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# IDENTIFYING FARM LEVEL CONSTRAINTS AND EVALUATING NEW TECHNOLOGY IN THE PURDUE FARMING SYSTEMS PROJECT IN UPPER VOLTA

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Mahlon Lang, Ron Cantrell, and John H. Sanders*

In much of the Central Plateau of Upper Volta the pressure of the high man-land ratios is causing a shortening of the fallow rotation period (see Figure 1). In the absence of chemical substitutes for the fertility restoration effect of a long fallow, cereal yields decline (Ruthenberg, 1980; World Bank, 1981, p. 13; Saunders, 1980, p. 15). In this region a degradation of the sandy and loamy soils has occurred over time with more intensive cultivation and the subsequent erosion. Besides the declining organic material hence reduced capacity to retain either water or nutrients, the sandy soils often form a hard crust preventing water infiltration thereby increasing runoff and aggravating drought stress and erosion (United Nations, 1977, pp. 13, 14, 20, 31). Mossi farmers are not able to prepare the heavy clay soils of lowland regions with their available power sources (Jan Broekhuyse, conversation, 1983). Other areas of the country have greater agricultural potential, more rainfall and better soils, hence there is out-migration from the central plateau to these regions in the south. However, some of these more fertile southern areas also have other problems, as more disease and the difficulty of land preparation of the heavy clay soils. The World Health Organization and the World Bank attribute much of the difference in population densities between the Central Plateau and the south to disease. "Over half the country's population live on less than one-fourth the country's area, the central plateau, which is on the whole the most poorly endowed with resources." (Kamarck, 1976, pp. 71, 72). Kamarck attributes this population concentration principally to the problem of river blindness ("onchocerciasis") in the alluvial areas of the south and points out that the river valleys of the three branches of the Volta are practically deserted in spite of high potential soil fertility. Up to 700,000 Voltaics or 25% of the workforce work abroad, principally in Ghana and Ivory Coast. Since mainly young males migrate, high rates of dependency are left in regions such as the Central Plateau (for more historical information on Mossi migration see Skinner, 1965).

The focus of this SAFGRAD-FSU project is to increase crop yields in this small farmer, high population concentration principally on the central plateau before the farmers become migrants to the rural south, to urban areas, or leave the country.

After stating the operating hypotheses behind this Farming Systems Research project in the first section the next two sections describe the farming systems on the Central Plateau and present the most important results of the agronomist and farmer managed farm trials. A third section suggests some directions for future research and identifies some key issues in the interaction between agronomists and economists. Finally, a concluding section pulls these sections together.

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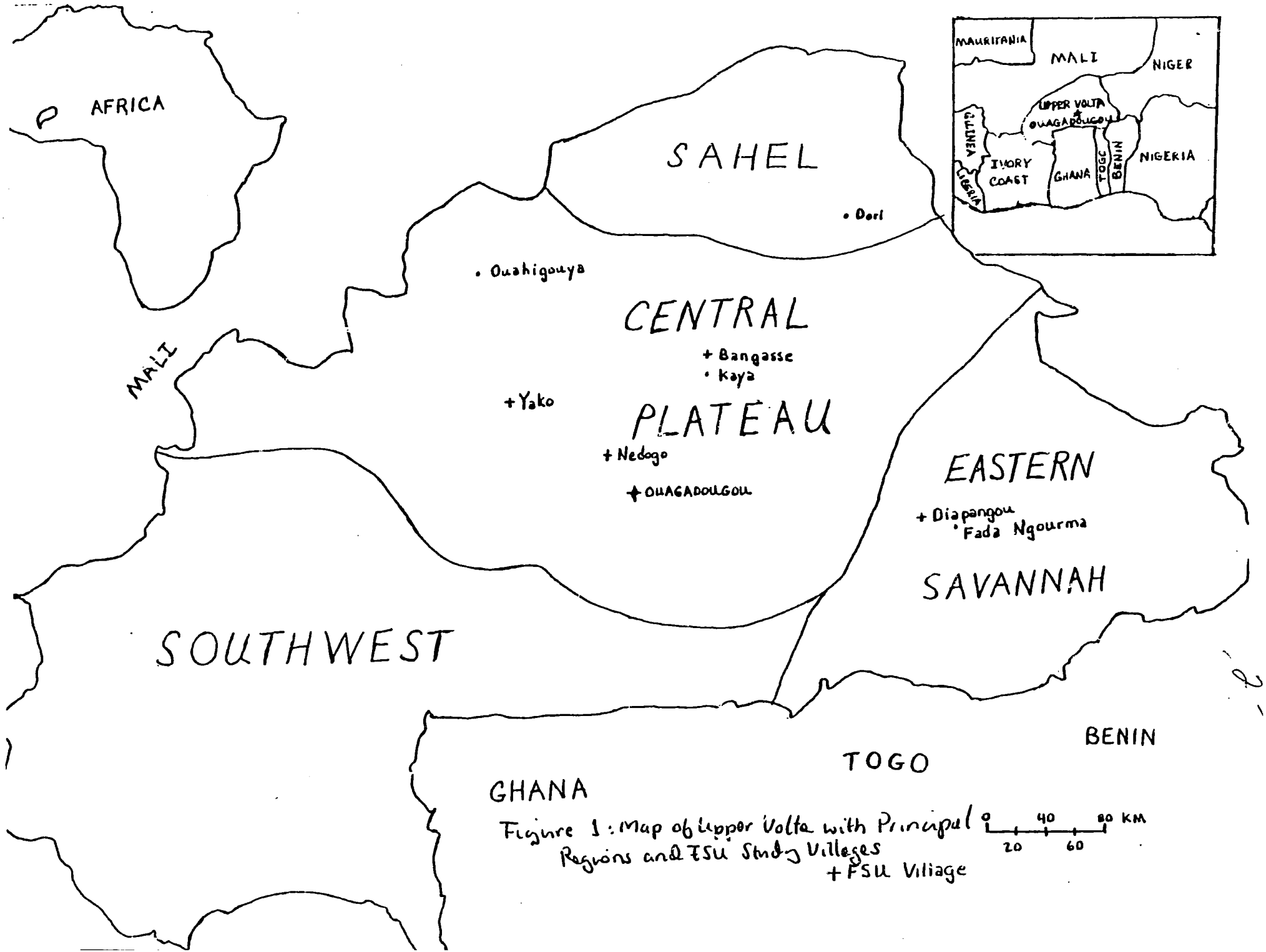


