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# DEVELOPING AND EVALUATING NEW AGRICULTURAL TECHNOLOGY FOR THE SAHEL: A Case Study in Burkina Faso

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## INTRODUCTION

World attention was focused on the African Sahel during the droughts of the Seventies (1968-1973) and again in the Eighties (1983-1984). In these seven countries (eight with Cape Verde) in the semi-arid transition zone between the Sahara Desert and the more humid coastal West African countries (Fig. 1), absolute yields are low and food output increases have not been accompanying population growth in spite of large increases in developmental assistance.[1] Agricultural production is difficult in these countries since the rainy season is short, rainfall is irregular, evapo-transpiration is high, and much of the present crop area is in fragile and low-fertility soils.[2]

Recent developmental literature to explain the stagnation of the agricultural sector in Sub-Saharan Africa can be crudely dichotomized into the agricultural policy and the technology-development advocates.[3] Proponents of the former stress the importance of removing distortions on input, output, and exchange-rate prices so that countries can ascertain their international comparative advantages within agriculture and in other activities.[4] Another related objective is to eliminate institutional barriers and increase infrastructure investment so that the market place can function better and farmers will have greater economic incentives to increase output. An implicit assumption is that in a more favorable economic environment, crop-area expansion or yield-increasing technology is presently available or could rapidly become feasible. Some argue that many of these Sahelian countries are not efficient agricultural producers and that they should depend more on international trade for their food supply.

The technology development advocates point out that the Sahel is a difficult environment, that the potential for land-area expansion is decreasing, that there has been little research investment in food crops in this region, and that producing yield-increasing technology is a difficult, long-term task. While not denying the

importance of a profitable environment for farmers, they put much more emphasis on increasing investments in agricultural research in the region and on improving its focus on farm-level constraints, especially those of the predominant small farmers. In spite of difficult conditions for agricultural development and large investment requirements for research and infrastructure, a political commitment exists in the Sahel countries to attain food self-sufficiency.[5]

Since the World Bank has been pressing many national governments in Sub-Saharan Africa to reform their agricultural policies, the future empirical tests of agricultural output responsiveness will help resolve the above debate.[6] Getting the prices right may be a necessary condition for agricultural development. However, the technology must also be available for expanding the land area or increasing yields.

This paper is concerned with defining and evaluating new agricultural technologies and reports results from four years (1982-1985) of fieldwork in Burkina Faso. The main problems addressed are: Are there new agricultural technologies potentially available for this region? What are the principal constraints impeding their introduction? What types of ex ante analysis are necessary to evaluate the potential impact of new agricultural technologies? Is

the observed adoption pattern consistent with the modeling results?

The fieldwork included both farm interviewing and farm-level testing of new technologies. The first section presents the rationale behind the design of the farm-level testing of new agricultural technologies. The second section briefly describes the farming systems in Burkina Faso. The next two sections review the results from the evaluation of agronomical and animal-traction technologies. Then the adoption process of these technologies is reviewed and the adaptation of these results to other regions is considered.

## Applying "Green Revolution" Concepts to Agricultural Technology Development in a Harsh Environment

The rapid diffusion of high-yielding varieties of wheat and rice in the late Sixties and Seventies in the developing world, especially in Asia, has led many to stress the roles of irrigation and of new varieties in the agricultural development process. However, conditions in the Sahel are very different from those regions in Asia participating in the "Green Revolution."

Where irrigated rice can be produced, irrigation has been shown to be privately and socially profitable and this is a very important activity combined with winter vegetable production in several of the river valleys in the Sahel.[7] Nevertheless the total irrigated crop area is extremely small in the region and the potential for expansion limited. Presently, irrigation levels in the Sahel are even lower than in the rest of Africa at 2% of all arable land and are increasing very slowly.[8] Moreover, groundwater in much of West Africa is less easily accessible, hence more costly to exploit than in many other semi-arid regions.[9] Besides the technical constraints that exist due to such factors as the unreliable seasonality of surface water flows and diseases in the irrigation projects, especially bilharzia, costs of building and maintaining irrigation schemes are very high. With estimated investment costs per hectare of $5,000 to $20,000, interest in irrigation has shifted from large investment projects to small-scale, labor-intensive projects.[10]

For dry-land farming in any semi-arid region, water is the principal constraint to increased agricultural output. Hence it will to be critical to search for lower-cost methods to obtain or to conserve water. After water, soil

fertility is expected to be the most pressing constraint for most of the Sahel. Deficient nutrient levels of nitrogen and phosphorus are prevalent with potassium, trace elements, and acidification becoming problems after intensified cropping.[11]

Combining water retention and fertilization reduces the riskiness of fertilizer and a strategy of high, combined input utilization has been generally followed in selection on experiment stations for cereals and legumes. The sorghum variety E35-1 yielded 3.5 to 4 t/ha. on the experiment station as compared with 0.4 to 0.7 t/ha. of local sorghum on farmers' fields.[12] However, under most farm-level conditions for producing sorghum in Burkina Faso, traditional varieties outyielded E35-1.[13] A breeding strategy of cultivar selection at high input levels on the experiment station is one explanation cited for the failure to produce and disseminate new food crop varieties in the Sahel, especially new varieties of the predominant cereals, millet and sorghum.[14] The problem can be visualized graphically as a crossover effect (Fig. 2).

Now directors of several international centers state that their new selection strategy is cultivars which will outyield traditional varieties at farmers' input levels but will substantially outperform them at moderate and high

input levels, as in Figure 2.[15] Selection would apparently still be at the higher input levels ($X_1$) on the experiment station, but earlier farm-level testing of the new cultivars would eliminate the crossovers.

The new selection strategy gives more emphasis to disease and insect resistance and to tolerance for stress from drought and low soil fertility. For example, in Burkina Faso, there is sorghum selection for striga resistance and drought screening. Techniques for selecting for disease resistance are now widely diffused. Drought and low soil-fertility tolerance are more recent objectives of selection in the international agricultural research centers. With the large regional variations in water availability and soil conditions and with the substantial between-season rainfall variation, the appropriate tolerance levels for selection purposes are difficult to define. Also, farmers in their different micro-regions have been implicitly selecting for these stress tolerances for some time.

More basic scientific work on the physiology of these stress mechanisms and applied research is necessary. However, finding new cultivars which outyield farmers' varieties at all input levels for a large number of micro-regions of high multiple stresses may not be successful. A better breeding strategy may be to shift the crossover

point A to the left rather than to look for dominance at all input levels. This type of strategy may also give a steeper slope to the new varieties when moderate input levels are utilized. Producers of food crops in the Sahelian countries are at points B or C, zero or very low cash-input expenditures. Hence, the first prerequisite for a successful breeding program may be to find economical methods to increase farmers' input levels and to thereby decrease the stress tolerance requirements of the new varieties, as with levels at point D (Fig. 2). The agronomic research objective then can be to find combinations of moderate input levels which will be adopted by farmers so that the breeder can select for crossover points at or to the left of D.

In the "Green Revolution," new varieties were introduced into old irrigation systems, as in Southeast Asia, or into regions with adequate groundwater, which could be exploited economically with tube wells, as in the Punjab. The availability of water control made high fertilization levels more profitable and less risky. One of the principal characteristics of the new varieties of rice and wheat was their greater ability than the traditional varieties to respond to higher input levels without lodging .

In the Sahel, applied agricultural research investment appears to be necessary to improve the agronomic environment for the future new varieties. As with the "Green Revolution," water availability and fertilizer are the principal components of an improved agronomic environment. The technical problems are more difficult than those in the Asian regions affected by the "Green Revolution." However, the basic concept of the "Green Revolution" of first improving the agronomic environment with water control and increased soil fertility and then introducing new varieties into this environment appears to be applicable. The research objective is then to define, evaluate, and diffuse these types of agronomic improvements. The third through fifth sections are concerned with this process in Burkina Faso. In the next section, a brief description is presented of the farming systems in Burkina Faso for which these agronomic improvements are designed.

Farming Systems in Burkina Faso:

Approximately 60% of Burkina Faso's population of 7.2 million (1983) lives on the Central Plateau. The rainfall isohyts marking the borders of this region vary from 600 mm/year in the north to 1,000 mm in the south[16] (Fig.3). The field research program was initially focused on the

Central Plateau due to the population concentration there. Associated with increasing population pressure in this region has been the gradual elimination of the bush fallow rotation system and further soil deterioration due to crusting, decreasing organic material, and overgrazing. Technologies developed in this region were expected to be easier to adapt in the Eastern Savanna and the Southwest due to the more favorable soil and rainfall conditions there. Farm surveys and testing were also undertaken in these two regions (Fig. 3.)

In the Eastern Savanna, the rainfall limitation is similar but the population pressure is not as great as on the Central Plateau. Here the bush fallow rotation is still more important and yields generally are higher than on the Central Plateau. The region with the largest potential for agriculture is the Southwest. Inorganic fertilizer consumption is higher for both the cash and food crops and cotton and sorghum production and yields have rapidly increased in the last decade. As in many of the higher rainfall regions of the Sahelian Savanna, disease has been a restriction to higher population densities. River blindness has been an especially serious problem in many of the river valleys of the Southwest.[18]

The Central Plateau is principally settled by small farms of 3-8 hectares with approximately 1 ha. cultivated

per active household member.[19] Farm-size varies with the number of active workers in the household and type of power source.[20] Most labor is done with simple hand tools. Donkeys are the principal source of animal traction and are becoming more common in the Central Plateau while oxen and horses are more prevalent in the Southwest and the Eastern Savanna.

