BURKINA FASO

MESRS/CNRST/INERA

INSTITUT D'ETUDES ET DE
RECHERCHE AGRICOLE

ORGANIZATION OF AFRICAN UNITY

OAU/STRC/SAFGRAD

SEMI-ARID FOOD GRAIN RESEARCH AND
DEVELOPMENT

FARMING SYSTEMS RESEARCH PROGRAMM

PROGRAMME DE RECHERCHE SUR LES SYSTEMES DE PRODUCTION

AGRONOMIC ASPECTS OF ON-FARM TESTING EXPERIENCE IN BURKINA FASO*

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Septembre 1987

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* Paper presented at the SAFGRAD On-Farm Research Workshop, Maroua, Cameroun, 22 - 24 Septembre 1987.

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CONTENT

ON-FARM TESTING EXPERIENCE IN BURKINA FASO

1. INTRODUCTION

The paper briefly presents highlights of results of on-farm testing, within farming systems research framework of work done in Burkina Faso. The emphasis is on agronomic research experience. Work on other disciplines such as socio-economics does not make part of the paper. Within the agronomic work only results that were readily accessible are presented.

Although the importance of agricultural research, development and extension policy on technology generation and adoption is recognized, these do not fall within the discussion of the paper. With these limitations the paper concludes by suggesting changes needed to increase efficiency of on-farm testing for generation and adoption of technologies. Finally a brief synthesis of the orientation of the recent National Farming Systems Research Program of INERA is given.

2. GENERAL BACKGROUND

Burkina Faso is located between 9°20' and 15°5' latitude north and between 2°20' longitude east and 5°30' longitude west. The topography is flat with average elevation of 400 mm and the highest elevation of 600 m above sea level. It is estimated that more than half of Burkina Faso lies within climatic zones favorable to agriculture. Of the total area rainfed cultivation makes up 32.2 % (88,290 km^2), pasture land 47.3 %, timber and forest 12.7 % and the rest miscellaneous land. Irrigated area currently makes up a very small fraction of the cultivated land. Of the nine million hectares of arable land only one - third is currently being cultivated. However, there is little likelihood that the cultivated land in certain regions can be increased due to poor soils, or lack of adequate water. Fertile soils make up for a small part of the country (Bonkoungou, E.G. 1984).

The population density in the Central Plateau is high. In some localities it is nearly double the estimated maximum land carrying capacity of 40 inhabitants per square kilometer (upto 107 inhabitants/ km^2 on the Mossi Plateau). The total population is estimated at about 8 million (1985) with an annual growth rate of 2.7 %. An estimated 25 % of the working force, mainly young, single men work in the neighboring countries. This results in an annual net population growth rate of 1.7 %.

2.1. Climate.

Burkina Faso lies within the semi-arid climatic zone. The rainy season lasts for 3 ½ months in the North to 6 months in the Southern part of the country. The corresponding number of rainy days range from 30-60 (average annual rainfall of 400-500 mm) to 60-90 (upto 1000 mm). There are three distinct seasons: warm and dry during November to March, hot and dry during March to May and hot and wet from June to October. The start of the rainy season extends over two months, from April in the south to June in the north. In contrast rainfall stops rather abruptly by the end of September.

Potential evapotranspiration is high throughout the country with mean annual values of 1900 mm compared to 700 mm of rainfall for the Central Plateau. Temperatures are specially high just before and right after the rainy season, with day time values of 40°C range. The hot dry winds from the Sahara (Harmattan) further agrevate the drought condition.

Since the mid-sixties, annual rainfall has averaged 100 to 150 mm below the long-term values within each of the isohyets. Rainfall distribution is highly variable with location, between years and within season. Thus, long term mean values of rainfall are of limited value in understanding the status of crop moisture supply.