Figure 1: Map of Upper Volta with Principal Regions and FSU Study Villages
+ FSU Village

## UNDERLYING ASSUMPTIONS AND PHASES OF THE SAFGRAD FARMING SYSTEMS RESEARCH PROGRAM IN UPPER VOLTA

Farming Systems Research (FSR) is defined here as the institutionalization of the linkage between the experiment station and farmers. On the experiment station individual component pieces of new technology systems are identified and evaluated. These component parts are then combined to analyze how new production systems function in farmers' fields. These farm trials, the description of the farmers' production systems and objectives, and the economic analysis to evaluate the agronomic trials are the focus of this paper. The underlying assumptions are that:

a) the primary objective of agricultural development is to increase farm income thereby improving social welfare through the functioning of the marketing mechanism;

b) the principal source of new technology will be the experiment station;

c) new agricultural technology, which functions well on the experiment station or on regional trials, often performs poorly under farm conditions or encounters constraints not foreseen by researchers (Sanders and Lynam, 1982; Sanders and Johnson, 1982);

d) two-way communication linkages between farmers (especially small farmers) and the experiment station often function poorly in developing countries;

e) training programs for researchers and policymakers on FSR is less useful than the production of data and the analysis of the performance of new technology under farmers' conditions so that researchers on the experiment stations and policymakers in the capital can better understand the constraints faced by farmers in increasing agricultural production and respond to them with the application of scientific methods and the improvement of the economic environment faced by farmers.

In summary, the principal objective of the SAFGRAD-FSU program in Upper Volta has been to identify the output of experiment stations and regional trials ready for on-farm testing, to evaluate this new technology agronomically and economically, and to do other relevant research on the functioning of the farming system and the economic environment to facilitate the introduction of new agricultural technology.

The actual performance of the FSR research has been divided into three phases:

1) collection of socio-economic data from farmers on the constraints to the introduction of new technology;

2) agronomist managed farm trials;

3) farmer managed farm trials.

In the next section a simplified version of farming systems in the Central Plateau will be presented.

## FARMING SYSTEMS IN THE SAFGRAD-FSU PROJECT IN UPPER VOLTA

Considering the rainfall during the growing season (May-October) in 1982, indicates that Nedogo is in an intermediate rainfall position between Bangasse and Diapangou.

Table 1. Total Rainfall in the 1982 Crop Season (May-October)

| | |
|---|---|
| Bangasse | 494 mm. |
| Nedogo | 583 |
| Diapangou | 719 |

Source: R. Swanson, "Rainfall Variability, Labor Time Allocation, and Agricultural Production in Upper Volta," unpublished mimeo, August 1983, p. 11.

In all three regions cereals were the principal activity with over 90% of the area (Table 2). With the slightly higher rainfall in Diapangou the association of a legume in with the millet or sorghum was more important than in the other two sites. In all of these regions peanuts had 5 to 6% of the area principally as a cash crop. In spite of the variation in rainfall there was little difference in peanut areas in the different regions. Farmers stated that peanuts were necessary for their cash requirements to pay taxes, but that they took labor away from millet (SAFGRAD-FSU, 1983, p. 13). Since the expected economic value of peanuts was substantially higher than that for millet, this crop choice appears to indicate a preference for building up a grain stock and reducing the risk of crop failure with millet rather than maximizing cash income extending the peanut area. Peanut yield variability was shown to be significantly higher ($F > .99$) than that of millet (SAFGRAD-FSU, 1983, p. 21). Rice occupies the low-lying areas with a drainage problem. Average total area cultivated per household apparently depends upon the type of power utilized, ranging from 4.6 to 8.6 ha. (SAFGRAD-FSU, 1983, pp. 39. 40).

Figure 2 illustrates a simple model of farmers' land allocation to take into account the differences in resistance to drought stress of the three principal cereals. Corn is the most sensitive of the three to both drought and soil fertility stress with millet being the least sensitive. In this model farm the small area near the village, referred to as compound area, is utilized to dump nightsoil, animal manure, stubble, and other organic material. On this very small area (.1 to .2 ha.) with higher fertility and greater water retention capacity due to the organic fertilization corn is planted and reasonably high yields of 0.6 to 1.4 t/ha. are obtained. Regression results indicated that the area in corn was highly significantly related ($F > .99$) to the family size (SAFGRAD-FSU, 1983, p. 18). Sorghum is then planted on the more low-lying area where there is slightly more water accumulation and higher soil fertility with a concentration on sandy loams or silt loams (Stoop, et al., 1982, p. 519). Then

Table 2. Average Land Use by Cropping Activity in the Three Farm Sites

| Crops | Bangasse | Nedogo (%) | Diapangou |
|---|---|---|---|
| Sorghum | 26 | 28[a] | 7 |
| Millet | 55 | 64 | 16 |
| Millet or Sorghum Association with a Legume[b] | 8 | negligible | 65 |
| Corn | 1.7 | 2.4 | 3.2 |
| Rice | 1.5 | 0.3 | 1.2 |
| Total Cereal | 92.2 | 94.7 | 92.4 |
| Peanuts | 6 | 5 | 5 |
| Bambara Nuts | 1.2 | 0.7 | 0.6 |
| Soybeans | --- | --- | 1.6 |
| Cowpeas | --- | --- | 1.3 |

Note: The above does not necessarily sum to 100 due to rounding.

