women's activities.
- The development of certain women's activities is made possible thanks to the benefits that the women themselves gain from them - such as freedom, and financial independence.

V. METHODOLOGY

For this survey,concerning women's activitites, activitites performed by women and specific activities of women in the RSP village research sites, several methods and techniques were used to collect the data. The following steps were taken:

1. A survey was done of the women's activities of a previously established sample group. With the help of a questionnaire, we surveyed all the women's activities in the three village research sites, namely, Yasso, Dimolo, and Kayao. The survey of activities did not cover Kawara, because we already had previously collected date on women's activities on this site.

2. Personal interviews were held with the women. Both directed and open interviews were conducted. For the directive interview with the women of the restricted sample, a questionnaire was developed which enabled us to record all the women's replies. As for the open ended interview, this involved a limited sample of Kawara women.

3. Direct observation during our visits to the village research sites provided invaluable complementary information to the actual questions asked and to any dialogue that ensued.

The documentary techniques employed were very useful to us, since they enabled us to acquire socio-cultural information about the village research sites.

VI. SAMPLE SELECTION

The survey's sample population includes women of all categories, ages and ethnic backgrounds. The sampling unit was the farm.[1] To record the activities we proceeded using a random choice of

[1] A farm can be defined as "the people, or group of people, generally blood relatives or united by marriage, who usually live together in the same compound, and who produce crops and share livestock together, and who have the right to partake in meals which come from a single, shared kitchen (...). Ministry of Agriculture and of Animal

farms. The census focused on 25 farms in Kayao, 18 in Dimolo, and 17 in Kawara. For practical reasons, we were not able to survey more than 18 farms in Yasso. All the women living as part of the farm selected for the survey were interviewed . This meant conducting a survey of a total of 70 women in Kayao, 35 in Dimolo, 30 in Yasso and 58 in Kawara.

Table 1. The population of women in the villages, and the size of the sample.

Villages	Total population of women	Survey sample
Yasso	556	30
Kayao	490	70
Dimolo	186	35
Kawara	254	58
Total	1486	193

Our sample covered 13% of the total number of women in the RSP western zone villages.

The distribution of women according to ethnic group is variable. A random choice was made of women representative of the various ethnic groups. As far as the directive interview was concerned, a judgement sample was made from the pool of women surveyed taking into account activities and by ethnic group. The questionnaire was administered to 12 women in both Yasso and Dimolo.

VII. GENERALITIES CONCERNING THE VILLAGE RESEARCH SITES OF THE RSP/WESTERN ZONE

The RSP village research sites are Yasso, Dimolo, Kayao and Kawara. They were chosen based on the types of crops grown and the level of animal traction used. The availability of irrigated perimeters, population density, and the importance of emigration are criteria retained to differentiate the sub-zones. What are the physical, socio-economic and cultural characteristics of these village research sites?

Physical environment. The village research sites are all situated in the Western Zone, sharing a climate characterized as of the Sudanian or North Guinean zone. Soil in these areas is mainly of the ferruginous tropical and leached kind.

Geographical location of the villages. Yasso is a village which is situated in the Balavé department in Kossi Province. It was chosen as representative of the sub-zone in which cotton production is well developed and animal traction is widely used.

Husbandry. June, 1990, p.11. The farm is managed by the head of the household who is the primary decision maker.

Dimolo is a village situated in the Loropéni department of the Poni Province, 45 kilometers from Gaoua, and 20 kilometers from Bouroum-Bouroum. Dimolo was chosen to represent the zone which cultivates an income crop other than cotton (igname) with little animal traction.

Kayao is a site situated in the Koti department of the Bougouriba Province. The criteria which prevailed in the choice of this village included: the dominance of food production and the high level of animal traction. A transition from subsistence agriculture to commercial agriculture is occurring, with the introduction of cotton growing in the production systems of its farmers. Kawara is situated in the Sindou department of the Province of Comoe, 7 kilometers from Sindou. Agriculture at the Kawara site is dominated by food crops, with very little mechanization.

Rainfall in the area. Rainfall in the Western Zone is generally above 800 mm. The rainy season in 1992-93 had a difficult start, with several dry periods of varying duration. In Yasso the dry spell lasted from mid-June to mid-July. The rains were, however, well spaced out during the agricultural season. In general, the rainy season lasted until mid-November, unlike the previous year when the rains had already ceased by October.

The rainfall recorded in the village research sites throughout the rainy seasons of 1991 and 1992 are as follows:

	Dimolo	Kawara	Kayao	Yasso
1991	1157 mm	1068 mm	922 mm	958 mm
1992	1086.5 mm	825.3 mm	930.5 mm	943.5 mm

Rainfall for 1991 was generally better than that in 1992 in all four villages.

Human environment. This description of the human environment will focus on the socio-economic and cultural dimensions of the village research sites.

The village of YASSO. Yasso has a population of 2,752 (RSP census, 1990). This is a zone with a high level of emigration. Consequently, the population density is high: 60 inhabitants per square kilometer.[2] The principal ethnic groups represented in Yasso are the Dafing (60%), the Mossi (23%), the Dogons (or, Kaado, 9%) and the Fulani (7%). The Dafing are native to Yasso. There are some Dafing, however, who count as migrants, because they do not originally come from Yasso. Among the infrastructure present in Yasso, of particular importance is its large market, where one can observe both wholesale dealers and retail merchants. Yasso also boasts a school with three classes, mills for grinding millet, and boreholes for household water. A major road runs through Yasso, linking it to Dédougou. The village of Yasso has a Village Women's Group (Groupement Villageois Féminin (GVF) which is quite active.