The principal cereal crops in Burkina Faso are millet and sorghum, occupying an estimated 80% of the crop area. Cereal land allocation is mainly determined by the land-quality differences. A small amount of maize is grown on the compound areas around the household. Here the animals are tethered or gathered at night and household garbage further supplements soil fertility. The maize variety is a short-season one to be harvested during the "soudure" or hungry season shortly before the harvest of the millet and sorghum.

Farther down on the toposequence there are depressions and valleys where the runoff has resulted in more silt deposits and heavier soils. On these better soils sorghum is generally planted. On the sandier, less fertile upper portion of the toposequence the principal crop, millet, is planted.[21] Where there are less clear divisions of land quality, the sorghum and millet are often intercropped. On

the lowland heavier soils with poor drainage ("bas-fonds") small areas of rice production are found in higher rainfal areas and sorghum in the lower rainfall regions.

The fertility and water-retention differences of the soil types are suited to the different agronomic requirements of the cereals. Millet is most tolerant to low soil fertility and drought stress; maize is least tolerant. Besides rice, sorghum can tolerate some flooding.

Millet and sorghum are often intercropped with cowpeas. However, the production of cowpeas is seriously limited by field and storage insects and soil-fertility problems so yields, planting density, and total production are very low. A small area of peanuts is usually planted to meet basic cash requirements.[22] Various types of livestock, including chickens, guinea hens, goats, sheep and donkeys, supplement the crop activities. On the Central Plateau and in the Eastern Savanna, cattle are often entrusted to the Fulani who return them after the harvest to graze the stubble.[23] In this way cattle still can be utilized for the acquisition of wealth even though the opportunity cost of the grazing land has become too high to graze them in many crop areas.

Cereal yields are low since inorganic fertilizers are not commonly used and in much of the Central Plateau higher

population pressures have been breaking down the traditional bush fallow system. Maize yields range from 0.4 to 1.2 t/ha., sorghum from 0.4 to 0.7 t/ha., and millet from 0.3 to 0.5 t/ha.[24] The areas planted in maize and sorghum are generally determined by the quantities of the higher quality lands available. In contrast, the area of millet is extended as far as the available labor for the critical seasonal operations permits.[25]

Land is communally owned with long-term allocation rights set by village chiefs for household heads. On the household land, the objective of production is to assure an adequate grain supply for the family during the year. Extended family members have to provide labor on this land as dictated by the household head. The household head also allocates private plots to family members for which they provide the inputs and keep the output.

There is little agricultural use of hired labor since there are active seasonal and long-term migration flows to Burkinaba urban areas and other countries. An estimated 25% of the potential labor force works outside the country.[26] Labor exchange does exist but most labor comes from the extended-family system.

Farmers in most regions state their principal objective as being a subsistence goal of setting aside sufficient

grain for family consumption during the year. However, in the Eastern Savanna where land pressure is less, farmers' stated objective is often increasing wealth (livestock).[27]

On the Central Plateau, the primary concern of farmers is to increase cereal production. To increase yields, the principal constraints appear to be water and fertility. The area cultivated can be enlarged by expanding family size or shifting to animal traction. The next two sections consider the economic issues involved in these two strategies for increasing cereal production.

Evaluation of a Yield-Increasing Strategy:

The principal barrier to increasing yields in any semi-arid region is water. One technique of water conservation for heavier soils is tied ridging. With this technique, ridges are constructed perpendicularly, leaving a depression in the middle where water accumulates instead of running off. The grain crop is then planted on the ridge. Tied ridges were tested on experiment stations in Nigeria in the Sixties but there has been little adoption.[28] Why? One hypothesis is that the tied ridges are not effective under farm-level conditions.

In Burkina Faso farm-level trials, the effect of tied ridges on maize yields in the compound areas ranged from yield increases of 29% to 71% (Table 1). In this more

fertile soil, no fertilization treatment was included. On the lower-fertility sorghum land, the effect of tied ridges alone on sorghum yields was much less. In most cases fertilizer alone had an equivalent or greater effect than tied ridges in increasing sorghum yields. The combined effects of tied ridges and chemical fertilizer on sorghum were substantial, increasing sorghum yields by 1.9 to 4 times (Table 2).

A more difficult problem is faced on the lower-fertility millet land. Again in farm-level trials, the combination of tied ridges and fertilization was successful, increasing millet yields by 1.4 to 2 times but both the absolute yields and the yield increases were less than on the more fertile sorghum land (Table 3). Farmers prefer sorghum to millet for storage[29] but millet is considered to be agronomically superior for its tolerance to drought and low-fertility, sandy soils. With the improved agronomy on these millet soils, is it possible to extend sorghum production there? The sorghum yields were lower than the millet yields but the differences were not significant. For millet, these are only one-crop season results because earlier experiments had attempted unsuccessfully to reduce fertilizer costs by utilizing the more insoluble Volta phosphate rather than the cotton fertilizer (N-P-K of 14-23-25) available on the Burkina

Faso market. (For sorghum and maize, there were three crop years of similar results. Contact the authors for a technical appendix.)

In summary, the farm-level testing of tied ridges with maize and of the tied ridges and fertilization for sorghum and millet indicated that these technologies performed well in increasing yields on farmers' fields. Increased yield is not a sufficient criterion for adoption. Farmers are more interested in the profitability of the new technologies. Tied ridges and fertilizer on sorghum individually and in combination increased cash revenue across sites and years (Tables 4 and 5).

In most cases the fertilizer effect was greater than the tied-ridges effect but the combination substantially increased yields and profits, especially in 1984. In 1983 the gains were less for the tied ridges; however, the returns were high for fertilization in most cases. Since fertilization involves cash expenditure and the response to fertilization will vary substantially with rainfall distribution, there is more risk of cash loss to farmers than with tied ridges. Combining fertilization and tied ridges reduces the riskiness of fertilization as indicated by a reduced number of farmers taking losses.

The principal input for the tied ridges was their substantial labor requirements. This was not a cash

expenditure but a reallocation of family labor. The average wage rate during the season in 1984 was 40 to 50 CFA/hour. Returns/hour of labor were substantially above this in almost all cases for both fertilization and tied ridges together and individually. However, the relevant wage rate is the value of family labor at the time of constructing the ridges.

To evaluate these new technologies, taking into account the high implicit cost of family labor during the crop season, a simple linear programming model of a representative farm was developed. The representative farm first satisfied a subsistence consumption constraint for maize and then maximized profits. This representative farm on the Central Plateau utilized donkey traction. Animal-traction farmers are expected to be more rapid innovators since the weeding and constructing of the ridges or furrows in one direction[30] can be more easily done with a donkey. This partial mechanization reduces the labor requirements for tied ridges.

The representative farm plants all the maize in the compound land with tied ridges but only one-half the sorghum area (Table 6). In the sorghum and millet activities with new technology, the tied ridges and fertilization are individual and combined activities. Only the combined tied ridges-fertilization activities enter the

solutions. Household farm income and cereal production are increased by 24% and 18% with the combined agronomic technologies. However, the large seasonal labor requirements in a peak labor-demand period constrain the extension of tied ridges onto the rest of the sorghum land and into the millet land. To further extend the tied ridging, it is necessary to overcome this seasonal labor constraint.

A tractor-drawn ridger was adapted for animal traction in Burkina Faso and 50 prototypes of this machine were field-tested in 1985. With the reduction in labor made possible with this machine, all the sorghum land goes into the tied ridges-fertilization technology according to the model results. If the tying can be done with only one pass of the machine, then 40% of the millet area would also be put in tied ridges. However, 60% of the millet area stays out of the new technology, so the seasonal labor requirement remains an important constraint. Hence, continuing research to raise the profitability of the tied ridges-fertilization technology and to evaluate the effect on yields of constructing the tied ridges during other periods appears to be a high-priority research area.

Most yield-increasing strategies and especially tied ridges will increase the demand for labor. The tied ridges require large inputs of labor at critical times of peak

seasonal labor demand. Large-scale adoption of tied ridges on the farm requires the utilization of the animal-traction ridger. However, partial adoption on the compound area and one-half the sorghum area was possible without the ridger on a representative farm with donkey traction. In the modeling of a representative farm without donkey traction, there was minimal adoption of the tied ridges. According to the model results, the utilization of animal traction is necessary for the introduction of the tied ridges even in the absence of a ridger. In the next section, some of the economic issues involved in the diffusion of animal traction in Burkina Faso will be considered.

## The Economics of the Introduction of Animal Traction in Burkina Faso:

It has been frequently argued that labor, especially seasonal labor, is the principal output constraint in much of Sub-Saharan agriculture and agricultural development projects should concentrate on releasing this constraint with mechanization. Animal traction programs have been actively promoted by the government of Burkina Faso at various periods and most recently in the Seventies.[31] In Burkina Faso, this diffusion of animal traction has been proceeding fairly rapidly with an estimated 10% of the agricultural households having access to animal traction in

the late Seventies.[32] Animal traction has been concentrated in the Southwest where oxen are utilized in cotton production but the number of farmers utilizing animal traction grew by ten times in the Eastern Savanna in the late Seventies[33] and donkeys are increasingly utilized in the Central Plateau.