[a] 10% of this was red sorghum for beer

[b] 75 to 90% of the area was in millet with the remainder in sorghum combined with one of the grain legumes.

Source: Adapted from SAFGRAD-FSU, 1983, p. 16.

CENTRAL PLATEAU - High man-land pressure

Disappearance of fallow land

450-750 mm of rainfall concentrated in 2.5-4 months

CROP YIELDS (kg/ha)

| | | |
|---|---|---|
| MILLET | 300-600 | No fertilizer |
| SORGHUM | 400-800 | Cowpeas in association with one or more of cereals |
| CORN | 650-1400 | |
| COWPEAS | 200-400 | |

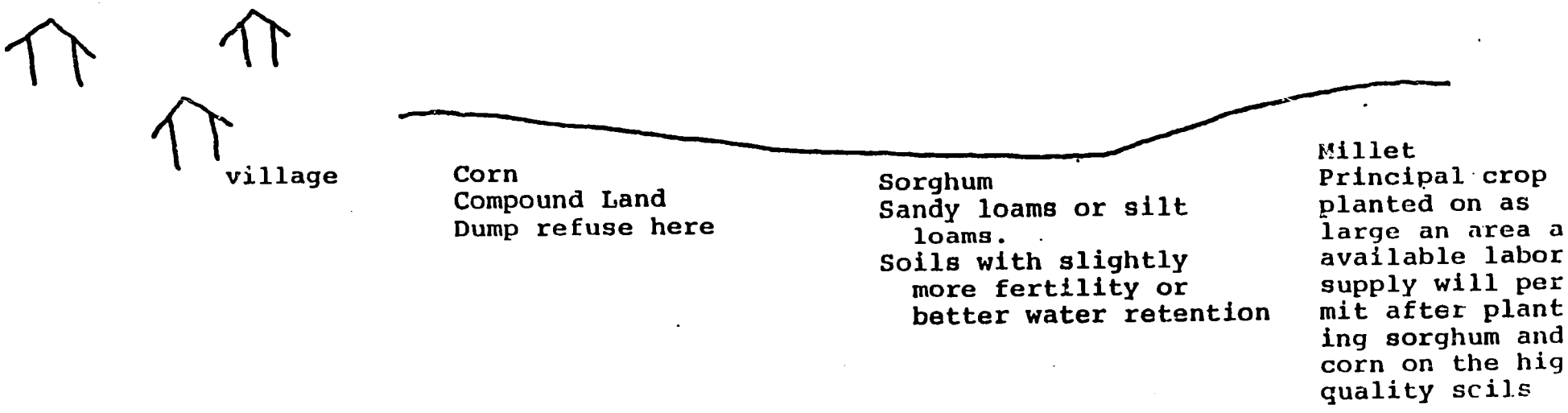


FIGURE 2: TYPOLOGY OF FARMING SYSTEM IN THE CENTRAL PLATEAU

on the rest of the poorer area millet is planted. (For further detail, see Matlon, 1980, pp. 16-18, 49.) The total area in millet was highly significantly related (F > .99) to the available workers in the household (SAFGRAD-FSU, 1983, p. 17). In summary, corn is very risky but the short season variety and the use of the compound area reduces this risk and it is a preferred food fresh. The mix of sorghum and millet then depends upon land quality and available labor.

Some marketed surplus of both is sold (1 to 13% of millet and white sorghum, 27% of the red sorghum in Nedogo, SAFGRAD-FSU, 1983, p. 10) but most of these basic food grains are stored between crop seasons for home consumption. Voltaic farmers also often buy grain in bad years with the revenue earned from livestock sales, trades, and crafts. The chief source of savings for these grain purchases, 60 to 80% over the period 1972-81, came from the livestock sales (SAFGRAD-FSU, 1983, p. 11). Thus, livestock is a "store of value" and an insurance policy for grain purchases in bad years. Unfortunately, in drought years the value of livestock declines substantially as many farmers try to sell at the same time.

Besides the differences in stress resistance the storage capacity of the two basic food grains, sorghum and millet, is different with sorghum being preferred because it can be stored twice as long as millet according to farmers (SAFGRAD-FSU, 1983, pp. 14, 19, 20). Thus, sorghum's greater susceptibility to drought and soil fertility stress than millet is partially offset by its storage advantages. In a climate, characterized by large rainfall variability therefore high risk, farmers utilize available land and organic material to reduce their risk and produce the three basic cereals, corn, sorghum, and millet, plus small areas in peanuts and cowpeas.

The area in corn is very small and appears to depend upon the quantity of organic material available to raise soil fertility. Farmers apparently utilize all their remaining household labor to produce the maximum quantities of millet after first planting corn on compound land and sorghum on the better "village land" or "sorghum land".