2.2. Soils.

General reconnaissance study (Boulet, 1976) and some investigations (El-Swaify et al, 1984) indicate that sandy gravel soils of low fertility prevail in the area. The major soil groups of the Sudan Savannah are classified in the USDA system as Alfisols, and in the French classification system, as Ferruginous tropical and Ferrallitic soils. There is variation of soil types with position on the toposequence. On the lowlands Vertisols and Hydromorphic soils are foound.

2.3. Role of Agriculture in the National Economy.

Agriculture is the largest sector of the economy and contributes 41 % of the GDP. Over 90 % of the population is engaged in farming and livestock production. The staple crops are millet, sorghum and maize. Cash crops include cotton, shea nuts (Karité), peanuts and rice. Mixed cropping is the norm in the area.

The share of livestock in agriculture amounts to 49.2 % of the total export of the country. With varying degrees of emphasis, mixed farming is practiced in virtually all the farming systems of the country. Due to drought in the past decade the area of livestock concentration has shifted to the central and southern parts of the country. There is strong interdependence between the predominantly herder community and the agriculturalists throughout the country.

2.4. Regions.

Based on population density, rainfall, vegetation and access Burkina Faso can be divided into four regions: South-West, Central (Mossi) Plateau, Eastern Savannah and the Sahel (FSU/SAFGRAD, 1986 - Fig. 1).

South-West has a Sudano-Guinean climate characterized by adequate rainfall above 900 mm spread over five months, adequate water resources, relatively fertile soils and a moderate population density. Access to markets is good. Cotton, sorghum, millet and maize are grown with average yields higher than in the other regions. It has the most potential for agricultural intensification.

Central Plateau in the Sudanian zone, with rainfall between 600-900 mm over a four months period, has predominantly poor and eroded soils, a high population density and few permanent water courses. This region has a road network linking to the capital, Ouagadougou, which is the major consumption center. The staple crops are sorghum, millet and maize. Potential does exist for agricultural intensification but not as good as the South-Western region.

Eastern Savannah is in the east of the Central Plateau and in the South-eastern part of the country. It has similar rainfall and soils to the South-West but is sparsely populated and has few roads and water courses.

Sahel is in the North-East of the country and receives less than 500 mm of rain annually. Population is sparce and access difficult. Livestock raising is a major occupation. The staple crop is millet.

2.5. Challenge to Agricultural Intensification.

The unpredictable rainfall pattern in the area has always made agricultural production risky. Traditional agricultural pratice worked well in the area when land was abundant. Higher population pressure and increasing integration in the market economy have lead to more parcellization of land and reduced fallow period. As a result there is serious problem of natural resources degradation. This results in migration to the South, where land is relatively more abundant. However unless the agriculture system is stabilized by increasing production per unit area and conserving natural resources the problem faced in the Mossi Plateau would occur in the new settlement areas as well.

There is concern of desertification in the northern part of the country. Droughts in recent years caused enormous hardships and brought to the forefront the challenges of supporting higher population pressure in such fragile ecosystem. The evolution of the agricultural system in the area is discussed by Marchal (1983) and Kohler (1971), among others.

The farmers' primary objective under these conditions is to assure food security for their families, and next to acquire capital mainly in the form of livestock and small ruminants. The national goals for agriculture as stated in the 1986-1990 five year plan are:

- assure food self sufficiency
- improve income and standard of living of farmers
- conserve and restore nature resources of the country

3. RECENT WORK ON FARMING SYSTEM RESEARCH AND ON-FARM TESTING

Major research efforts in farming systems have been carried out in the area since 1970's. The region with the most concentration of activities has been the Central (Mossi) Plateau. Detailed farming systems research work in the other regions have yet to be conducted, although work on regional scale exists. Hence the paper deals mainly with results from the Central Plateau.

For the Mossi Plateau there has been studies on on-farm trials by:

- FSU/SAFGRAD Program 1979-1986
- ICRISAT FSR Program 1980-1986
- IRAT Research and Development Program, since 1981.