Frequent failures in mechanization schemes and wide variation in estimated returns have been recorded.[34] One recent study of animal traction in villages on the Central Plateau and Eastern Savanna has suggested several reasons for the variation in performance.[35] Jaeger showed that farmers with more years of experience with animal traction had larger cultivated areas per worker. Apparently there is a learning-curve phenomenon associated with animal traction. Also he showed that the principal operations mechanized were either the first weeding or land preparation. This principal operation varied between regions and most farmers did not mechanize both. Those farmers able to reduce the learning time or to mechanize both operations could substantially increase the rates of return from mechanization. Farmers who introduced only the ox plow, for example, had marginal income gains as compared with hand tillage (Fig. 4). As the number of animal traction activities expands so does the profitability of

this investment. Furthermore, a larger animal stock will be associated with a shorter learning curve as a market for trained animals evolves and farmers' capabilities to utilize animal traction increase.

On the Central Plateau, agricultural production is risky and there are very limited areas of moderate to high soil fertility. Animal traction introduction alone encourages expansion onto even more marginal land area. Without simultaneous measures to increase yields,[36] animal traction would be expected to hasten the process of soil deterioration already being observed with the disappearance of the bush fallow rotation system.

In summary, in the previous section the model results indicated that the utilization of animal traction was a prerequisite for introduction of the tied ridging. However, animal traction without the yield-increasing technologies on the Central Plateau is expected to hasten the soil-deterioration process. A more stable, long-term strategy of agricultural development would emphasize the yield-increasing technologies with specific task mechanization to facilitate their introduction.

Adoption and Adaptation of
the Improved Technologies:

The interrelated nature of the new technology components becomes apparent as the evaluation technique passes from yield differences and profitability to whole-farm modeling. One check of the adequacy of ex ante technology evaluation is whether farmers adopt the technologies that pass the evaluation criteria.

The sample included only those farmers in the five villages involved with the project either in the farm testing or the socio-economic interviewing. There was no extension activity in this project. However, some farmers were able to observe the tied ridges and fertilization in the fields over a long period. In the higher rainfall regions, Poedogo and Dissankuy, fertilizer was already being utilized, especially on cotton in Dissankuy (Tables 7 and 8).

The tied ridges were a new technique for farmers but adoption was taking place in the three sites where the rainfall constraint was most serious. In two of these three sites both tied ridges and fertilization were being adopted. Bangasse has lower rainfall and is farther from the main urban areas so chemical fertilizer would be riskier, more difficult to obtain, and more expensive. In the two higher rainfall regions, Poedogo and Dissankuy, the adoption of the tied ridges was minimal (see Fig. 3). With the higher rainfall, fertilizer use is less risky in these

two villages. Also there are more non-farm activities for labor so the opportunity costs of constructing the tied ridges are expected to be higher in these two villages. The adoption process was just beginning and the areas in the new technologies were still small. Nevertheless the observed adoption does give some support to the modeling results.

Once these agronomic technologies were diffused, a less hostile environment would be available for new varieties. Over generations farmers have been selecting for yield response and yield stability in their harsh conditions. There is no a priori reason for traditional varieties to respond well in the improved agronomic environment. Traditional sorghum and millet varieties tend to be tall and problems with lodging would be expected in the improved fertility environment. By reducing the stress levels from drought and low soil fertility, the efficiency of the breeding-selection process for other characteristics[37] should be increased. Moreover, the differences between micro-environments will be reduced so the regional adaptation requirements for breeding will be less. Even larger yield increments are expected from the future combined effects of tied ridges-fertilization-new varieties.

In many regions with sandier soils, especially in the brown soils of the Sahel vegetation, tied ridges tend to be either washed away or blown down. Nevertheless the same agronomic principle may still apply of directing research towards low-cost methods to increase soil fertility and water retention capacity. On these sandier soils, such as those which predominate in much of Niger, water retention may be improved economically by increasing the level of organic materials in the soils. Traditional fallow systems serve this function; however, in many regions these systems are breaking down with higher population pressure. Low-cost methods to utilize crop residuals and manure might be appropriate applied research directions. More intensive rotation systems, such as some adaptation of the Australian ley system, may be feasible in the long run.

In summary, the construction of tied ridges is very labor-demanding, hence some of the process will undoubtedly need to be mechanized. Moreover, on sandier soils, the tied ridges are not viable. Continuing research to find lower-cost methods of water retention on different soil types may also encounter methods to reduce the costs and labor requirements of the tied ridges. Putting all these components together, tied ridges-fertilization-animal traction is a major change in the farming system and may explain the observed lack of introduction of tied ridges in

West Africa since farmers tend to adopt innovations sequentially.[38] Nevertheless there appear to be substantial potential income gains for these combined technologies. And farmers in two of the three villages with the most adverse rainfall conditions were adopting the new combined technologies on a small scale.

Conclusions:

The Central Plateau is a high population pressure, marginal rainfall region with generally infertile and fragile soils. Adapting the "Green Revolution" concepts to the agricultural-resource situation of the Central Plateau leads to the hypothesis that water and soil fertility are the principal constraints to increasing cereal yields. Agronomic improvements involving a water-retention measure and moderate chemical fertilization substantially increased farmers' cereal yields. This combined innovation was highly profitable and less risky than fertilizer alone. The whole-farm modeling indicated the necessity to overcome the seasonal labor bottleneck with animal traction to handle the increased labor demand for constructing the tied ridges. On the Central Plateau, animal traction was considered a prerequisite for implementing the yield-increasing agronomic technology rather than an alternative form of extensive technological change.

All three technologies, tied ridges, fertilization, and animal traction, have been available in the Sahel for several decades. There has been some introduction of the individual components, but not of the

combination. Since farmers tend to adopt innovations sequentially and animal traction and fertilizer require investment and an annual cash outlay, respectively, their combined adoption is a significant change. The importance of the combination of technologies was made clear by the farm modeling. The difficulty of implementing the combined innovations may explain the observed lack of diffusion of tied ridges in the region. Nevertheless as animal traction and chemical fertilizer become more available in the region, the feasibility of introducing tied ridges should substantially increase and the technology combination is expected to be relevant for other areas in the Sahelian countries, especially in the Sudan vegetation zone (Figure 1). On very sandy soils as in much of the Sahel vegetation zone the tied ridges do not hold up but the agronomic concept of combining a low cost technique to improve water retention with increased fertilization may need to be a priority topic for future applied agricultural research for these sandier soils.

After the "Green Revolution" of the late Sixties and Seventies, plant breeding has been the central

focus of most international and national agricultural research organizations. The lack of success of plant breeding in the Sahel countries and the evidence of high potential returns presented here indicates that the initial highest returns to applied agricultural research in harsh environments may be in improved agronomy, especially if the complementary or synergistic effects from combined input utilization can be achieved. Once the agronomic environment is improved, a higher success rate with new varieties of sorghum, millet, and maize is expected than has occurred in the past.

In Burkina Faso and in most of the Sahelian countries the regional resource allocation problem is important. The population of Burkina Faso is concentrated on the Central Plateau but the agricultural potential of the Southwest is greater due to its higher rainfall and larger area of alluvial soils. Land area expansion and resettlement in river valleys and higher rainfall regions is an alternative strategy for agricultural development in many Sahelian countries once the necessary public health investments are

made.[39] Increased investments in public health to improve the living conditions in the higher rainfall regions should make agricultural research investment more efficient by enabling concentration on regions with more agricultural potential. The complementarity of agricultural research and public health investments may need to be explicitly considered in agricultural development planning in Sahel countries.[40]

Finally, in the debate between the agricultural policy and the technology development schools, there has been a recent emphasis on inappropriate agricultural policy as the principal obstacle to agricultural development in the Sahel. Many have become frustrated with technology development due to the failure of food production growth to keep up with population growth in the Sahel in spite of the large aid flows since the 1968-73 drought. The failure of technological change to increase agricultural output more rapidly in the Sahel during the last decade may have resulted from an inappropriate choice of technologies. The emphasis of agricultural development efforts has been on irrigation, varietal breeding, and animal traction. The

principal conclusion of this paper is that in the adverse conditions of the Central Plateau the combined effect of agronomical improvements and animal traction on yields and profits could be substantial. Improved price policy would facilitate the introduction of this technology, but the long run prime mover of agricultural development will be the production and adaptation of new technologies. In the enthusiasm of international lenders to modify price and exchange rate policies it is critical to maintain investment in the development of the national agricultural research institutions in the Sahel so that the institutional capacity to respond to region specific agricultural problems will be improved.

NOTES:

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1. Utilizing 1969-71 as the base years (100), food production per capita ranged from 73 to 95 in 1980-82 in the Sahelian countries. The total population in the Sahel countries in 1983 was 33 to 34 million, hence the absolute size of the problem was small but population growth rates were expanding rapidly. Population growth rates from 1970-82 ranged from 2.0 in Burkina Faso to 3.3% in Niger. World Bank, World Development Report 1984 (New York, Oxford University Press, 1984):228, 254 and Population Reference Bureau, "World Population Data Sheet," (Washington, D.C., 1983).

Official development assistance ranged from $50 to $100/capita in several Sahelian countries during the late Seventies and early Eighties as compared with $12/capita for all developing countries. An estimated $2.5 billion of donor assistance was put into Sahelian agriculture since the 1970 drought. Carl K. Eicher, "Agricultural Research for African Development: Problems and Priorities for 1985-2000," (paper prepared for a World Bank conference on Research Priorities for Sub-Saharan Africa, Bellagio, Italy, 1985):5,14; and Carl K. Eicher, "International Technology Transfer and the African Farmer: Theory and Practice," mimeographed (Harare, University of Zimbabwe, 1984):28.