In Bangasse and Nedogo, the lower rainfall regions, farmers stressed the subsistence goals of acquiring sufficient grain for survival purposes as being their principal motivation. However, some farmers in Diapangou stated their principal objective as wealth, held in the form of cattle (SAFGRAD-FSU, 1983, pp. 9, 10). Farmers' objectives in West Africa are expected to vary with the extent of rainfall at the start of the season (Balcet and Candler, 1981) and they are expected to move away from a subsistence first orientation over time as incomes increase (Norman, 1982, pp. 641, 642).

In summary, the primary research problem in all three regions is to increase the production of sorghum, millet, and corn and then the grain legumes with new technology. Food and nutritional problems appear to be still sufficiently serious in rural and urban Upper Volta so that the primary purpose for obtaining increased cereal yields would be to improve human nutrition. Nevertheless, the price elasticity of demand for these cereals is clearly an important empirical problem and a Ph.D. dissertation on urban food consumption in the capital of Upper Volta is presently in

progress at Purdue. A substantial sustained increase over time of the cereals could ultimately enable some of them to be utilized as feed grains. The economics of their utilization as feed grains would need to be evaluated.

## CONSTRAINTS, INTERACTIONS, AND AGRONOMIC RESULTS

In identifying constraints an implicit production function of the following type is generally assumed:

$$Y = f(A, L, K_A, K_L)$$

Y: output
A: land
L: labor
$K_A$: capital substituting for land
$K_L$: capital substituting for labor

In questioning farmers in the Upper Voltean farm interviews seasonal labor requirements, at the first weeding and at planting, and in some sites high quality land (a soil fertility problem) were most frequently cited as the most pressing constraints (SAFGRAD-FSU, 1983, p. 21ff). Moreover, much of the literature on the development of new technology in sub-Saharan Africa emphasizes these seasonal labor constraints (for example see Helleiner, 1975, pp. 29, 30). However, a narrow definition of land and labor can result in overlooking two obvious points. In any semi-arid area by definition the most pressing constraint is water. If more water can be made available, the expected returns to several other factors of production will be substantially increased.

Irrigation of semi-arid areas tends to be capital intensive and often will not be technically and economically viable. Nevertheless, methods of improved water retention with better land preparation, such as tied ridges, have been studied at the experiment station in Africa since the sixties (Dagg and Macartney, 1968; Lawes, 1966). The advantages of tied ridges will depend upon the simultaneous application of other inputs. First, there will be increased labor requirements to construct the tied ridges. There are alternative times at which the tied ridges can be implemented. Some of these times are at seasonal labor peak demand periods so the substitution of human power with donkey or oxen power may be necessary (see Jaeger, 1983).

Moreover, in the Central Plateau (sites of Bangasse and Nedogo) with its high man-land pressure and declining cereal yields, soil fertility is expected to become constraining as soon as water is provided. Improved water retention will increase the probability of an economic return to fertilization thus the water availability decreases the risk incurred when the farmer purchases inorganic fertilizer. The actual profitability of different levels of fertilizer will depend upon other stochastic factors outside the farmers' control, including rainfall and insect and disease attack, as well as the factors within his control or potentially known to him before application, such as his initial soil fertility and his management practices. Moreover, the economic environment, involving the price of output

and the costs of fertilizer will also be important in determining profitability and adoption of new technology in sorghum production. However, the simple technical or agronomic point is that in many years, the simultaneous application of both inputs, improved water retention and inorganic fertilizer, is expected to be necessary to substantially increase farmers' yields.

In Table 3 the mean results across four sites of tied ridges in two different periods and two fertilization levels for sorghum on "sorghum land" are summarized. These are agronomist managed trials utilizing the local sorghum. The two inorganic fertilization levels are zero, as practiced by the farmer, and 100 kg/ha of the locally available "cotton fertilizer" (14-25-15 of NPK) plus 50 kg of Urea. This latter fertilization level of approximately 36 units of nitrogen and 25 units of phosphorous is still very low given the deficiency of these nutrients in most soils of the Central Plateau. By international standards the absolute yield level of the sorghum is still low at 1.1 t/ha even with the tied ridges and the low fertilizer level. The positive side, though, is that the combination of tied ridges and a low level of inorganic fertilization outyielded farmers' practices (utilizing the check to represent farmers' practices) by 2.5 to 2.9 times depending upon the period in which the tied ridges were implemented. One surprising result was that the yield effect of the tied ridges after planting was greater than that before planting. Since drought stress during germination often results in poor germination or low seedling vigor, this was a surprising result. There may be an effect of improved cultivation from the late tied ridges or a deterioration of the pre-planting tied ridges.

The effects of tied ridges and of fertility were both highly significant ($F > .99$). The interaction effects were also highly significant. The maximum yield increase of 745 kg/ha is impressive enough to be noticed by the extension service and the farmer. Moreover, the partial budgeting analysis showed that the combination of these two practices would be highly profitable for the farmer (SAFGRAD-FSU, 1983, p. 62). Before considering other components of new sorghum technology, a comparison with the corn results is useful.