The programs identified the principal constraints to increased food production, evaluated new production technologies under farmers' conditions, and developed methodologies for on-farm testing. Additionaly the FSU program trained national staff. IRAT started FSR program in the northern part of the Mossi Plateau in 1981, in collaboration with the Rural Development Organization.

In 1985 a National FSR program was started as one of the departements of INERA (Institut National d'Etudes et de Recherche Agricole). It has two teams: one based in Kamboinsé research station to cover the Mossi Plateau and the second in Farako-Bâ to cover the western part of the country. It is planned to extend the program to the other two regions in phases. The IRAT FSR has been integrated into the national program.

The NFSR is viewed as a "horizontal" department which links all the other eight departments of INERA to one another, to extension agencies and to farmers so as to increase their efficiency in solving agricultural development problems. Besides the foregoing, many other institutions conduct on-farm trials in Burkina Faso such as:

- The Research and Development Units of the Rural Development Organizations.
- The Accelerated Crop Production Unit.
- and Multilocational trials by disciplinary researchers.

3.1. Constraints to Increased Agricultural Production.

The constraints to increased agricultural production in the area have been identified for the Central Plateau (Lang et.al. 1983, INERA/SAFGRAD NFSR Reconnaissance Survey 1986) and for the West African Semi-Arid Tropics (WASAT) in general (Matlon 1983). The main physical constraints for agricultural production are:

a) For crop production:

- Inadequate moisture
- Low soil fertility and land quality deterioration
- Labor bottlenecks during periods of peak demand
- Low productivity of agricultural implements
- Crop pests and diseases
- Striga weed attack

b) For animal production:

- Inadequate feed resource and water supply, particularly during the dry season.
- Livestock diseases.

c) For agro-forestry:

- Shortage of water for seedling establishment
- Termite attack of seedlings
- Shortage of seedlings
- Damage by stray animals

Inadequate moisture and land quality deterioration:

Rainfall is highly variable even within a season and between adjacent locations. High temperatures during the planting and grain formation stage result in severe moisture stress periods. The few heavy showers that occur in the season create serious soil erosion and runoff losses. In the Center and Northern part of the country up to 10 % of the annual rainfall can be expected to occur in one day and up to 50 % in eight rainy days (BUNASOL 1985). Soil depth is shallow in most of the area. Further, the poor physical property of the soil (surface crusting, compaction, low water holding capacity) contributes to the inadequacy of moisture supply to crops. Even on gentle slopes (2 %) soil loss of 10 t/ha/yr was measured under crop, and up to 40 t/ha/yr on bare soil (Roose 1981) in the Central Plateau at SARIA. Runoff losses of water can amount to 50 % of the rainfall. Once the soil erosion process is at advanced stage reversal to productive state is impractical. Some soil exhaustive cultural practices accentuate the degradation. Some of these are:

- Near total removal of crop residues from the fields.

- Over exploitation of the forest, depriving the soil of perennial vegetative cover.

- Inadequate soil conservation measures.

Low soil fertility:

Some investigations (Prudencio, 1983, INERA/SAFGRAD Annual Report 1985, among others) indicate that coarse soils of low fertility prevail in the area. The major characteristics are:

- Low organic matter content (less than 1 %)
- Low ion retention and low buffering capacity (C.E.C. less than 4 meq/100 gm).
- Low nutrient supplying capacity, especially nitrogen and phospharus.

The general soil characteristics are modified by micro-variations linked to toposequence position which determine a particular field's capacity to support a crop or a cultivar (Matlon, 1983). Under these conditions of soil variability and unreliable rainfall the farmers have adopted cultural systems that minimize risk with little purchased inputs. The cropping pattern follows the toposequence, with millet on the dry upland part, maize on humid gentle slopes, sorghum on the mid-slope and rice on the flooded lowlands (Van Staveren and Stoop, 1986) (Fig. 2).