2. For a technical discussion of the climatic factors see S. E. Nicholson, "The Sahel: A Climatic Perspective," mimeo for Club du Sahel, (Paris, Organization for Economic Cooperation and Development, Paris, November 1982):80 pages. For soil and some other technical problems of the Sahel see: J. M. Kowal and A. H. Kassam, Agricultural Ecology of Savanna, A Study of West Africa (Oxford, Clarendon Press, 1978); Peter J. Matlon, "The Technical Potential for Increased

Food Production in the West African Semi-Arid Tropics," (paper presented at a Conference on Accelerating Agricultural Growth in Sub-Saharan Africa, Victoria Falls, Zimbabwe, 1983); and C. Charreau, "Some Controversial Technical Aspects of Farming Systems in Semi-Arid West Africa," Proceedings of an International Symposium on Rainfed Agriculture in Semi-Arid Regions (Davis, CA, Consortium for Arid Lands Institute, 1978):313-360).

3. The most well-known example of the agricultural policy school in Africa is the Berg report, World Bank, Accelerated Development in Sub-Saharan Africa: An Agenda for Action (Washington, D.C., 1981). Also see World Bank, Sub-Saharan Africa: Progress Report on Development Prospects and Programs (Washington, D.C., 1983). United States Department of Agriculture, Food Problems and Prospects in Sub-Saharan Africa: The Decade of the 1980s, Foreign Agricultural Economic Report No. 166 (Washington, D.C., 1981). United States Department of Agriculture, Food Policies in Developing Countries, Foreign Economic Report No. 194 (Washington, D.C., 1983). Both World Bank publications and the

first USDA report above also discuss the problems of technology development. For a more recent synthesis of the agricultural policy view, see U. Lele, "The Role of Risk in an Agriculturally Led Strategy in Sub-Saharan Africa," American Journal of Agricultural Economics 66(Dec. 1984):677-683.

For examples of the technology development school, see the previous papers cited by Matlon, Charreau, Eicher (1984 and 1985), and Peter Matlon and Dunstan S. Spencer, "Increasing Food Production in Sub-Saharan Africa: Environmental Problems and Inadequate Technological Solutions," American Journal of Agricultural Economics 66(Dec. 1984):671-676; Dunstan S. C. Spencer, "A Research Strategy to Develop Appropriate Agricultural Technologies for Small Farm Development in Sub-Saharan Africa," (paper presented at a Workshop on Technologies Approriate for Farmers in Semi-Arid West Africa, Ouagadougou, Burkina Faso, 1985); Office of Technology Assessment, Africa Tomorrow: Issues in Technology, Agriculture, and U.S. Foreign Aid, A Technical Memorandum (Washington, D.C., Congress of the United States, 1984).

4. Clearly, the two objectives can be conflicting in the short run, as the case of Niger indicates. After the worst crop year in remembered history in 1984, substantial emergency food aid was received and distributed. In the fall of 1985, as a nearly normal harvest of millet and sorghum was starting to come in, food-aid cereal shipments were being distributed all over the interior. Moreover, the government of Niger was under increasing pressure from the United States Agency for International Development and the World Bank to eliminate its fertilizer subsidy. Under these conditions of fertilizer cost-product price profitability squeeze, there is decreased economic incentive for farmers to adopt yield-increasing technology and an increasing pressure on Nigerien policymakers to increase food imports.

5. In the Bamako, Mali conference of March 1974 the Sahel countries defined self-sufficiency in food as one of their three primary objectives. A. de Lattre and A. M. Fell, Le Club du Sahel, Etude sur une Autre Cooperation Internationale, (Paris, Organisation de Cooperation et de Developpement Economiques, 1984):28.

The Third Five Year Plan of Burkina Faso for the 1977-1981 period set food self-sufficiency as one of its three national objectives. J. G. Nagy, H. W. Ohm, and S. Sawadogo, "Burkina Faso, A Case Study of the Purdue University Farming Systems Project," Mimeo (Ouagadougou, Burkina Faso, Farming Systems Project, 1985):4.

From 1970-72 to 1980-82 cereal imports into the Sahel countries doubled, reaching one million metric tons in this latter period. Trade Yearbooks, 1970-1982 (Rome, Food and Agriculture Organization of the United Nations, 1970-1982). One consequence of the increasing food imports has been the extension of the import substitution argument for industrialization into food production. D. Rimmer, The Economies of West Africa (New York, St. Martins Press, 1984):249.

6. For the latest supply response review in Sub-Saharan African agriculture and a debate on its interpretation, see Marian E. Bond, "Agricultural Responses to Prices in Sub-Saharan Afrian Countries," International Monetary Fund Staff Paper 30 (Washington, D.C., 1983):703-726; and Christopher L. Delgado and

John W. Mellor, "A Structural View of Policy Issues in African Agricultural Development," American Journal of Agricultural Economics 66(Dec. 1984):665-670.

7. Actually, the analysis is of the private and social profitability of different types of rice production including irrigated rice. Scott R. Pearson, J. Dirck Stryker, Charles P. Humphreys, and others, Rice in West Africa, Policy and Economics (Stanford, Stanford University Press, 1981:342-351 for the Mali case.

8. In the Sahelian countries there are 339,000 irrigated nectares in 14.95 million ha. of cropland or only 2.2% of the crop area is irrigated (1983). Gambia was not included in this calculation due to lack of data on total crop area. Devres, Inc., "Assessment of Agricultural Research Analysis and Strategy," (Washington, D. C., 1984):2-5. For all of Sub-Saharan Africa, irrigation has been estimated to occupy 5% of the crop area as compared with 30% in India (Eicher, 1982, p. 168).

The Club du Sahel estimated that the area expansion from new irrigation perimeters has been approximately equal to the irrigated area that becomes unusable each year in the Sahel. Cited in C. Eicher, "West Africa's Agrarian Crisis," paper presented for the 5th Bi-Annual Conference of the West African Association of Agricultural Economists (Abidjan, Ivory Coast, 1983):58.

9. Charreau, 1978, p. 345 and Matlon, 1983, p. 13.

10. Eicher, 1985, p. 30.

11. P. M. Ahn, "Soil Factors Affecting Rainfed Agriculture in Semi-Arid Regions with Particular Reference to the Sahel Zone of Africa," Proceedings of an International Symposium on Rainfed Agriculture in Semi-Arid Regions (Davis, California, Consortium for Arid Lands Institute, 1978): 128-145.

12. The experiment station yields of E35-1 were taken from ICRISAT annual reports from the Burkina Faso station and cited in Nagy, Ohm and Sawadogo, 1985, p. 13. The farm-level sorghum yields vary by rainfall zone and between years. These are the estimated range from literature review and field observations in M. Roth and J. H. Sanders, "An Economic Evaluation of Selected Agricultural Technologies with Implications for Development Strategies in Burkina Faso," International Programs in Agriculture Staff Paper (West Lafayette, Purdue University, Oct. 1984):6.

13. R. D. Singh, E. W. Kehrberg, and W. H. M. Morris, Small Farm Production Systems in Upper Volta, Descriptive and Production Function Analysis, Agricultural Experiment Station Bulletin No. 42 (West Lafayette, Purdue University, Dec. 1983); also Matlon, 1985, pp. 23, 25.

14. In the West African semi-arid tropics, which include the Sahel and the semi-arid regions of the West African coastal states, down to the isohyt level of 1300 mm rainfall/year, only an estimated 5% of the

sorghum and millet area is in varieties developed with modern selection methods (Matlon, 1985, p. 1).

15. Public lectures of Dr. L. D. Swindale, Director General, ICRISAT, and Dr. John Nickel, Director General, CIAT.

16. Matlon, 1985, p. 12.

17. World Bank, Upper Volta, Agricultural Issues Study, (Washington, D.C., 1982):32.

18. Andrew M. Kamarck, The Tropics and Economic Development (Baltimore, Johns Hopkins University Press, 1976):71.

19. William K. Jaeger, "Agricultural Mechanization: The Economics of Animal Traction in Burkina Faso," unpublished Ph.D. thesis (Palo Alto, Stanford University, 1984):29.

20. Semi-Arid Food Grain Research and Development Program, Farming Systems Research Unit in Upper Volta

(SAFGRAD-FSU), 1983 Annual Report (West Lafayette, Purdue University, 1984):21.

21. For further agronomic description of these soil types, see W. A. Stoop, C. M. Pattanayak, P. J. Matlon and W. R. Root, "A Strategy to Raise the Productivity of Subsistence Farming Systems in the West African Semi-Arid Tropics," in Sorghum in the Eighties, L. R. House, L. K. Mughogo, and J. M. Peacock (editors), Proceedings of the International Symposium on Sorghum, Vol. II (Hyderabad, India, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), 1982):519-26.

The area estimates would vary substantially between farms and regions. After a review of available literature, the area estimates for a representative farm were:

Compound area - 0.1 to 0.2 ha.

Sorghum area - 1 to 1.5 ha. In some regions distinctions were also made between red and white sorghum.

Millet area - 3 to 4 ha.

Roth and Sanders, 1984, for more details.

22. SAFGRAD-FSU, 1982 Annual Report, 1983, p. 13.

23. C. Delgado and J. McIntire, "Constraints on Oxen Cultivation in the Sahel," American Journal of Agricultural Economics, 64(May 1982):188-196.

24. This is the Roth and Sanders 1984 summary of literature and estimates of farm yields. Clearly there would be a wide variation between crop seasons and between years.