On the small areas of compound land corn with farmers' practices gave very respectable yields at 2.2 t/ha. (Table 4). Corn varietal trials also indicated reasonably high absolute yields at 1.9 to almost 2.6 t/ha. in Bangasse and Diapangou on compound lands. Yields at Nedogo were much lower at 550 to 1100 kg/ha. The difference was apparently due to greater drought stress in Nedogo as there was no response there to the higher level of fertilization (SAFGRAD-FSU, 1983, pp. 68, 69). The effect of tied ridges was highly significant (99% level) and the absolute yield increase of 529 to 691 kg/ha. (Table 4) compared favorably with the yield effect of the combined tied ridges and fertilization with sorghum on "sorghum land". Implementing the tied ridges on the very small compound areas would not require much more labor even in the seasonal peak times so this is a highly profitable activity. This problem of putting an economic value on family labor at the peak seasonal times for the village will be returned to. Meanwhile, since corn yields in the compound were so high and sorghum yields on "sorghum land" were so low, the obvious question is how does corn do on "sorghum land" with tied ridges and fertilization?

Table 3. Mean Yield Effect of Tied Ridges at Two Different Times and Two Different Fertilization Levels on Sorghum[a] in the Agronomist Managed Farm Trials in Four[b] Sites of Upper Volta in 1982 (kg/ha).

| | Water Conservation | | |
|---|---|---|---|
| Fertilization | No Tied Ridges | Tied Ridges Before Planting | Tied Ridges 30 Days After Planting |
| Without Inorganic Fertilizer | 385[c] | 580 | 561 |
| With Inorganic Fertilizer[d] | 759 | 949 | 1130 |

[a] The sorghum was planted on the land the farmers defined as "sorghum land". See the discussion of the previous section and the figure.

[b] Besides the three usual sites of Bangasse, Nedogo, and Diapangou. A fourth site in the lower rainfall zone in Yako was also included. See the map in Figure 1.

[c] This treatment should be considered as a proxy for farmers' practices in the three sites.

[d] 100 kg/ha of (14-25-15 NPK) plus 50 kg/ha of Urea.

Note: The l.s.d. at the 95 percent probability level was 79 kg/ha.

Source: Adapted from SAFGRAD-FSU, 1983, p. 63.

Table 4. Mean Yield Effect of Tied Ridges at Two Different Times on Corn in Compound Land in the Agronomist Managed Trials in Three Sites of Upper Volta in 1982 (kg/ha).

| Water Conservation | | |
|---|---|---|
| No Tied Ridges | Tied Ridges Before Planting | Tied Ridges 30 Days After Planting |
| 2220[a] | 2911 | 2749 |

[a] This treatment was considered to be a proxy for farmers' practices.

Note: The l.s.d. was 262 kg/ha.

Source: Adapted from SAFGRAD-FSU, 1983, p. 59.

Here the plot thickens so the mean yields in the three different sites are considered first. Diapongou receives more rainfall than Nedogo and corn is much more susceptible to drought stress during critical periods than either sorghum or millet. Table 5 indicates very poor mean corn yields in Nedogo of 625 kg/ha. Besides having higher rainfall and therefore being less risky for corn production farmers in Diapongou say that there is more "new land" available. In Diapongou a shifting cultivation system of moving to new land areas is regularly practiced. Due to the higher rainfall and greater soil fertility Diapongou appears to have substantial potential to increase the production of corn on"sorghum land". Mean corn yields at Diapongou were very high compared with mean sorghum yields on "sorghum land", 1.9 to 3.1 t/ha. for corn at the two sites. The latter site was owned by a Fulani with a large cattle herd which grazed on this corn site so this site should really be considered equivalent to a compound area. Even on the lower fertility Diapangou site the local corn variety apparently has more yield potential than the local sorghum varieties. Since corn tends to be more susceptible to both drought and fertility stress than sorghum, further delineation of the rainfall and soil fertility requirements for regions in which corn can successfully substitute for sorghum is necessary.

In Table 6 the mean corn yields across sites "on sorghum land" with tied ridges and fertilization are summarized. Comparing the two checks on "sorghum land" the mean corn yields of 1.5 t/ha. were much higher than the 385 kg./ha. of sorghum. The short season corn varieties are undoubtedly more recent introductions than the traditional sorghum varieties and better able to respond in a reasonably good year in regions where water stress is not as serious. In the other two sites with lower rainfall the substitution of corn on "sorghum land" is expected to be riskier. However, the low absolute yields of sorghum, even with improved water retention and fertilization at 1.1 t/ha., indicate the importance of looking for new varieties of sorghum or corn selected to respond to the conditions in different rainfall regimes on "sorghum land".

Across the three sites (two in Diapangou and one in Nedogo) the tied ridges with corn production on "sorghum land" did not have a significant effect on yields. In Diapangou there was apparently sufficient rainfall for the corn without the water retention technology and in Nedogo the drought stress was too intense in two different periods for the tied ridges to help. The effect of the fertilization of the corn was highly significant especially in the Diapangou site with more typical "sorghum land", where the low level fertilization treatment increased yields by 600 kg./ha. and was highly profitable. This result should be contrasted with the lack of effect of fertilization on the compound land in the varietal evaluation in the same site and in the other Diapangou site with high initial soil fertility (SAFGRAD-FSU, 1983, pp. 61, 69). Fertility response obviously depends upon initial soil fertility as well as water availability at the critical periods of plant development.

In summary, tied ridges and fertilization had a substantial effect on sorghum yields. Even with both new technologies absolute sorghum yields were still poor at 1.1 t/ha. These low absolute yields indicate the importance of identifying a variety of sorghum which can perform better in an improved environment. There is no reason to expect local varieties, which

Table 5. Mean Corn Yields on "Sorghum Land" Across Treatments in the Three Different On-Farm Experiments.

| | Corn Yields (kg/ha.) |
|---|---|
| Nedogo | 625 |
| Diapangou I | 1891 |
| Diapangou II | 3143 |

Source: SAFGRAD-FSU, 1983, p. 61.