Implication of the soil variability on technology development by researchers and adaption of packages by farmers have been discussed by Prudencio (1986). Even an advanced type agriculture would require a range of technological options in terms of improved varieties and cultural practices to meet the large diversity in land types and rainfall conditions of the area (Van Staveren and Stoop, 1986).

The cropping systems on the Mossi Plateau vary with distance from the household compound. Near the compound soil fertility is improved by addition of large amounts of farmyard manure. Farther down moderate amounts of both organic and mineral fertilizers are added and some cereal legume intercropping or rotation is practiced. On the farthest fields, soil fertility is maintained mostly with fallows and cereal-legume intercropping or rotation. As a result, soil fertility is generally higher near the compound fields and around the village. Grain yields are doubled or tripled when moving from the farthest fields to those near the compound (Prudencio, 1983). In general more than 60 % of the cultivated farm area is subjected to low management levels and is consequently characterized by low soil fertility and low yields.

Among the common soil and water conservation techniques used traditionally are: construction of bunds (stone, or earth), mulching, and planting of grass strips. Most of the traditional techniques cannot keep up with the severity of the erosion problem.

The percentage of farmers who own animal traction implements is highly variable from site to site within the Mossi Plateau. In general, the size of household and the total cultivated area are greater on animal traction than on hand tool farms.

3.2. Farmers Adjustment Mechanism to Environmental Changes.

Traditional farming systems in the area are described as being dynamic, with adjustment mechanisms which enable adapting to changes in their environmental conditions so as to minimize the consequences of such changes on the farmers' objectives (Prudendio, 1986). Some of these adjustment mechanisms are:

a) Varietal changes:

Farmers look for shorter cycle varieties to escape drought effect and displace longer cycle varieties to lowland. Thus, a number of varieties for each crop are grown in the same village with differing growth cycles. Farmers introduce desired varieties from adjacent villages or even other regions. They tend to select varieties for the different land types: compound, village and bush fields. Short cycle varieties are retained for hunger season crop whereas longer cycle and more productive varieties may be retained for grain storage and sales purposes.

b) Expansion of traditional soil water conservation techniques and of water catchment construction:

Technologies traditionally used in fields with highly valued crops (e.g. maize, tobacco) are being extended to other fields and in some cases to other regions (e.g. stone and grass bunds).

c) Increasing utilization of organic fertilizer:

Under persistent drought conditions use of mineral fertilizer is decreasing whereas relative importance of organic fertilizer is increasing. Use of compost pits is also expanding.

d) Dry planting before the rainy season to improve timing of cropping activities:

e) More intensified cropping and abandoning of fallow practice as land pressure increases.

Substitution of red sorghum for white sorghum is observed to achieve food security, at the sacrifice of taste preference.

f) Progressive abandon of non edible cash crops, like cotton.

g) Increasing investment in livestock and off-farm activities.

h) Expansion of cultivated area into less fertile lands.

i) Out migration.

4. INDICATIVE RESULTS OF TECHNOLOGY TESTS

4.1. Soil and Water Conservation.

4.1.1. Mechanical measures:

a) Tillage:

Techniques to improve soil moisture storage have been investigated on multilocational sites from the Sudano-Sahelian to the Sudano-Guinean zones of Burkina Faso. The efficiency of the different techniques depend on several factors: soil, toposequence location, rainfall, and the cropping history of the area. Work of several years along this line has been presented by Nicou et al (1987).

In a recently cleared field soil disturbance is discouraged, whereas in land previously under cultivation plowing at the beginning of the season is necessary to increase soil moisture storage, and indispensable for maize cultivation. Scarification early in the season followed by repeated hoeing can increase soil moisture storage, through mulching effect and control of weeds. It is as effective as plowing in areas of less than 800 mm rainfall. Ridging is not efficient unless accompanied by tying of ridges.