25. Only the millet area had a significant statistical relationship with the family labor supply in various models attempting to explain differences in crop areas between farms. SAFGRAD-FSU, 1982 Annual Report, 1983, pp. 16, 17.

26. Jaeger, 1985, p. 21.

27. SAFGRAD-FSU, 1982 Annual Report, 1983, pp. 9, 10.

28. Dagg, M., and J. C. Macartney, "The Agronomic Efficiency of the NIAE Mechanized Tied Ridge System of Cultivation," Expt. Agriculture 4(1968):279-294; D. A. Lawes, "Rainfall Conservation and the Yields of Sorghum and Groundnuts in Northern Nigeria," Expt. Agriculture, 2(1966):139-146.

Eicher reports that tied ridging was promoted by the colonial research service in Nigeria in the 1940s. See C. K. Eicher, 1984, p. 13.

29. SAFGRAD-FSU, 1982 Annual Report, 1983, p. 14.

30. If the ridges in one direction are made with donkey traction, then the tying or putting in the other perpendicular ridges is normally done by hand. The machine for tying the ridging will then mechanize this second step.

31. P. Munzinger, Animal Traction in Africa (Eschborn, German Agency for Technical Cooperation, 1982); for discussion of earlier mechanization campaigns, see V. Barrett, G. Lassiter, D. Wilcock, D. Baker, and E. Crawford, "Animal Traction in Eastern

Upper Volta: A Technical, Economic, and Institutional Analysis," MSU International Development Paper No. 4 (East Lansing, Department of Agricultural Economics, Michigan State University, 1982):13ff.

32. This 10% is the estimate of Nagy, et al. (1985, p. 9). From 1965 to 1979, the number of oxen teams increased from 12,000 to 26,000. If an equal number of donkeys is assumed and one-half of this for the number of horses, an animal stock of 65,000 for animal traction was available then. Some rental of these animals could raise the number of households with access to animal traction to 80,000. In the 1975 census, there were 569,580 agricultural households with an average size of 10. These crude calculations result in an upper-boundary estimate of approximately 14% of the agricultural households utilizing animal traction. The data were taken from World Bank, Upper Volta, Agricultural Issues Study (Washington, D.C., 1982):211,224.

33. In the Eastern Savanna, animal-traction farmers were estimated to increase from 180 in 1974 to 1,740 in 1979-80. See V. Barrett, et al., 1982, p. 1.

34. One review of animal traction projects in Sub-Saharan Africa emphasized the low levels of the area and yield effects actually achieved, the lack of institutional support, and the high costs of animals and equipment. Cited in C. K. Eicher and D. C. Baker, "Research on Agricultural Development in Sub-Saharan Africa: A Critical Survey," MSU International Development Paper No. 1 (East Lansing, Department of Agricultural Economics, Michigan State University, 1982):143.

35. Jaeger, W. K., 1984.

36. A Michigan State review of their study of animal traction in the Eastern Savanna concluded: "The results revealed that in the absence of a proven biologically stable and economically profitable package, it was unwise to encourage farmers to purchase animals (donkeys and oxen) and animal-powered equipment." (Eicher, 1985, p. 39) Hence, the Michigan

State evaluation of animal traction also gave primary emphasis to the need to increase cereal yields of sorghum and millet. The role of animal traction is to facilitate this process of developing yield-increasing cereal technologies. This study also emphasizes the need to maintain soil fertility when shifting from the traditional fallow to the more intensive animal-traction systems. See Vincent Barrett, et al., 1982, p. 9.

37. New sorghum varieties were tested in the improved environment in the farm trials of 1984. These trials identified two other production problems with spittlebug and sorghum midge. This feedback process of providing farm-level information to the experiment station researcher is a critical aspect of the research process. See SAFGRAD-FSU, 1984 Annual Report, 1985, p. 31.

38. Agronomists often emphasize the interrelated nature of new agricultural technologies, whereas farmers tend to adopt one innovation at a time in a

sequencing process. See Eicher, 1985, p. 28 and the references cited on sequencing.

39. In 1973 the World Health Organization began a program to control river blindness ("onchocerciasis") and Burkina Faso created an organization to resettle the river valleys, the Autorite des Ameragements des Vallees du Volta (AVV). M. O. Saunders, "Agriculture in Upper Volta: The Institutional Framework," Farming Systems Research Unit Working Papers, mimeo (West Lafayette, Purdue University, April 1980):14.

40. The World Bank supports both the international agricultural research organizations and the World Health Organization. See C. Weiss, Jr., "The World Bank's Support for Science and Technology," Science, 227 (Jan. 18, 1985):263, 264. The relevant planning decisions need to be made at the national level in defining the objectives of agricultural research and the role in agricultural development of area expansion into those areas where public health investments have been or could be made. The emphasis here has been on river blindness but the higher rainfall

regions of the Sahelian countries have other limiting disease problems such as the tse-tse fly and bilharzia in irrigation projects.

Table 1. Maize Yields on Compound Land With Tied Ridges in Farmer-Managed Trials in Five Villages, 1984.

| | Farmers' Practices | Tied Ridges |
|---|---|---|
| | (Kg./.ha) | |
| Nedogo | 869 (19) | 1305* |
| Bangasse | 341 (12) | 466* |
| Poedogo | 1339 (8) | 1953 |
| Diapangou (Eastern Savanna) | 710 (7) | 1212* |
| Dissankuy (Southwest) | 564 (16) | 725* |

* Significantly different from the control at the 5% level with the "t" test. The standard errors were Nedogo, 92; Bangasse, 102; Diapangou, 273; Poedogo, 351; Dissankuy, 35..

SOURCE: SAFGRAD-FSU, 1984 Annual Report, 1985, p. 19.

NOTE: The tied ridging was done one month after planting. The numbers in parentheses indicate the number of farmers with trials in each village.

Table 2. Sorghum Yields on Sorghum Land With Tied Ridges and Fertilization in Farmer-Managed Trials in Four Villages, 1984.

| Villages | Farmers' Practices | Tied Ridges | Fertilization | Tied Ridges and Fertilization |
|---|---|---|---|---|
| Nedogo | 186[a] (11) | 446[b] | 441[b] | 751[c] |
| Bangasse | 293[a] (12) | 456[ab] | 616[b] | 944[c] |
| Dissankuy (Southwest) | 447[a] (25) | 588[b] | 681[c] | 855[d] |
| Diapangou (Eastern Savanna) | 433[a] (19) | 655[b] | 806[c] | 1106[d] |

NOTE: Different letters indicate significant differences between the treatment levels at the 5% level. The fertilization level was 200 kg./ha. of cotton fertilizer of N-P-K (14-23-15) and 50 kg./ha. of urea. The numbers in parentheses are the number of farmers involved in these villages. The standard errors were: Nedogo, 78; Bangasse, 145; Dissankuy, 35; Diapangou, 52.

SOURCE: SAFGRAD-FSU, 1984 Annual Report, 1985, p. 12.

Table 3. Tied Ridges and Fertilization With Sorghum and Millet in Farmer-Managed Trials at Three Villages, 1984.

| Villages | Millet With Farmers' Practices | Millet With Tied Ridges and Fertilization | Sorghum With Tied Ridges and Fertilization |
|---|---|---|---|
| Nedogo | 294 (13) | 600* | 592* |
| Bangasse | 291 (27) | 544* | 411* |
| Dissankuy | 435 (23) | 626* | 459 |

* Significantly different from farmers' practices at the 5% level. The fertilization level was 100 kg./ha. of (14-23-15) and 50 kg./ha. of urea. The number of farmers participating in these trials is given in parentheses. The standard errors were: Nedogo, 62; Bangasse, 49; Dissankuy, 36.

SOURCE: SAFGRAD-FSU, 1984 Annual Report, 1985, p. 29.

Table 4: Economic analysis of farmer managed trials of sorghum with fertilizer and tied ridges, 1984.