Table 6. Mean Yield Effects of Tied Ridges at Two Different Times and Two Different Fertilization Levels on Corn in "Sorghum Land" in the Agronomist Managed Farm Trials in Two Sites of Upper Volta in 1982 (kg/ha).

| | Water Conservation | | |
|---|---|---|---|
| Fertilization | No Tied Ridges | Tied Ridges Before Planting | Tied Ridges 30 Days After Planting |
| Without Inorganic Fertilization | 1506[a] | 1609 | 1915 |
| With Inorganic Fertilization[b] | 2091 | 2087 | 2110 |

[a] This treatment should be considered as a proxy for farmers' practices.
[b] 100 kg./ha/ of the "cotton fertilizer" (14-25-15 NPK) and 50 kg./ha. of Urea.

Source: SAFGRAD-FSU, 1983, p. 61.

are generally selected for yield stability under adverse conditions, to be able to perform well in an environment with more available moisture and increased soil fertility. Breeding then provides the key to the next big increase in yields. In Table 7 the four interrelated components of increasing sorghum yields are summarized. The interactions of water retention and increased fertilization were shown to be highly significant and profitable innovations. The combination of these various input changes is the critical part of farming systems research. First, water, then soil fertility, and then a new variety to take advantage of the new environment all appear to be required for a substantial yield increase. The animal traction probably will also be necessary to overcome a seasonal labor bottleneck in the preparation of the tied ridges.

Introducing new technology in corn production may be simpler because the locally available variety already demonstrates substantial yield potential when the corn is not put under drought stress. In 1982 moving the corn into the "sorghum land" was successful and profitable in Diapongou. The potential riskiness of this crop shift implies the need for caution in analyzing results for one crop season. Moreover, some consideration of marketing problems would also be necessary since corn was only produced in small areas for fresh consumption by the farmers.

Besides the above cereals research, agronomist managed farm trials were also concerned with:

a) evaluation of an improved grain legume technology;

b) the technical and economic impact of a low cost, locally available source of rock phosphate.

Good stands of several grain legumes were obtained and the main constraint, thrips, was controlled with three sprayings. However, absolute, monoculture yields were still very low at 375 to 700 kg./ha. At these yield levels the grain legumes can not pay for the chemical inputs (SAFGRAD-FSU, 1983, p. 57). The local rock phosphate was utilized for fertilization on the grain legumes and in other trials on sorghum and millet. In these sorghum and millet farm trials with the Voltaic rock phosphate there was no yield effect from different levels of fertilization apparently due to the slow release of the phosphorous from the Voltean rock. Utilization of the Voltaic rock in the farm trials may first require the identification of new chemical treatments at the experiment station to make it more soluble. This is a surprising result because earlier FSU experiments at the farm and IRAT experiment station results had indicated an economic return to rock phosphate in sorghum production (Christensen, 1981).

Increasing grain legume yields in the Central Plateau may need to be given a high priority to improve human and animal nutrition or in the case of peanuts increase cash sales. Moreover, a cereal rotation or intercropping with a grain legume could help with the soil fertility problem. Grain legume yields of 1.5 t/ha. have been obtained regularly with low cost agronomic practices in other regions (Sanders and Johnson, 1982). The low absolute yields of grain legumes in these Upper Volta results indicates substantial potential to improve yields. Besides phosphorous, improved water retention, and improved Rhizobium fixation may also be necessary.

Table 7. Principal Constraints to Increasing Sorghum Production in the Upper Voltean Research Sites.

1. Water at critical stages of plant development.

2. When water is available, soil fertility becomes limiting.

3. When both water availability and soil fertility are improved, will need a new variety to take advantage of the improved environment.

4. Seasonal labor availability for one or more critical operations such as weeding or land preparation can become a critical barrier to expanding the area cultivated. Animal traction with the appropriate implements may then be necessary to overcome this seasonal labor bottleneck.

Sources: The ideas for this ranking of constraints and the stressing of their complementarity were taken from conversations with John Dillon in the Northeast of Brazil and Ron Cantrell in the SAFGRAD-FSU Project in Upper Volta. Also see H. Ruthenberg, Farming Systems in the Tropics, Third Edition, Clarendon Press, 1980.

Storage insect problems can be devastating with cowpeas in Upper Volta even with the farmers' traditional storage practices. However, low cost treatments with vegetable oil have been shown to be effective with field beans in Colombia (Schoonhoven and Cardona, 1979, p. 396). A combined series of technical innovations in grain legume production and storage will become an important research area once cereal yields are increased. This type of diversification with multiple cropping or rotation could improve soil fertility and help provide a feed base for oxen as an improved power source. Besides cowpeas and peanuts the introduction of a more drought resistant grain legume, such as pigeon peas, may also be of interest.

The farmer managed farm trials confirmed the technical viability and profitability of tied ridges and fertilization in sorghum production while also indicating the need for a more soluble source of phosphorous than the Voltaic rock.

In summary, the socio-economic analysis helped identify farmers' objectives and rationale for cropping decisions on different types of land. The agronomic trials indicated that by overcoming one or more constraints substantial yield gains could be achieved in sorghum and corn. Further gains in sorghum yields would be expected from introducing a new variety into the improved environment with more water and higher soil fertility. The agronomist managed farm trials also indicated a series of problems for future research to be considered in the next section.