The effect of plowing on millet, sorghum and maize on grain yield and yield components was marked. As an illustration, for sorghum maximum storage of water is needed during the heading to grain formation stage. Plowing early in the season markedly increased yields by promoting panicle formation. More yield is obtained with tied ridging constructed before the heading stage (6th-7th week after planting on the Mossi Plateau). Example of findings is given in Table 1 . Other benefits of plowing indicated were better weed control, better germination, faster root and vegetative growth and higher straw yields.

Despite the well established benefits of early season tillage by research the practice is not well spread on the farms of Sudanian and Sudano-Sahelian zones. There are numerous constraints to the adoption of the practice in the area, such as lack of time required for performing this operation at the beginning of the season, due to the brevity of the rainy season and the need to seed early. Another factor is the poor state of animals after a long dry season. At the end of the rainy season, the soils are, generally, too hard for work to be carried out with animal traction. The combined effect of these and other draw backs have prevented farmers' adoption of the technology (Nicou and Charreau, 1985).

b) Tied ridging:

Tied ridging has been found to markedly increase yields for maize, and cowpea (IITA/SAFGRAD Annual Reports 1984 and 1985), and sorghum and millet (Perrier, 1984) on the Sudanian zone. Trials have further been conducted on farmers fields by FSU (Ohm et. al. 1985). They have shown that (Tables 2 and 3) construction of tied ridges can result in significant increases of cereal crop yields throughout the Central Plateau even on areas with very gentle slopes. Although tied ridges constructed prior to planting can result in greater yields than those constructed later in the season, it is impractical to do so due to labor shortage at the time. An alternative is to construct tied ridges during second weeding (about two months after planting) when labor is more available and plants are tall enough for ridging.

There is evidence that some farmers are adopting the practice on villages where work on the technology has been conducted (Table 4). The farmers adopting the practice on small areas tend to have larger farm size, more cash crop area and higher management level (Ohm et. al. 1985). On farm testing of tied ridging in the Central Plateau is on-going by the INERA/SAFGRAD FSR program among many others (INERA/SAFGRAD NFSR Annual Report 1986 in preparation) (Table 5).

A device for tying ridges mechanicaly has been developed by IITA/SAFGRAD (Wright and Rodriguez 1985) to reduce the labor requirement of tied ridging. The implement is drawn by ox or donkey traction and on-farm trials have been conducted to determine its effectiveness and acceptability by farmers (Nagy et.at. 1986). More work is needed to reduce the weight of the machine for donkey traction, to adopt it for attachement to multiple other implements and define the agro-pedologic domains of its use. Similar to other land preparation practices, such as plowing, the technology of tied ridging on a larger area is dependent on availability of animal traction. Tied ridging may not be effective on sandy soils, because of bank failure of ridges. In areas with high rainfall, effect of tied ridging was not observed (IITA/SAFGRAD Annual Report 1985).

c) Contour bunds:

Contour bunds are detention barriers placed along contour lines to reduce erosion and increase soil moisture storage. Traditionally bunds were constructed with stone materials. Development workers (Wright, 1985) have introduced the technique of placing bunds along contour lines. Recently research work on farmers' fields have documented the benefit of the practice in terms of soil moisture storage and soil conservation (Hulugalle 1987a). Rock bunds increased soil water content immediately adjacent to a rock line whereas away from a rock line bunds had no effect on soil water. Clay content of the surface soil (0-5 cm) increased in the presence of rock bunds. Soil moisture storage of field was higher with tied ridging than with rock bunds but tied ridging had no effect on clay content of the surface soil (Ibd.). These findings are consistent with what would be expected. Influence of rock bunds, a more permeable barrier, on soil moisture storage would be less than that of tied ridges.

Influence of rock bunds on sorghum yield was reported from work by ICRISAT FSR BURKINA FASO Program (ICRISAT Annual Report 1985, Table 6) on farmers' fields in the Sudan and Sudano-Guinean zones. Yield increases, even on the first season, were otained from the package of rock bunds with minimum fertilizer (18, 12 and 8 kg/ha of N, P_2O_5, and K_2O) and improved sorghum variety. Nearly all farmers reported substantial accumulation of soil and organic matter at the bunds.