[2] D. Ilboudo: "*Peuplement de l'Ouest Burkina. Quel projet de société villageoises*" *(Populating West Burkina: What a project of village society) Table 2, p. 7.*

The village of Kawara. Kawara has a population of 1,186. The principal ethnic groups encountered there include: The Natioros (20%), the Sénoufos (30%), the Dioulas-Griots (34%), the blacksmiths Samoghos (14%) and the Fulani (2%). The chiefs all come from the Nationros, who were the first to settle on this site. The different ethnic groups present in Kawara live together harmoniously. One particularity of Kawara is the predominance of the Islam, which has been a contributing factor to the harmonious life on this site.

In Kawara special days are set aside on which work is forbidden. The dates vary by ethnic group. These days correspond to certain traditional market days, or to days when ancestors are remembered. Also noteworthy are the remaining vestiges of certain animist practices in this village. Kawara has one, unfinished school, which was built by the local population. The local market is very limited. Villagers go to neighboring markets to buy or sell products.

The village of Kayao. This village has a population of 2,262 inhabitants, with the following ethnic distribution: Bwaba (23%), Mossi (58%), Dagari (8), and Fulani (11%). The Bwaba are indigenous. There has been significant emigration to Kayao. The population density is 28 inhabitants per square kilometer. Kayao has a school and a large market which draws vendors from all directions (generally from other villages in the vicinity).

The village of Dimolo. Dimolo is a Lobi village, with 1002 inhabitants, 79% of which are Lobi, 4% are Dioula, 14% Fulani, 3% Mossi, and just a few Dagari. In Dimolo, the Lobi culture dominates. Family kinship is bilinear with matrilinear predominance, which means that in this society individualsare identified by their mother's family. In the Lobi language (Lobiri), the name Dimolo signifies "where there is (game) to eat". The village of Dimolo has a school and a very small market. It is linked to neighboring villages by tracks. In Dimolo there is a Women's Village Group (GVF) which mobilizes the women for certain activities (management of a mill, mutual aid for agricultural tasks).

The land-tenure at the village research sites. In all study villages, land is still collectively owned by indigenous families. The land chief intervenes in land management when there are disputes or to control the rites and sacrifices made to ensure better productivity. The land chief serves as intermediary between the indigenous landowners and the emigrants.

On the question of land management, women may have the right to use land for individual fields. In these fields they generally cultivate crops which are used to feed the family, (mainly condiments). Only rarely are cereals grown by women. In Kawara, Sénoufo and Natioro women cultivate rice for the whole family in quasi-individual fields.

As far as the management of shea nut and Néré trees is concerned, men own both trees and their fruit. Women generally have full access to the fruit trees, even without the prior authorization of their husbands. The sale of products from these trees (shea nut and Néré), constitutes an important source of income for women from rural areas.

In Kawara there are two distinct types of soil that can be cultivated, each requiring different management. Upland which is inherited and mainly worked by men. The lowlands are kept for rice. This land is divided into the following two categories: the irrigated perimeters, and unimproved lowlands. In the area affected by the Comoé Operation Rice Project (Projet Opération Riz comoé), those involved with the Rice Project were responsible for allocating parcels of land. Priority was given to the wives ofthe farmers who cultivated these lowlands before the project.

On the unimproved lowlands, all first requests by women for parcels of land, are passed through their husbands. The men served as intermediaries between the women and the land chiefs.

Rice is an important crop in Kawara. It is almost exclusively grown by women. In Kawara, rice production has cultural significance. When the Sénoufo marry, a rice parcel is allocated to the mother of the prospective bride by the parents-in-law, as a sign of recognition to the mother for having brought up the daughter. Natioro women, of whatever rank in the household, are entitled to receive rice parcels from their husbands. These sociological realities connected with rice culture show to what extent women play a very important socio-economic role among the Sénoufo and Natioro peoples.

Description of the Lobi of Dimolo. Dimolo is a village where the social life is dominated by Lobi culture. The latter is distinguished by its matrimonial institution which we outline here. In order to do so, we took as a starting point the work of Madeleine Pere, 1988, pp. 292-295. For the Lobi, marriage is recognized by the payment of a dowry to the family of the woman to be married. It is only when the husband has paid the dowry in full, that he obtains full rights to the woman and to the children that the woman will bear him. Marriage initiated at the request of a young girl to her parents necessitates a long engagement period. Generally, the request has been made to the girl's family when she was an infant, or even as early as at her birth.

As a first step in approaching the girl's parents, the boy's family proceed to give cowry shells to the mother of the young girl (usually about twenty cowries). These cowries are called "cowries for the search". As well as these cowries, the boy's family gives gifts of vegetable fibers. From the then on the young girl is considered "proposed" for a certain boy. However, the boy will only prove himself worthy of the girl through working, and good behavior to the prospective in-laws.

The long period of engagement is characterized by certain tasks: the young man, along with his friends or acquaintances, must cultivate the father-in-law's fields, as well as provide firewood for his mother-in-law. The length of time that the boy has to continue farming these fields depends on the age of the fiancée at the outset of the engagement, and continues until the girl herself becomes a mother.