| | Treatments 1/ | | | | 4/ | 4/ | Number |
|---|---|---|---|---|---|---|---|
| | C | TR | F | TR.F | S.E | CV | of Farmers |
| **Nedogo, Manual Traction** | | | | | | | |
| Grain Yield, kg/ha | 157 | 416 | 431 | 652 | 75.1 | 43 | 11 |
| Yield Gain Above Control, kg/ha | - | 259 | 274 | 495 | | | |
| Gain in Net Revenue, CFA 2/ | - | 23828 | 13275 | 33607 | | | |
| Return/hr. of Additional Labor, CFA 3/ | - | 238 | 140 | 172 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 27 | 9 | | | |
| **Nedogo, Donkey Traction** | | | | | | | |
| Grain Yield, kg/ha | 173 | 425 | 355 | 773 | 63.4 | 44 | 18 |
| Yield Gain Above Control, kg/ha | - | 252 | 182 | 600 | | | |
| Gain in Net Revenue, CFA | - | 23184 | 4811 | 43267 | | | |
| Return/hr. of Additional Labor, CFA | - | 309 | 51 | 255 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 50 | 0 | | | |
| **Bangassa, Manual Traction** | | | | | | | |
| Grain Yield, kg/ha | 293 | 456 | 616 | 944 | 145.0 | 62 | 12 |
| Yield Gain Above Control, kg/ha | - | 163 | 323 | 651 | | | |
| Gain in Net Revenue, CFA | - | 14996 | 17783 | 47959 | | | |
| Return/hr. of Additional Labor, CFA | - | 150 | 187 | 246 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 8 | 17 | | | |
| **Dissankuy, Ox Traction** | | | | | | | |
| Grain Yield, kg/ha | 447 | 588 | 681 | 855 | 35.1 | 19 | 25 |
| Yield Gain Above Control, kg/ha | - | 141 | 234 | 408 | | | |
| Gain in Net Revenue, CFA | - | 12972 | 9595 | 25603 | | | |
| Return/hr. of Additional Labor, CFA | - | 173 | 101 | 151 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 28 | 0 | | | |
| **Diapangou, Manual Traction** | | | | | | | |
| Grain Yield, kg/ha | 335 | 571 | 729 | 1006 | 48.4 | 23 | 19 |
| Yield Gain Above Control, kg/ha | - | 236 | 394 | 671 | | | |
| Gain in Net Revenue, CFA | - | 21712 | 24315 | 49799 | | | |
| Return/hr. of Additional Labor, CFA | - | 217 | 256 | 255 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 26 | 0 | | | |
| **Diapangou, Donkey Traction** | | | | | | | |
| Grain Yield, kg/ha | 498 | 688 | 849 | 1133 | 45.6 | 18 | 19 |
| Yield Gain Above Control, kg/ha | - | 190 | 351 | 635 | | | |
| Gain in Net Revenue, CFA | - | 17480 | 20359 | 46487 | | | |
| Return/hr. of Additional Labor, CFA | - | 233 | 214 | 273 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 21 | 0 | | | |
| **Diapangou, Ox Traction** | | | | | | | |
| Grain Yield, kg/ha | 466 | 704 | 839 | 1177 | 46.8 | 18 | 19 |
| Yield Gain Above Control, kg/ha | - | 238 | 373 | 711 | | | |
| Gain in Net Revenue, CFA | - | 21896 | 22383 | 53479 | | | |
| Return/hr. of Additional Labor, CFA | - | 292 | 236 | 315 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 5 | 0 | | | |

1/ C = control (no tied ridges or fertilizer); TR = tied ridges constructed one month after seeding; F = 100 kg/ha 14-23-15 two weeks after seeding plus 50 kg/ha urea one month after seeding.

2/ Net revenue = yield gain x grain price (92 CFA/kg) minus fertilizer cost; (78 CFA/kg for 14-23-15, and 66 CFA/kg for urea). Includes interest charge for six months at rate of 15%.

3/ Net revenue/additional labor of tied ridging and fertilizer application. Manual, Donkey, and Ox traction require 100, 75, and 75 hours of additional labor/ha for tied ridging respectively. Fertilizer application requires 95 additional hours/ha.

4/ S.E. = the standard error of the difference between two treatment means. CV% = coefficient of variation.

SOURCE: Joseph G. Nagy, Linda L. Ames, and Herbert W. Ohm, "Technology Evaluation, Policy Change, and Farmer Adoption in Burkina Faso," paper presented at the Farming Systems Symposium (Manhattan, Kansas State University, 1985):20

Table 5. Economic analysis of farmer managed trials of sorghum with fertilizer and tied ridges, 1983.

| | Treatments 1/ | | | | | | Number |
|---|---|---|---|---|---|---|---|
| | C | TR | F | TR,F | S.E. 4/ | CV 4/ | Farmers |
| **Nedogo, Manual Traction** | | | | | | | |
| Grain Yield, kg/ha | 430 | 484 | 547 | 851 | 121.9 | 29 | 3 |
| Yield Gain Above Control, kg/ha | - | 54 | 117 | 421 | | | |
| Gain in Net Revenue, CFA 2/ | - | 4968 | -1169 | 26799 | | | |
| Return/hr. of Additional Labor, CFA 3/ | - | 50 | - | 137 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 56 | 0 | | | |
| **Nedogo, Donkey Traction** | | | | | | | |
| Grain Yield, kg/ha | 444 | 624 | 604 | 962 | 128.7 | 49 | 11 |
| Yield Gain Above Control, kg/ha | - | 180 | 160 | 518 | | | |
| Gain in Net Revenue, CFA | - | 16560 | 2787 | 35723 | | | |
| Return/hr. of Additional Labor, CFA | - | 221 | 29 | 210 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 58 | 42 | | | |
| **Bangasse, Manual Traction** | | | | | | | |
| Grain Yield, kg/ha | 406 | 493 | 705 | 690 | 94.8 | 46 | 12 |
| Yield Gain Above Control, kg/ha | - | 87 | 299 | 284 | | | |
| Gain in Net Revenue, CFA | - | 8004 | 15575 | 14195 | | | |
| Return/hr. of Additional Labor, CFA | - | 80 | 164 | 73 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 21 | 17 | | | |
| **Diapangou, Manual Traction** | | | | | | | |
| Grain Yield, kg/ha | 363 | 441 | 719 | 753 | 37.6 | 23 | 24 |
| Yield Gain Above Control, kg/ha | - | 78 | 356 | 390 | | | |
| Gain in Net Revenue, CFA | - | 7176 | 20819 | 23947 | | | |
| Return/hr. of Additional Labor, CFA | - | 72 | 219 | 123 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 8 | 8 | | | |
| **Diapangou, Donkey Traction** | | | | | | | |
| Grain Yield, kg/ha | 481 | 552 | 837 | 871 | 43.5 | 22 | 25 |
| Yield Gain Above Control, kg/ha | - | 71 | 356 | 390 | | | |
| Gain in Net Revenue, CFA | - | 6532 | 20819 | 23947 | | | |
| Return/hr. of Additional Labor, CFA | - | 87 | 219 | 141 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 12 | 16 | | | |
| **Diapangou, Ox Traction** | | | | | | | |
| Grain Yield, kg/ha | 526 | 578 | 857 | 991 | 50.8 | 24 | 25 |
| Yield Gain Above Control, kg/ha | - | 52 | 331 | 465 | | | |
| Gain in Net Revenue, CFA | - | 4784 | 18519 | 30847 | | | |
| Return/hr. of Additional Labor, CFA | - | 64 | 195 | 181 | | | |
| % Farmers Who Would Have Lost Cash | - | 0 | 20 | 12 | | | |

1/ C = control (no tied ridges or fertilizer); TR = tied ridges constructed one month after seeding; F = 100 kg/ha 14-23-15 two weeks after seeding plus 50 kg/ha urea one month after seeding.

2/ Net revenue = yield gain x grain price (92 CFA/kg) minus fertilizer cost; (78 CFA/kg for 14-23-15, and 66 CFA/kg for urea). Includes interest charge for six months at rate of 15%.

3/ Net revenue/additional labor of tied ridging and fertilizer application. Manual, Donkey, and Ox traction require 100, 75, and 75 hours of additional labor/ha for tied ridging respectively. Fertilizer application requires 95 additional hours/ha.

4/ S.E. = the standard error of the difference between two treatment means. CV% = coefficient of variation.

SOURCE: Nagy et al., 1985, p. 21.

Table 6. The Effect of Tied Ridge Technologies With Donkey Traction on Areas Cultivated, Production, and Net Farm Income Estimates, Central Plateau (Model Results).

| Variable | | Traditional Management (Donkey) | Tied-Ridging Technology /a | | |
|---|---|---|---|---|---|
| | | | Tied by Hand | Tied With Machine | |
| | | | | Two Passes | One Pass |
| Total Area Cultivated (hectares): | | 5.50 | 5.60 | 5.70 | 5.60 |
| Maize: | Traditional | .20 | | | |
| | With Tied Ridges | | .20 | .15 | .15 |
| Sorghum: | Traditional | 1.40 | .70 | | |
| | With Tied Ridges | | .70 | 1.48 | 1.55 |
| Millet: | Traditional | 3.18 | 3.15 | 3.18 | 1.88 |
| | With Tied Ridges | | | .05 | 1.27 |
| Peanuts | | .76 | .86 | .79 | .71 |
| Fertilizer Used: (kgs./farm) | Urea | | 45.00 | 84.00 | 149.00 |
| | Cotton Fertilizer | | 90.00 | 168.00 | 298.00 |
| Total Cereals Production: (kgs.) | Per Household | 2103.00 | 2604.00 | 2970.00 | 3354.00 |
| | Per Resident b/ | 150.00 | 186.00 | 212.00 | 240.00 |
| Net Farm Income ('000 FCFA): c/ | | | | | |
| | Per Household | 215.30 | 253.20 | 273.20 | 296.40 |
| | Per Worker d/ | 30.80 | 36.20 | 39.00 | 42.30 |

a/ Based on 50 kg./ha. urea and 100 kg./ha. cotton fertilizer, labor times of 75 hrs./ha. for tying the ridges by hand, 20 hrs./ha. for machine--2 passes, and 2 hrs./ha. for machine--one pass. Yield estimates are given in Nagy et al.

b/ Based on 14 residents/household.

c/ Annualized cost of 4,400 FCFA for tied-ridging machine subtracted in columns 3 and 4.

d/ Based on 7 active workers/household.

SOURCE: Joseph G. Nagy, Linda L. Ames, and Herbert W. Ohm, "Technology Evaluation, Policy Change, and Farmer Adoption in Burkina Faso," paper presented at the Farming Systems Symposium (Manhattan, Kansas State University, 1985):20.