## FUTURE RESEARCH DIRECTIONS IN THE SAFGRAD-FSU PROJECT

Clearly, the most important results for research orientation are coming from the agronomist managed farm trials. Traditionally, farmer managed farm trials have had such high coefficients of variation that neither researchers at the experiment station nor agricultural policy makers in the capital have taken them seriously. One innovation of the SAFGRAD-FSU Project on the farmer managed trials to handle the large within plot variation in soil fertility was to substantially increase the plot size.

The primary source of new agricultural technology is the experiment station and the principal function of the researcher managed farm trials is to put the component pieces coming from the experiment station together and analyze their effect under farmers' conditions. Similarly, the socioeconomic analysis is a necessary complement to resolve the problems identified in the agronomist managed trials.

The next stage of this socioeconomic analysis is a detailed economic analysis of the more promising agronomic results. After identifying the technical viability of a technology on the farm, simple profitability calculations have been made (Figure 3). For this crop season profitable practices in Upper Volta were:

1) tied ridges and fertilization of sorghum on "sorghum land";

2) tied ridges with corn on compound land;

3) fertilization of corn on "sorghum land" in slightly higher rainfall regions.

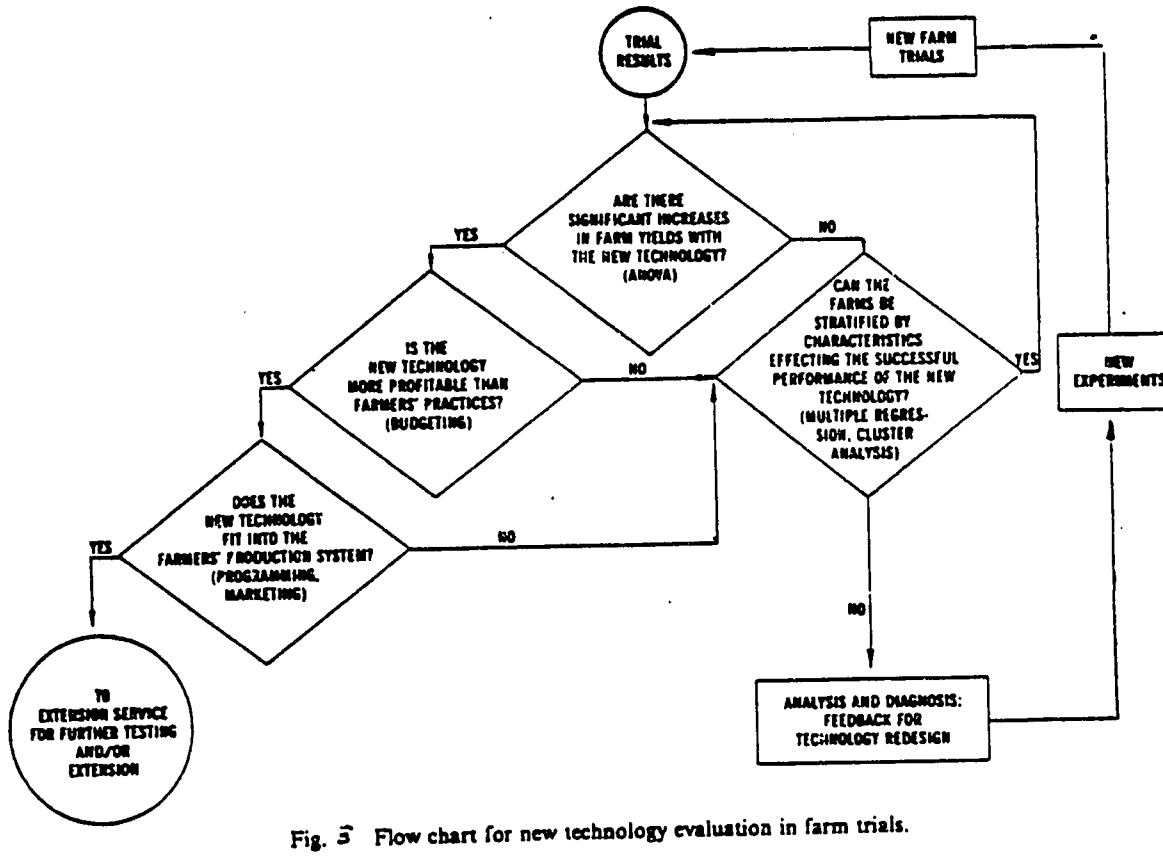


Fig. 3 Flow chart for new technology evaluation in farm trials.

Source: Sanders and Hynam, 1982, p.100

Simple budgeting is not sufficient to evaluate the fit of new technology into farmers' systems of production. The next stage of analysis is linear programming to identify with the shadow prices the marginal value product of labor during the various times at which the tied ridges could be done for both sorghum and corn on compound land. The economic viability of alternative power sources for this operation can also be undertaken. The substitution of corn for sorghum on "sorghum land" is another important issue which needs to be addressed with LP analysis.

Since rainfall is so variable and is one principal determinant of yields, LP profit maximizing analysis needs to be extended to incorporate this yield variation. The simplest method is to utilize the MOTAD variation of LP. Field work is presently being undertaken in a Ph.D. thesis in Upper Volta with this technique. Further, work is planned especially to evaluate the profitability-risk trade-off of a series of fertilization strategies on sorghum and corn on different land types. To earn more money farmers must take more risks. The quantity of risk farmers will take is expected to increase over time as farmers see the new technology under similar conditions to their fields and as they increase their incomes (Goodwin, et al., 1980, p. 739). Researchers should not make subjective decisions about how much risk farmers are willing to take. Rather they need to evaluate a series of new technologies and quantify the potential profitability and riskiness of each alternative.