Generally, the young man's father gives two to three cattle to the girl's father. These cattle represent compensation as a sign of recognition of the work invested by the young girl's father in raising her. It is by performing this series of tasks that the fiancé gradually earns the right to spend the night alone in one room of the family of his future father-in-law. Then, it is the turn of

the young girl to go and spend one night with her fiancé (she shares a sleeping mat with him). After this, the parents of the young man (the fiancé) demonstrate their agreement by accompanying the young girl back to her family.

During the engagement period, although the young girl continues to live in her parent's home, she makes occasional visits to her prospective husband's family, which increase in duration as time goes on; then she returns to her parents. These "comings and goings" generally last for as long as it takes for the services owed for the marriage, or the dowry, which constitutes the "price of the fiancée" to be paid in full.

However, during the engagement period, the woman may give birth since she is already considered the wife of her fiancé, even before the marriage becomes official. The children that the fiancée has before the dowry is completely paid to her parents, or those children who are not recognized by her future husband, will stay with her family. This happens quite frequently in Lobi territory, and it is generally tolerated that an unmarried woman has children, while still living with her parents.

The content of the dowry may vary from one family to another. However, it is generally the equivalent to the dowry paid for the mother of the young girl. As long as the dowry (matrimonial compensation) remains unpaid, the dignity of the woman is not recognized, and she finds herself looked down on, and loses status. This state of affairs may even lead to conflicts between the woman and her husband.

This unresolved situation (when payment of the dowry compensation is incomplete) along with the effects that such a situation engenders, such as the women's frustration, may lead certain women to leave their conjugal home to live alone.

These particular examples of Lobi culture illustrate the situation of the status of single women in this society. In general, single women live with their children, for whom they assume sole responsibility. The status of single women should surely play a part in determining their involvement in production activities.

The RSP village research sites are characterized above all by their ethnic plurality. In the following pages, we shall concentrate on studying the production activities associated with the various ethnic groups, and their development.

VIII. ORGANIZATION OF WOMEN'S ACTIVITIES ON THE VILLAGE RESEARCH SITES

The women of Yasso, Dimolo, Kayao and Kawara, as in all Burkinabè* villages, have very diversified activities. The different activities involving the women concern essentially the following:

- domestic tasks, such as cooking, provision of water and firewood, child care, and looking after her husband
- agricultural work, such as cultivating the individual and family fields,
- small animal husbandry.

To all these activities should be added small scale commerce, the processing and sale of forest and agricultural products, such as soap-making, the preparation of shea nut butter and of dolo; and also, artisanal activities such as cotton spinning and pottery.

One should also note that there are other activities of cultural significance which the women are involved in. It is especially important to find out how the women organize themselves around all these different activities on the village research sites, during the two principal seasons of the year.

The activities of women during the rainy season on the four village research sites. This survey of activities concerned 193 women who were representative of the various ethnic groups.

Table 2. The distribution of women in the village research sites, according to ethnic group.

Ethnic group	Percent of Women
Mossi	23%
Bwaba	12%
Lobi	12%
Fulani	10%
Dioula	9%
Natioro	8%
Sénoufo	7%
Dafing	7%
Samogho- blacksmith	6%
Dagari	3%
Dogon	1%
Others*	2%
Total	100%

*Others = Goin, Pougouli, and Samo.

In our sample, the majority of women were married (88%), some were widows (9%), 2% were single and 1% were divorced.

The women's ages ranged between 15 and 88 years, 31% of the women were under 30, 57% were between 30 and 59, and 8% were 60 or over. For practical reasons (unavailability of data) the age of the remaining 4% was not included in our analyses. The average age was 36 years.

Table 3. Distribution of the women in the four village research sites, according to the principal activities they are involved in during the rainy season.

Villages	Yasso	Kayao	Dimolo	Kawara
Activities				
Agriculture	20%	96%	77%	*66%
Shea nut collecting	13			
Housework	5%			
Preparation and sale of dolo	13%		6%	5%
Sale of Milk	30%	4%	14%	3%
Trading	6%			
Pottery	10%			24%
Small animal husbandry			3%	
Preparation of soap+pottery	3%			
Preparation of soap				2%
Total	100%	100%	100%	100%

*Agriculture mainly represented by rice growing

Agriculture is clearly the activity that involves the women most during the rainy season. About 72% of the women are involved during this period. Generally, the role of women in agriculture is limited to the tasks of sowing, planting out of seedlings and harvesting, all of which take place in the fields belonging to the farm.

The "feminization" of these three operations, takes on a religious meaning, as Dieudonné Ilboudo pointed out in "Potentialités et Contraintes Humaines des quatre Villages-Sites RSP" (Human Potential and Constraints in the four RSP village research sites), page 92. Thus, in the act of sowing seeds, the woman as symbol of fertility is meant by her actions to help the earth produce well. This is why in all African societies it is the women who are responsible for performing the task of planting the family fields.

Like the act of sowing seeds, the process of transplanting is a religious act where the woman, by her act of placing the young plant in contact with the earth, helps the crop thrive. In harvesting (cutting and transporting home the harvested crop) the women are taking possession of the fruit of the work of men, which she thenceforth takes charge of, transforming it in her cooking, or by marketing it.

The precise form taken by this division of agricultural tasks varies from one ethnic group to another, since each ethnic group has its own specific culture.

The Dafing and Dogon women of Yasso, for example, do not traditionally do agricultural labor at all. This fact reflects the influence of Islam on these societies, placing the woman at home, where her duties are limited to purely domestic tasks.