Earthen bunds have also been constructed in the area by development agencies (FEER - Fond de l'Eau et de l'Equippement Rural). They are less stable than rock bunds. Bunds increased sorghum grain yields by 30 % and those of pearl millet by 43 % in the North, Central and South-East of Burkina Faso. Earthbunding is reported to be economically attractive in the central and south eastern regions (Ibid.).

Some of the attractive features of rock bunds can be summarized thus:

- that the technology is traditionally practiced
- construction can be done during the period of low labor demand
- it is effective in controlling soil erosion
- yield increments have been noted even on the first year

This is a good example of a technology for on-farm testing. So far only limited work has been done on it. Similarly, no station research work has been undertaken. Research on design criteria of bunds such as spacing, height of barriers (as a function of soil type, slope and rainfall characteristics), use of different barrier materials (vegetative as well as mechanical) and economic evaluation of the technology would seem to be worthwhile topics for research station work while on-farm testing goes on simultaneously. Farmers of the area have taken active interest in the technology of contour bunds and are practising it on field scale with little material assistance from outside source (Dugue 1986, 1-2).

d) Runoff collection for supplementary irrigation:

The high runoff of the area with low infiltration capacity of the soil would suggest that possibility of runoff collection on properly selected sites exist. The water collected could be used for supplementary irrgation of crops during critical periods of growth. Initially this could be done on a small area. The farmers already irrigate small vegetable gardens during the rainy season using runoff water collected in natural ponds.

In the ICRISAT center application of small doses of irrigation at critical stages of growth have given remarkable increase in yield (Table 7, El Swaify et. al. 1985). This could be expected to be the case in parts of the Sudanian and Sudano-Sahelian zone of Burkina Faso. Initial work along this line has been reported (Dugue, 1986, II-3). The long term study required (as for rock bunds) would suggest that such work be started on station as well as on villages sites.

4.1.2. Biological measures:

a) Mulching:

Research station work over four years indicated that mulching significantly increased sorghum and millet yields (Perrier, 1984). Farmers apply mulch on degraded soils in the area (Prudencio, 1986). However, there is no systematic study of mulching done on farm sites as far as we know. It is often stated that mulching material is not available on the farms (Nicou and Charreau 1985). Certainly availability of straw will differ with farmers in the area as a function of animal feed, firewood, and construction material requirements. Some farmers could be interested if benefits on crop yield are demonstrated on the farm. Similarly mulch availability could increase through other management options e.g. agroforestry species, tillage where feasible, and even natural grass collecting.

b) Use of cover crops:

Some grass and legume cover crops which could serve as in situ mulch materials have been tested on research station for the Sudanian zone (Hulugalle, IITA Annual Report, 1986). The most promising cover crops were: Echnichloa colona, Digitaria ciliaris, Lablab purpureus cv. Highworth, Macroptilium artro purpureum cv. Siratro, Marcroptilium lathyroides and Psophocarpus palustris.

In 1987 season a trial of maize crop following some of these species (Echnichloa, Siratro, lablab) was seen to be growing better than maize following fallow, or that of continuous maize. The cover crop -

maize rotation trial was on an alfisol typical of the area, under minimum plowing, with some fertilizer addition*. Results of such study can be expected to provide the much needed alternative technologies for on farm testing.

Several grass and legume species which could serve as cover crops are being tested in the Sudano-Sahelian zone. Among the promising ones are Stylosanthes hamata, Cenchrus ciliaris, Andropogon gayanus and local volunteer grasses (CILSS/FAO 1984).

c) Alley cropping with perennial crops:

In 1985 the INERA/SAFGRAD NFSR program tested Leucaena leucocephala and pigeon pea (Cajanus cajan) for establishment on marginal fallow land on one site in the Sudanian zone (INERA/SAFGRAD Annual Report 1985). Pigeon pea established well without inputs (except for plowing at the beginning of the season), grew to a height of 1.60 m and provided good soil cover with leaf fall, and stayed green upto four months after the end of the rains. Leucaena leucocephala was slow on establishment due to termite attack but recovered later in the season. Plants were browsed to bare stem by stray animals during the dry season. The next year (1986) plants were observed to revegetate with the arrival of the first showers.