Table 7. Percent of Farmers Adopting Tied Ridges (TR) and Fertilizer by Village, 1984.

| Village | Years[a] | No. of Farmers | % Farmers Adopting TR | % Farmers Adopting Fertilizer |
|---|---|---|---|---|
| Nedogo | 5 | 69 | 25 | 10 |
| Bangasse | 3 | 53 | 23 | 0 |
| Poedogo | 2 | 27 | 4 | 33 |
| Dissankuy | 2 | 60 | 3 | 97[b] |
| Diapangou | 3 | 61 | 25 | 8 |

[a] Number of years the research project was in the village.

[b] Figures relate only to land in cotton. Small amounts of fertilizers are used on cereals.

SOURCE: Nagy et al., 1985, p. 24.

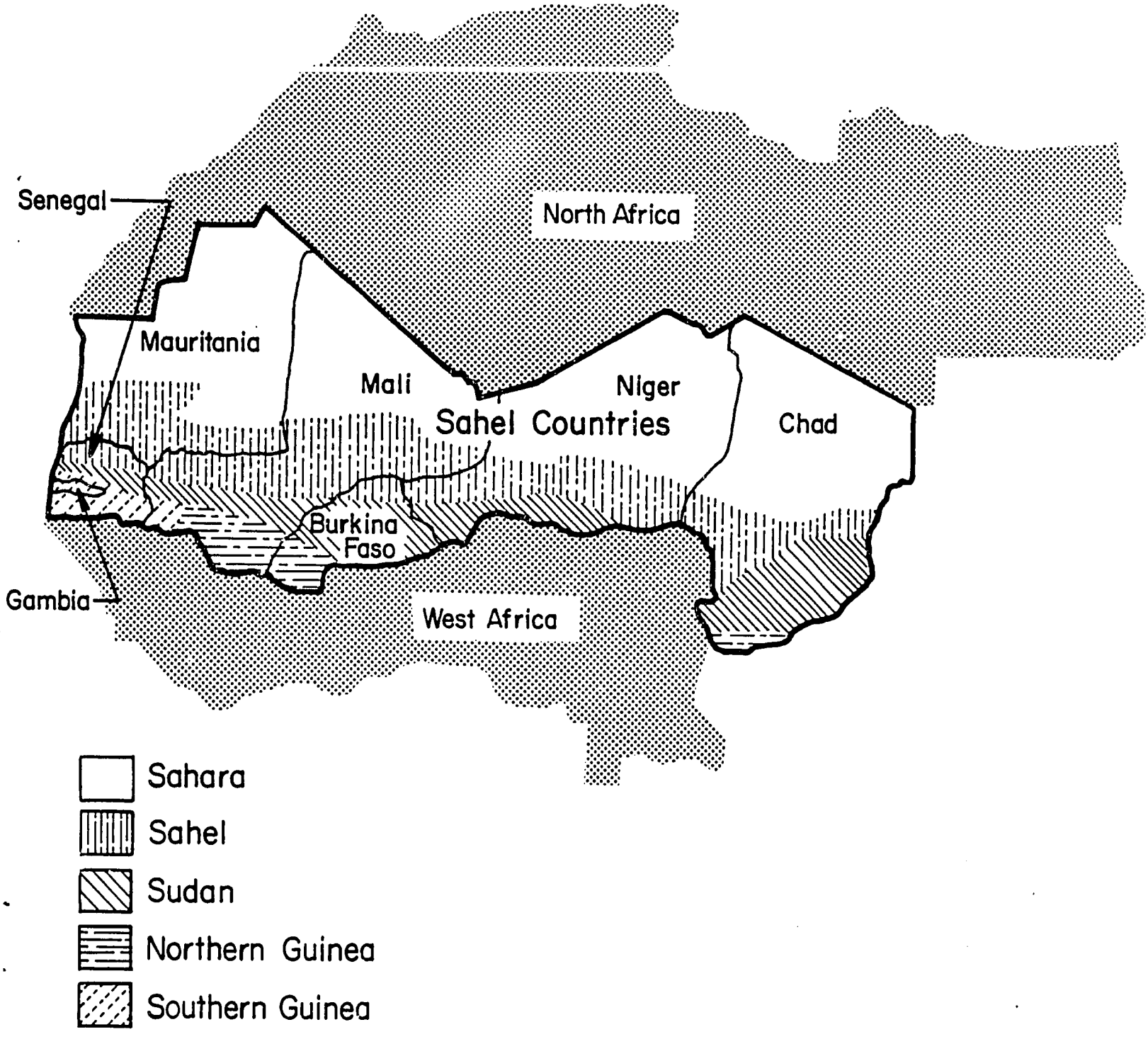
Table 8. Average Hectares of Technology Adoption, 1984.

| Technology | Villages | | | | |
|---|---|---|---|---|---|
| | Nedogo | Bangasse | Poedogo | Dissankuy | Diapangou |
| | ha. | | | | |
| Tied Ridges | .32 | 0.03 | .11 | .03 | .18 |
| Fertilizer | .46 | 0.00 | 3.00 | 3.00 | .34 |

SOURCE: Nagy et al., 1985, p. 24.

Figure 1. Vegetation zones of the Sahel.

Vegetation Zones Of The Sahel




Source: M. J. Jones and A. Wild, Soils of the West African Savanna, The Maintenance and Improvement of their Fertility (Farnham Royal, Slough, England, Commonwealth Agricultural Bureaux, 1975): 19

Figure 1.

Note: These are the earliest classifications of Savanna vegetation dating from a paper in 1900. More recently the vegetation divisions have been related to the climate, specifically the quantity and duration of rainfall. The first classification is desert and includes approximately one-half the area of the Sahelian countries. The Sahel is a transition zone between the desert and the Sudan. The northern Sahel (100 to 350 mm/year of rainfall) is the northern border for cropland. The predominant economic activity is nomadic grazing. In the southern Sahel (350 to 500 mm) the principal activity is millet production with small patches of sorghum where there is better soil fertility and water retention. The rainy season is short, less than 80 days.

The Sudan is the principal crop region in the Sahelian countries and supports a high population concentration. The rainfall ranges from 500 mm to 1000 mm/year with a rainy season of 80 to 130 days, hence the risks of agricultural production are substantially less than in the southern Sahel. The research reported in this paper is concentrated here.

The northern Guinea ecological zone ranges from 900 to 1300 mm/year of rainfall within a rainy season of 130-190 days. Southern Guinea is transitional towards two rainy seasons in contrast with the wet and dry seasons of the rest of the savanna regions above. The rainfall is 1000 to 1500 mm/year with a rainy season of 190 to 250 days. In these Guinean regions there are more insect and disease problems. The tse-tse fly is a serious problem limiting livestock production here. Both Guinea regions have low population densities apparently for health reasons. The above definitions were taken from Jones and Wild, p. 20. For a slightly different definition of these zones and an excellent discussion, see J. M. Kowal and A. H. Kassam, Agricultural Ecology of Savanna, A Study of West Africa (Oxford, Clarendon Press, 1978):28, 107-111

Figure 2. Hypothetical yield responses of new and traditional varieties to higher input/management levels.

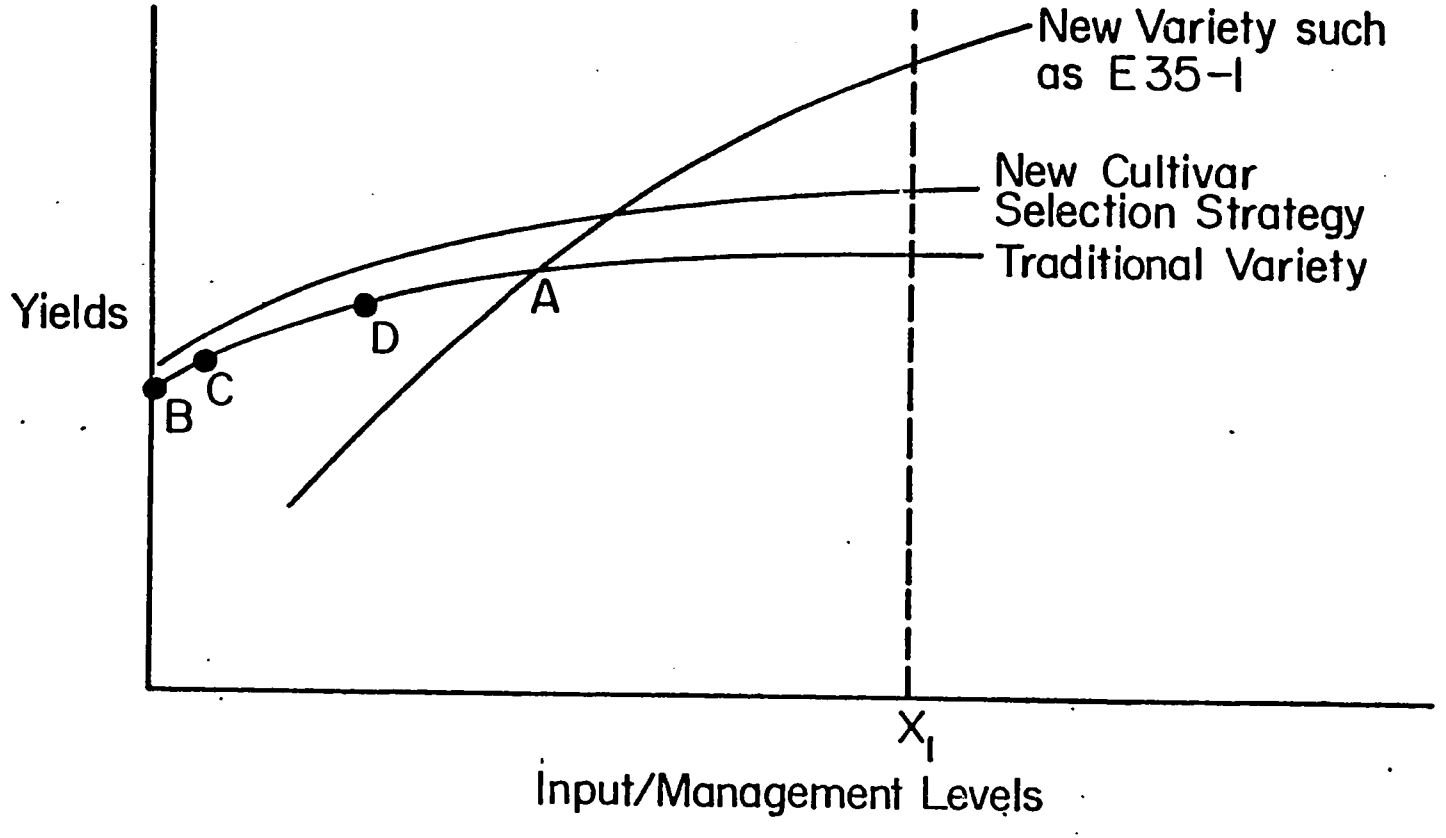

New Variety such as E35-1
New Cultivar Selection Strategy
Traditional Variety
Yields
A
B
C
D
$X_1$
Input/Management Levels