Today one remarks how the influence of emigrants, and especially of the Mossi, has brought about a change in attitude among these people, so much so that some Dafing and Dogon women have begun spending some of their time doing agricultural work[3].

In the Yasso sample, 3% of Dogon women said that they possessed a personal field where they cultivated condiments (gombo, sorrel, etc.). Some 7% of Dafing women said they were involved in sowing and harvesting on the family farm. The Fulani women, who do not have a farming tradition, nevertheless had 3% who performed tasks of sowing seed on the collective field of the family farm.

In addition, since the Dafing, Dogon and Fulani women do not traditionally practice agriculture they are principally involved in a range of other activities during the rainy season. These activities include the following: collecting shea nuts, and processing them into shea nut butter and/or soap; the preparation of dolo (millet beer), pottery, trading and milk sales. These essentially commercial activities enable the women to have a cash income which covers family expenses, which are generally the women's responsibility (condiment money) and mainly to look after the needs of their children. Under these conditions, the economic strategies of these women may vary, according to the number and age of their children.

Table 4. Distribution of Yasso women by ethnic affiliation and their principal employment during the rainy season.

Ethnic group	Mossi	Fulani	Dafing	Samo	Dogon
Activities					
Agricultural	67%	10%	14%	-	50%
Shea nut gathering	-	-	29%	-	-
Preparation & sale of dolo	-	-	29%	-	-
Poultry farming & milk sales	-	90%	-	-	-
Pottery	-	-	21%	-	-
Trading	-	-	7%	100%	-
Soap prep. & pottery	-	-	-	-	50%
Household chores	33%	-	-	-	-
Total	100%	100%	100%	100%	100%

[3] Dieudonné Ilboudo, idem, pp 92-93.

In Dimolo, all the women in our sample who were involved in agriculture worked both in the family fields and on their own individual parcels. The tasks performed by the women in the family fields included: sowing, transplanting and harvesting.

In addition, the "single" women, widows and those separated from their husbands by divorce cultivated their own parcels, unlike the married women. These women assumed responsibility for the farms.

The term 'single' in this society, does not carry the same connotations as it does in modern society. To be a single woman here signifies being in an incomplete situation vis-à-vis marriage (see the explanation for this above). The woman carries on living with her parents, or alone, because her dowry has not been paid in full.

The reason why single, widowed and divorced women choose to devote their time in working on the land may be explained by their need to act as breadwinners for their children. They play the key decision making role on their farm where they are the household head.

Table 5. Distribution of Dimolo women, by ethnic group and their principal employment during the rainy season.

Activities Ethnic group	Agricultural	Dolo: prep. & sale	Small animal husbandry	Milk sales	Total
Lobi	87%	9%	4%	-	100%
Mossi	100%	-	-	-	100%
Dioula	100%	-	-	-	100%
Fulani	-	-	-	100%	100%

In Kayao, the principal farming activities done by women include the sowing, harvesting, and rarely, weeding. Women in Kayao are much sought after to help harvest cotton, which is the principal crop of the sub-zone. As far as the individual fields are concerned: 24% of the women claim to have their own personal field. (16% Mossi, 7% Bwaba and only 1% of the Dagari women).

Table 6. Distribution of Kayao women by ethnic group and by their principal rainy season activities.

Activities Ethnic group	Agricultural activities	Milk sales	Total
Mossi	100%	-	100%
Fulani	-	100%	100%
Bwaba	100%	-	100%
Dagari	100%	-	100%
Pougouli	100%		100%

In Kawara, rice growing is traditionally undertaken by Natioro and Sénoufo women as their principal activity. In our sample[4] some 39% of Natioro women, and 37% of Sénoufo women grow rice.

Women perform various tasks in the rice fields including: sowing, transplanting, weeding, pesticide applications, harvesting the rice and post-harvest transformation.

Men do not work in the rice fields, except for ploughing the fields and sometimes helping with the harvesting. When the women have no other help on their farm, they often pay men for ploughing.

In Kawara, pottery, dolo preparation and selling milk are considered like rice production, specific activities which are designated to certain ethnic groups. Thus, for Dioula-Griot women pottery is their principal activity. Samogho-blacksmith women, on the other hand, specialize in the preparation and sale of dolo. The Fulani, here as everywhere else, take care of selling milk.
For most women, household chores comprise the second rainy season activity. In Yasso, 90% of the women place housework second to their primary activity. In Kayao, 66% of the women consider housework together with collecting shea nuts as their secondary activity.

At Dimolo, 52% of women consider collecting shea nuts and housework as secondary activities. Some 34% consider housework alone the secondary activity, and 14% combine housework with milk sales.

In reality, it is the housework which constitutes the principal activity of the women during the rainy season. Then come the other activities, notably agriculture.

Housework consists of the sum of household chores: food preparation, fetching water and wood supplies, child care, looking after the husband, washing. Where housework was not cited by the women as their primary activity, this can be explained by the fact that domestic chores are not generally considered as "activities" in the full sense of the word. Nobody is concerned about what the women do. Women themselves devalue domestic chores. When one asks, for example, a "housewife" what she does for a living, she will usually reply: "I don't do anything". In point of fact, she works hard, for her domestic chores are demanding and time-consuming.

This completes our overview of women's activities on the village research sites during the rainy season, next, we shall record what they do for the remainder of the year.

[4] The sample under consideration here is the one used in Nebie Néc Traore T.M.