Estimating risk from cross-sectional observations of variance has been shown to be a poor proxy for the more appropriate time series variance (Evenson, 1978, p. 14). The variance in yields relevant to the farmer comes from rainfall, insect, and disease attack and should not include static from the variation in soils and management practices picked up in cross sectional estimates. In short, substantially more effort needs to be put into quantifying the riskiness of new technology alternatives. Then the ultimate decision on the appropriate level of expected income and risk is taken by the decision maker, the farmer.

All agricultural systems are in transition. On the Central Plateau the situation is deteriorating with declining cereal yields. However, the amount of risk farmers take now or say they are willing to take has little relevance to the amounts they may take when new cereal technologies are demonstrated in climatic conditions similar to their own. Moreover, availability of a new technology, technically viable, potentially profitable, and with a good fit into the farmers' production system (see Figure 3), gives a new series of options to Voltaic governmental policymakers to implement price policies, risk insurance, or other changes in the economic environment to facilitate new technology introduction.

The agronomic research on sorghum and corn has advanced sufficiently so that slightly more sophisticated modeling efforts can be utilized, i.e., LP with MOTAD. These are simple research innovations with immediate policy applications and they are presently being put on the microcomputers in the Ministry of Agriculture of Upper Volta with Purdue assistance. Research in millet and the grain legumes still has not progressed sufficiently to justify these more sophisticated modeling approaches.

A more basic and general problem in farming systems research needs to be briefly discussed. Agronomists are trained to be extremely careful in data generation, to wait a number of years to verify results, and to do a series of statistical techniques, variations of analysis of variance, whose principal objective is to control the quality of the data. Policymakers need new technology suggestions in short time periods and farmers are more interested in the profitability and fit into their operations of one or two new systems of production rather than identifying the level of significance of the treatments and their interactions. Economists with simple modeling and sometimes synthetic estimates of variance and other data can help fill the gap between the public policymakers' and the farmers' demands for new technology information and the output from agronomic researchers. Some knowledge of agronomy and some simple modeling are the necessary components of the economist's contribution. Effective interdisciplinary collaboration means that the agronomists and the economists have to continually interact not only in the analysis of the data but also on experimental design and even number of repetitions. For effective interaction a thorough understanding of each discipline is necessary, including the predominant statistical techniques utilized. Another component of this interaction is the desire to respond rapidly to real world problems of technology evaluation and generation even if the data utilized are preliminary and synthetic. Preliminary results can always be refined and improved with further experiments and/or data collection and analysis.

One further comment on agronomist managed trials is that a large number of repetitions on different farmers' fields have been shown to be essential to evaluate new technology. Fertilizer response will vary with initial soil fertility. The performance of a striga resistant variety will depend upon the existence of a striga attack. Hence, a stratification of the farm trials will frequently be necessary to identify the factors associated with successful and unsuccessful performance of the new technology on various farms. At CIAT and IRRI researchers involved in farm testing have reached a similar rule of thumb that a sample of approximately 15 farms per agro-climatic region is necessary (Sanders and Lynam, 1982; Gomez, et al., 1979). This recommendation often runs into opposition from agronomists wanting a large number of repetitions on each site; however, within farm yield variance has been shown to be much less than between farm variance in Colombian farm trials. Moreover, the objective of the farm trials is not to minimize the non-treatment variance as on the experiment station but rather to evaluate in a systematic way those sources of variance between farms influencing the performance of the new technology.

## CONCLUSIONS

The farm trials indicate that it is possible to increase yields and small farmers' incomes with the introduction of new technology in the production of sorghum and corn. Due to low and irregular rainfall and poor soil fertility in much of the central plateau, this is a substantial accomplishment. The areas in the south especially the southwest have greater agricultural potential due to more rainfall and higher soil fertility. However, even in this resource poor region of the central plateau, the combined effect of improved water retention and increased soil fertility almost tripled sorghum yields. So the application of scientific

results from the experiment station is a powerful tool in the farm trials, when successful component parts are combined.

Increasing the yields in the farm trials of millet, cowpeas, and peanuts still remains to be done. Moreover, the introduction of new sorghum varieties into the improved agronomic environment with tied ridges and fertilization is expected to have a high payoff. The next stage of economic analysis will be LP modeling of the whole farm operation including a simplified treatment of risk with MOTAD. Estimating the expected profitability and income variance of different fertilization levels for different land types is a priority research area since soil fertility constraints to yield increase will become increasingly important as water retention is improved.

Finally, any agricultural development program for the Central Plateau needs to be concerned with the potential long-run degradation of the soils. Eliminating the brush, reducing or eliminating the fallow period, and opening up of the sandy loam or silty loam soils has often led to decreased organic material and crusting hence further depletion of soil fertility and reduced water retention. More soils research on the technical potential and the economics of substituting inorganic for organic fertilizer is urgently needed for these types of regions. Moreover, farming systems research needs to fit into the overall agricultural development of the country. More emphasis may need to be put in Upper Volta on the development of the southwest and the southeast. The higher corn yields in the Diapangou site are indicative of the difference between the Central Plateau and the eastern savanna. The marginal rainfall area of the Sahel above the Central Plateau is the most difficult agricultural region. By concentrating efforts on the Central Plateau this project chose the most difficult of the three other regions to increase agricultural productivity and substantial gains were made. With more applied research further gains in the Central Plateau and the other two regions (Figure 1) are undoubtedly feasible.

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