Figure 3. Regions, isohyts, and agricultural research sites in Burkina Faso.

# BURKINA FASO

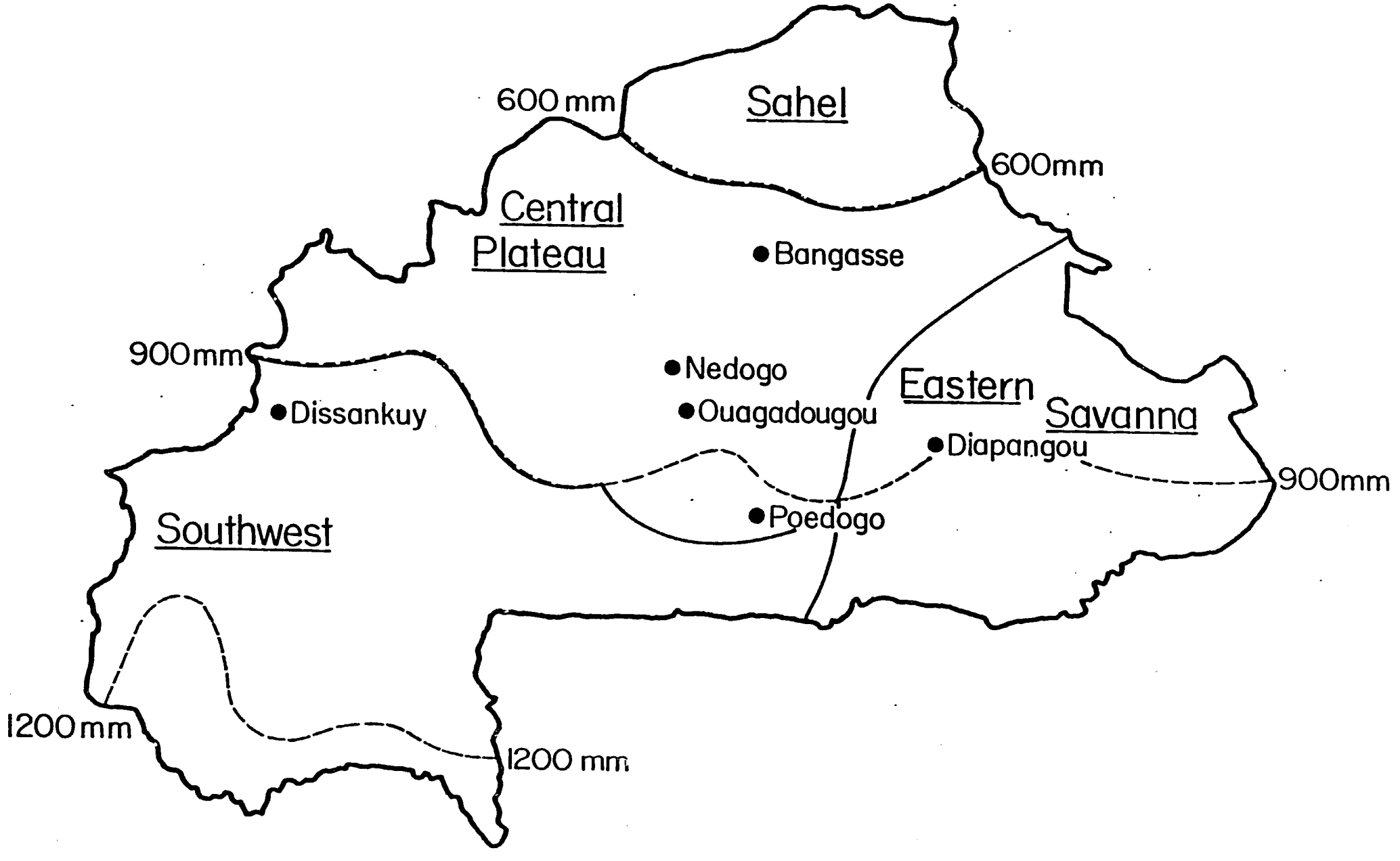
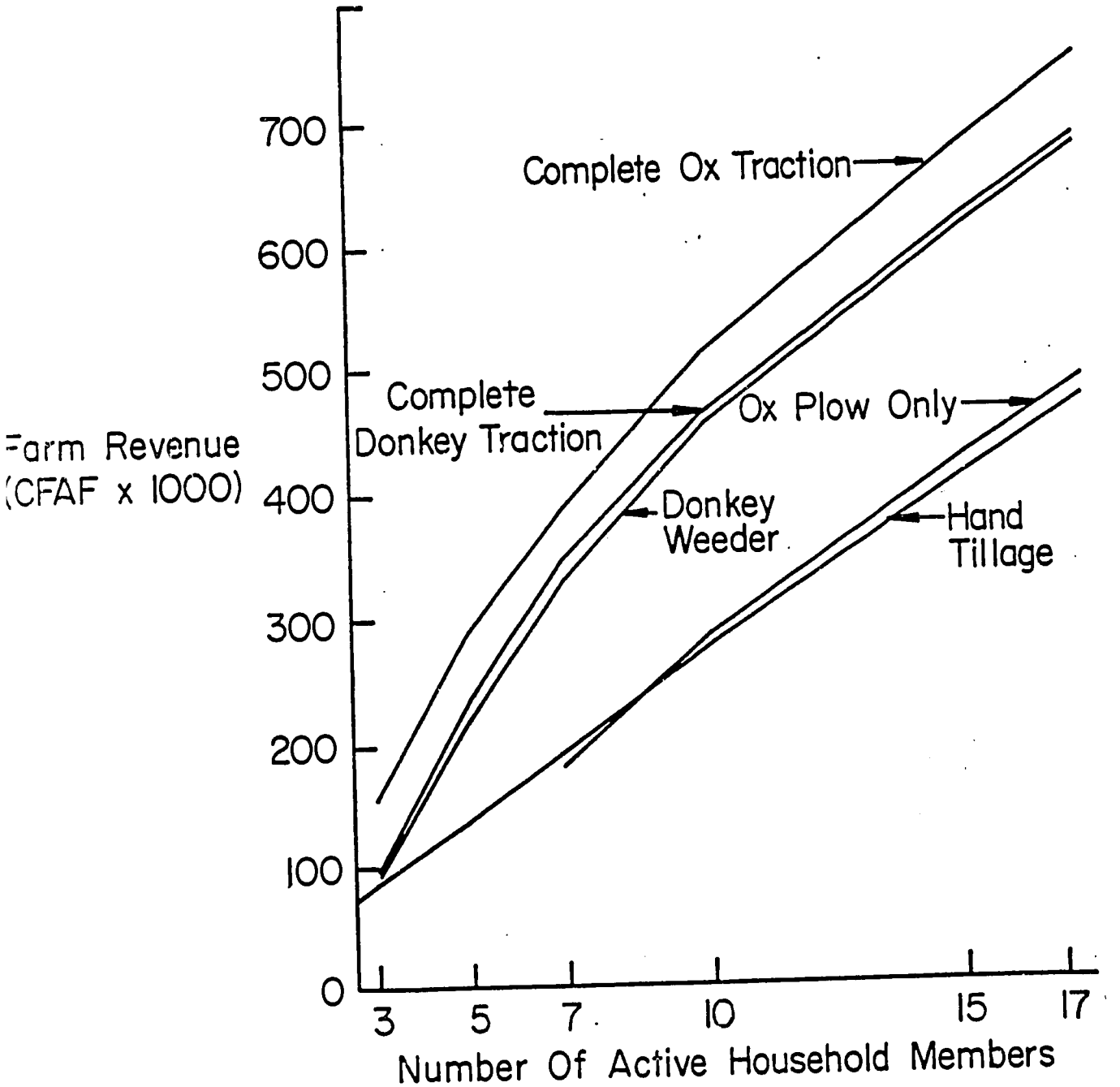


Figure 4. Farm revenue for different utilization rates of two types of animal traction for different family sizes in Burkina Faso.




Note: 437 CFAs = 1 U.S. dollar (1984)

Source: W. Jaeger, (1984 ), p. 132.