Table 7. Women's activities during the dry season in the RSP village research sites.

Villages	Yasso	Kayao	Kimolo	Kawara
Activities				
Housework	20%	73%	39%	-
Trading sale of: - condiments - local sweets - dolo - milk	70%	15%	61%	8%
Crafts - spinning pottery	10%	7%	-	24%
Rice growing	-	-	-	66%
wild fruit	-	5%	-	-
soap making	-	-	-	2%
Total	100%	100%	100%	100%

In Yasso, most Dafing women are involved in trading. The trading essentially involves selling sweets and condiments which have been made from forest products (23% of the women), dolo (17% of Dafing women) and milk (30% of Fulani women). All those involved in selling milk also raise poultry.

Pottery is also made in Yasso by Dafing women, who belong to the blacksmith cast. The blacksmith's trade has traditionally been set aside for women who perform the job all year round.

In Dimolo, women are in charge of selling products originating from the forest, such as shea nut butter, soumbala, and the local soap; as well as for the sale of dolo, and the marketing of dolo and local sweets.

Most women (77%) who sell products from the forest come from the Lobi ethnic group. In fact, the Lobi women, whose husbands are landowners, and therefore own trees (shea nut and Néré) have easy access to the raw materials. The remaining women, in this case the Mossi and Fulani, are migrants, and as such do not, according to Lobi custom, have the right to touch the fruit trees, and especially not to touch the actual fruit, hence their lack of representation in the activities involving products from forest origin.

In Kayao, 15% of the women have sale of dolo as their principal activity (11% are Bwaba women and 4% are Dagari). Pottery in Kayao is mostly made during the dry season by Mossi women of the blacksmith cast.

In Kawara, the most important activities during both dry and rainy seasons are the specialized activities of the women. The Natioro and Sénoufo women are involved in rice farming, the Griot-Dioulas make pottery, and the blacksmith-Samoghos specialize in selling dolo and the Fulani in selling milk.

If for the principal activity during the dry season there is a homogeneous tendency, this is not the case for the secondary activity, whether comparing the different villages, or within the same village. Generally, the women who have housework as their principal activity during the dry season claim that instead they are primarily occupied with trading or some craft activity.

In Yasso and Kawara the secondary activity for a majority of women (80%) is still household chores.

In Dimolo: 37% of the women spent time trading (selling local sweets) as their secondary activity during the rainy season, 34% spent this time doing craft activities, and 29% doing household chores. The craft activities include spinning, pottery, basketry, and mat weaving.

In Kayao, the secondary activities of the women are listed as follows: 33% of women cited use of forest products (such as shea nut butter and soubala), housework was the second activity cited by 39%, and spinning was cited by 7% of the women.

Women's activities vary from one village to another and from one ethnic group to another. They also vary by matrimonial status and by the number of children the women have. If the development of certain activities is made possible thanks to favorable economic conditions, other activities are rooted in cultural tradition.

The activities specifically linked with certain groups of women. The site of Kawara is remarkable because of its very extensive range of specifically attributed activities. The origin of rice growing, for example, is given mythical dimensions.[5]. The story goes that the ancestor in going into the bush found the seeds of rice, millet and sorghum that the ants had piled up. He took back the rice seed to his wife, keeping the other seeds for himself. Ever since then, the Sénoufo women have set great store by specializing in rice cultivation, which enables them to provide for their needs.

For the Dafing women in Yasso, the blacksmith trade has an authentic meaning and is linked to the tradition of the past.

The women blacksmiths, as well as their role as potters (except in the case of the Samogho-blacksmiths in Kawara where they are dolo producers instead) above all act as mediators between the other layers of society. The function of mediator consists in asking for the hand of young girls and asking for pardons (reconciliation).

In Dimolo, the activity of processing shea nuts to make butter is also invested with cultural meaning. The shea nut is said to have been introduced to the Lobi by the monkeys who left the seeds in their excrement.

According to Lobi tradition, shea nut and Néré trees belong to the men, as do their nuts or seeds. The nuts that a Lobi woman gathers in her husband's field normally belong to her husband, and the proceeds from selling the butter produced from them also go to the husband. When the

[5] T.M. Nebie Né Traore. idem, p. 18.

woman gathers shea nuts in the wild, she is then entitled to keep the proceeds from whatever butter she makes and sells (unless she is in her husband's debt).

Certain specific activities of women go beyond the framework of work traditionally thought of as "women's work".

In Dimolo, for example, in addition to their own various activities, women help their husbands construct the houses. Their role consists in transporting the earth and in plastering the house. In our sample, 51% of the women (31% Lobi women, 14% Mossi, and 6% Dioula) were busy helping in construction.

In Yasso, Fulani women play an important part in cattle breeding. Their role consists of watering the herd, giving bran and salt to the calves, and watching over them.

After covering the activities of women living in the RSP village research sites, the next section of this report will concentrate on the difficulties which women encounter, in the discharging their duties.

IX. WOMEN'S ACTIVITIES - CONSTRAINTS AND SOCIO-ECONOMIC EFFECTS

The constraints specifically linked to certain activities of Yasso, Dimolo and Kawara women. The next part of the study will examine which difficulties confront women when they pursue activities in the following categories: domestic, agricultural, craft and commercial.

Constraints associated with domestic activities. There are many domestic chores, including: food preparation, washing up, washing clothes, grinding millet, drawing water from the well, gathering wood from the bush, sometimes caring for animals, and milking - all of these are activities which women devote themselves to tirelessly. In Yasso, as in Dimolo, most women declare that pounding the millet is the most arduous of all domestic tasks. A very few of the women cite as their idea of most difficult domestic task either wood collecting, looking after domestic animals, or washing up. Cooking, which means the preparation of meals, is considered by almost all the women to be the most gratifying women's activity because they feel that they are satisfying the whole family, especially their husbands.

Agricultural activities of women and their specific constraints. The agricultural activities of women fall into two categories: The individual fields, and the family fields. In the individual fields, the women generally cultivate crops such as okra, groundnuts, sorrel, cowpeas, and vandzou. Women help work in the family fields for tasks such as sowing, weeding and hoeing, planting out, thinning out of cotton, and especially they help harvest the crops. The cultural connections between women and certain operations present variations from village to village. However, in general, it is the men who are responsible for tilling the family fields.

Of all agricultural activities, women cite tilling, sowing and thinning out with daba hoes as the work they dislike most, which is understandable because these tasks are the most difficult of all the agricultural activities. On the other hand, those women who work their own individual parcels actually prefer the job of cultivating their land, because they are motivated by the knowledge that when they harvest the fruits of their labor, this will enable them to provide for their needs, which essentially means the needs of their family (e.g. expenses for condiments) and children.

As far as farming the land is concerned, women do encounter some constraints which are linked to their status as women.

The principal constraint derives from the fact that women in these African societies do no have the right to own property in their own right. The parcels that women farm are usually lent to them, on a temporary basis by either their husband or another member of their family. Also, the fields cultivated by women are generally of inferior quality soil (infertile). These facts do not encourage women to put a lot of effort into improving the parcels under their care.

Other factors that handicap the use of production factors by women include the current conditions attached to agricultural credit granted in Burkina Faso, which include belonging to an officially recognized group, along with all the conditions that go along with this; women are similarly hampered by the prohibitive cost of inputs, and of agricultural equipment.

Research programs have essentially focused on the activities of the male population. There is little research designed to increase the productivity, and facilitate the tasks of women in the same areas.

Constraints linked to the practice of crafts. Craft activities for women include spinning, pottery, basketwork and mat weaving. This section on crafts will also cover activities connected with processing forest products, including: preparation of shea nut butter, local soap and soumbala. Cotton spinning involves first extracting the cotton seeds. Then the cotton has to be carded* using an instrument called a "karada (a name used in Dafing and Fulfuldé*) so as to make the cotton fine. The cotton is then ready to be spun using a diènè (name used in Dafing and Fulfuldé).

The difficulties involved in spinning which the women mentioned were at the ginning stage of the process, when the work demands painstaking attention. Another problem is that the cotton, especially in villages like Yasso and Dimolo, is a rare commodity, because it is not produced on their local farms. Because of this problem, Women in these villages are obliged to stop spinning from time to time, for want of available cotton.

For women potters, their most challenging tasks consist, firstly, in digging out the earth to extract clay used in making earthenware jars (canaris) and, secondly, in having to transport the clay back to their homes. Clay extraction is a difficult operation which requires significant physical strength. The transport of clay requires adequate equipment (a cart).

Mat weaving is a specific activity associated with Fulani women. The mats are made from sorghum stems, which are interwoven with fibers taken from salt sacks, or with Hibiscus canabinus fibers.

Women involved in this mat weaving emphasize that their principal obstacle is the lack of reliable supplies of the sacks used to weave in with the stems.

Women who make shea nut butter, on the other hand, complain most about having to gather the nuts. This involves getting up at dawn to go into the bush, thereby exposing them to physical dangers, such as attack, rape, snake bites, cold etc.

As far as crafts are concerned, the women encounter real difficulties, which hinder their normal work, and restrict their development. These essential constraints are:

- The lack of raw materials for women involved in spinning. Most women state that they do not possess the instrument, called a karada, which they use to card* the cotton to ready it for spinning.

- The unavailability, or lack of a means (i.e. carts) of transporting the clay and the wood used in making pottery products.

The women often did not own carts. When there were carts on the farms, due to the urgency of certain kinds of field work, women had very little access to this equipment for the transport of clay and wood supplies. The lack of available carts limits the ability of women to transport anything, and may even constitute an obstacle to the development of a particular activity requiring transport.

Crafts produced in Dimolo (such as earthenware pots (*canaris*), mats and covers) are generally destined for home consumption. However, in Yasso, crafts tend to be intended for the marketplace rather than home consumption. As for the products derived from the forests of both Dimolo and Yasso, they are produced to be sold.

<u>Women's commercial activities and the constraints associated with these</u>. The difficulties encountered by women involved in commerce are of the following kinds:

- Sale of local sweets finds financing to be a barrier. This is why, in most cases, this activity is only done on a small scale.

- The producers of dolo emphasize the scarcity of wood, which often makes them stop their activities. They regret especially the lack of adequate technology to ensure the conservation of dolo which has already been prepared for consumption.

- For women who are potters, especially in Kawara, the problem of selling is an obstacle to pursuing this activity. The women involved in pottery have to travel long distances in order to

sell their products. They have to be away from home for periods of time in order to travel. To this problem of turnover, should be added the difficultes in transport, which have brought about broken pieces.

- The milk producers hope that a system could be put into place for the feeding of the cows so that they are able to produce milk during the dry season. They regret the lack of transformation technology which prevents them from making use of the surplus of milk during the rainy season.

All of the above difficulties are encountered as much in domestic, agricultural, and artisanal activities as in commercial ones. These difficulties also limit the women's participation in the work of developing the economy.

With the aim of recording the contribution of women to the amelioration of standards of living, and of the whole community a recording was made of the aspirations and sentiments of the women in relation to their actual activities.

The aspirations and feelings of the women from the village research sites. The survey of aspirations of women from these villages was separated into type of activity performed by them. There was the suggestion by the women that the men could properly acknowledge domestic activities, which were generally ignored, or depreciated. Women reported that domestic work "was minimized by the men, in spite of the fact that it took up a considerable amount of the women's time, even to the extent of preventing them from doing other activities".

With the aim of attenuating the difficulties that they encounter in their agricultural activities, the women proposed that the men support their efforts in the following ways: by participating at every stage in cultivating operations in the family fields, and specifically, by helping sow, thin out, plant out and harvest. They should help the women till their individual fields too, because this work (which is done manually out in the fields) is the most physically demanding. Also the multiplicity of tasks for which women are responsible often does not permit them to complete primary tillage at the most appropriate time.

The women (especially those from Yasso, who were involved in agriculture) asked to be able to work with the Production Systems Research team (RSP) so that they too could benefit from the diffusion of new technologies in agriculture.

Confronted by the social division of agricultural work, it is necessary to set up a dialogue between both men and women with a view to better managing the time spent on agricultural activities. It is necessary to set up program planning for the agricultural operations as a whole, which not only applies to the family farms (the husband's fields), but also a comprehensive plan encompassing the whole set of agricultural tasks linked to both the family fields and the fields individually farmed by the women. Such a reorganization of the work could not only help lighten the burden for women, but especially, bring up their productivity. On farms which own carts, the women do not often

have easy access to them when they need to transport clay and wood necessary for their pottery. Improved organization between men and women could help address this problem.

As far as craft activities are concerned, to reduce certain constraints involved in these activities, the women would like to help those who spin cotton, requesting that men adopt cotton growing as one of their crops. It should be remembered that the rarity of cotton was pointed out to be one of the major difficulties which Yasso and Dimolo women encountered.

In general, 73% of women (from Yasso and Dimolo) express the desire for men to take an interest in their commercial activities.

Those who sell local sweets (galettes and fritters) and dolo, ask for the men to concentrate on cereal production (millet, cowpeas, and sorghum) in order to meet their need for these commodities.

The women who sell milk would like the men to feed the cows well during the dry season, to enable them to have milk continuously, and thus maintain sales. These women also wanted the men to help them milk the cows since the latter are often difficult to control, giving kicks, breaking calabashes and upsetting the milk. To help them control this situation, the women would appreciate the men's assistance during the milking process.

There is a consensus of opinion in the women's desire to increase the men's involvement in women's activities. These aspirations are far from being simple demands, or claims, but constitute veritable indicators of the constraints that constitute serious obstacles to the development women's activities. By taking these aspirations into account, certain difficulties encountered by the women in the course of their duties and activities, which may not have been immediately apparent, are revealed.

Information on women's incomes. For most women, 65% in fact, the most profitable activity for them, which is to say the one that procures them the highest income, is trade, which essentially involves the sale of agricultural and forest products. For 13% of women, craft activities are the most profitable, compared with 17% who cite agriculture (from individual and collective fields) and 5% who cite animal husbandry as their most profitable activity.

Therefore, the women's income derives primarily from commercial activities. It was very difficult for researchers to pinpoint the actual amount the women earned. The women were very reticent to disclose full details of their earnings. In general, they replied that they could not remember, or even that they did not make anything for such and such activity, even though they had just specifically stated that this particular activity was the most profitable for them. This implies that the very term "profitability" here, should probably be considered with considerable reserve, since the activities were declared "profitable" merely on the basis of the women's own replies.

Earnings are spent in various ways, including the essentials such as: feeding the family (61%), providing clothing for the family, and especially for the children (57% of the women).

Very few women gave their income to the head of the household. As far as the level of expenditure of these incomes are concerned, the actual amounts quoted are unreliable, but they are nevertheless indicative of how the women spend their money, which is mainly on food and clothing for their children. Food expenses run between 590 F CFA to 650 F CFA. There is a greater variety in what was spent on food, between 2,500 and 47,500 F CFA. Clothing cost more than food.

The women also had other expenditures, especially having to pay for labor (1,500 F CFA) used to help till the fields and also the gift of money (3,600F CFA) to the woman's family.

It is important to note that certain women still manage to save (individual savings, tontines). Their savings range from 7,000 to 10,000 F*.

X. CONCLUSIONS AND RECOMMENDATIONS

Women are considered today to be the principal actors in the social and economic development of rural communities. However, the efficiency of their work, and its impact on the living conditions of their communities, are affected by significant social and economic constraints which the women encounter in the course of their activities. Diverse responsibilities in the family and in society as a whole are burdensome to the women, in view of their social status. The women's daily responsibilities include a wide variety of tasks: preparing meals, looking after children, providing water for the whole family, work in the fields or some minor trading, craft activities, etc..

In effect, if the women have to do so much, it is because she generally assumes heavy responsibilities vis à vis her husband, her children, and her parents.

Women's activities suffer largely because of the lack of adequate technology, such as shea nut presses, mills, more accessible water supplies, all of which would at least help reduce the burdensome amount of time the women have to spend on basic tasks.

The lack of adequate technology added to the lack of financial means which often confronts the women, combine to restrict women's activities to small-scale production systems (minor trading), crafts sold at a small market, very uncertain agriculture and animal breeding, etc...

If the traditional credit institutions in rural areas were directed towards developing income activities for women (such as trading, small animal husbandry, processing of agricultural and *forest products) this could be an enormous help to women.

The reinforcement of women's organizations in rural areas (in such women's groups as the GVF (Groupement Villageois Féminin), "tontines", and other organizations, could well be a positive strategy for the women, enabling them to find sources of financial aid to help improve and facilitate their activities.

With the goal of making a positive contribution to certain women's activities, the RSP intends to:

- Work with the women in order to enable them to benefit from certain innovations and use them in their own farming. For this, agronomic tests, introducing certain varieties will be undertaken on women's land parcels, notably in Kawara and Yasso.

- Improve the profitability of milk sales in Yasso. This will involve planning for milk production on a large scale, with a view to selling to other villages, or even to towns, during the rainy season. It will also mean developing collaboration with certain local institutions, such as the Faso Kossam milk project in Booboo, the Houaho Project in Bitou, in order to envisage future transformation of milk into processed products.

- Contribute to promoting trading amongst the Dimolo women (poultry farming), in collaboration with the National Poultry Center (Centre National Avicole), and to promote pig farming for the Kayao women.

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List of Abbreviations and Moré Words

AID	Agency for International Development
ADRK	Kaya Regional Development Association (Association de Développement Régional de Kaya)
ARTS	Agricultural Research and Training Support
CES	Water and Soil Conservation (Conservation des Eaux et des Sols)
CGIAR	Consultative Group for International Agricultural Research
CILSS	Interstate Committee to Combat Drought in the Sahel (Comité Inter-Etats de la Lutte contre la Sècheresse dans le Sahel)
CIRAD	International Agricultural Research Center for Development (Centre International en Recherche Agronomique pour le Développement)
CMAFRT	Gardening, Fruit Tree, Root and Tuber Program (Cultures Maraîchères, Arboricultures Fruitières, Racines et Tubercules)
CNRST	National Center for Science and Technology (Centre National de Recherche Scientifique et Technologique)
CRA	Agricultural Research Center (Centre de Recherche Agricole)
CRPA	Regional Center for the Promotion of Agriculture (Centre Régional de Promotion Agricole)
CRSP	Collaborative Research Support Program
D	Donsin
DESFIL	Development Strategies for Fragile Lands
DI	Dimolo
DVA	Direction de Vulgarisation Agricole
ESFIMA	Water, Soil, Fertility, Irrigation and Agricultural Machinery Program (Eaux, Sols, Fertilité, Irrigiation et Machinisme Agricole)
FM	Farmer Management
FPP	Foster Parents Plan
FSU	Farming Systems Unit
GDP	Gross Domestic Product
GIS	Geographic Information Systems

GREFMASS	Research Group for the Restauration and Maintenance of Soil Fertility in the Sudano-Sahelian Zone (Groupe de Recherches sur la Restauration et le Maintien de la Fertilité des Sols en zone Soudano-Sahelienne)
Ha	Hectare
ICRAF	International Center for Research in Agro-Forestry
ICRISAT	International Center for Research in the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IITA	International Institute for Tropical Agriculture
INERA	Institute for Agricultural Studies and Research
INRAN	National Institute for Agronomic Research in Niger (Institut National de Recherches Agronomiques du Niger)
INTSORMIL	International Sorghum and Millet
IRAT	Tropical Agronomic Research Institute (Institut de Recherches Agronomiques Tropicales)
IRBET	Institute of Botanical and Ecological Research (Institut de Recherche en Botanique et en Ecologie Tropicale)
IVRAZ	Voltaic Institute for Agricultural and Animal Science Research (Institut Voltaïque de la Recherche Agricole et Zootechnique)
K	Kamsi
Kg	Kilogram
Kw	Kawara
Ky	Kayao
LOP	Life of Project
LP	Linear Programming
Mg	Metric ton
Mm	Millimeter
MUCIA	Midwest Universities Consortium for International Activities
NGO	Non-Governmental Organization
NRM	Natural Resources Management
PAM	Policy Analysis Matrix
PDI	Integrated Development Project (Projet de Développement Intégré)
PNRA	National Agricultural Research Program
PPIB	Plan Parrainage International de Boulsa

RESPAO	Network for the Study of Farming Systems Research in West Africa (Réseau d'Etude des Systèmes de Production en Afrique de l'Ouest
RM	Researcher Managed
RSP	Production Systems Research (Recherches sur les Systèmes de Production)
SAFGRAD	Semi-Arid Food Grain Research and Development
SANREM	Sustainable Agriculture and Natural Resources Management
SOMIMA	Sorghum, Millet and Maize
SWC	Soil and Water Conservation
TA	Technical Assistance
TAT	Technical Assistance Team
TDY	Temporary Duty
Th	Thiougou
TROPSOILS	Tropical Soils
TSMM	Tropical Soil Moisture Management
USAID	United States Agency for International Development
WCASS	West and Central Africal Soil Science Association
WARDA	West African Rice Development Association
WID	Women in Development
Y	Yasso
Zaï	Manure-filled holes
Zi-pelé	Denuded Lands