A trial was conducted to evaluate a number of leguminous and non-leguminous shrub species for inclusion in alley cropping systems for the Sudanian zone at the Kamboinsé station (Hulugalle, 1987b). Twenty three species were evaluated with respect to growth, and survival criteria. Nearly half of the species showed moderate to high survival rate. Acacia difficilis, Acacia holosericea and Acacia torulosa were indentified as the most promising of the lot. Acacia holosericea was the best of all. Similarly, multipurpose shrub and tree species are being tested by development organizations for forage, wood, wind break and soil conservation purposes (CILSS/FAO 1984, Bama et. al. 1985, Weinstabel 1984).

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The INERA/SAFGRAD FSR program has initiated an active program on testing of multipurpose shrub/tree species, some of which could be used in alley cropping purposes for soil and water conservation purposes. On-farm research on the integration of perennial crops with cereal crops in the area is still at an early stage. This is in contrast to the fact that farmers purposely leave some trees (e.g. Acacia albida) in their fields because of demonstrated benefits on crop yields.

4.2. Soil Fertility Improvement.

Work on soil fertility improvement has been conducted since 1960's by IRAT and recently (70's) by IITA/SAFGRAD, ICRISAT, National Research and Extension Departments. The highlights of CIRAD-IRAT work were presented by Pieri (1985).

4.2.1. Mineral fertilization:

Under continuous cropping crop yields drop a few years after clearing, due to deficiencies in nitrogen and phosphorus. The chemical fertilizer used in Burkina Faso is N:P:K complex of ammonium phosphate, ammonium sulfate and potassium choride. Additionally urea is also used (BUNASOL 1985). Crop response to fertilizer application is dependent on moisture supply. Work by FSU/SAFGRAD (Ohm et.al.1985) indicated that fertilizer response of crops is higher in the presence of a soil water management technology (Tables 2 to 6). Under traditional cultural practices, fertilizer application is inefficient and is associated with unacceptable levels of risk. A study of the economic evaluation of fertilizer use conducted on farmers fields by ICRISAT in Burkina Faso (Matlon 1984a) showed that returns to fertilizer application even at low doses (50-100 kg/ha NPK) were profitable in the wet southern region (Sudano-Guinean), moderately profitable in the Sudanian zone and not profitable in the dry Sudano-Sahelian zone. Risk of financial loss was appreciable even in the wet region. Since then fertilizer prices have increased. Under the prevailing moisture and price conditions use of imported fertilizer is not within reach of majority of the farmers in the country.

The soils of the area have low buffering capacity. Continuous use of fertilizer application, in the form available, without application of amendements can lead to acidification of the soil. A long term research study conducted in Burkina Faso demonstrated the harmful acid forming effect of mineral fertilizer when not accompanied by manure application (Sedogo, 1981).

4.2.2. Use of rock phosphate:

The high cost of imported fertilizers motivated search for ways to utilize local materials. Rock phosphate is localy available. Trials of Burkina rock phosphate application on crops have been been conducted. Results, however, are inconclusive even over several years of field testing. The ineficiency is due to the low solubility of the material. Research on increasing rock phosphate solubility by acid treatment is on-going ([illegible]). Acidulation presupposes availability of acid plant. Another possibility of increasing solubility [illegible] incorporation in compost or silage. Results of these studies are not yet conclusive.

4.2.3. Cereal fertilizer recommendation:

The fertilizer recommendation used in Burkina Faso was based on that of cotton. The need to work out fertilizer recommendations on specific crop-soil-climate combination has been recognized. Hence, work on the topic is underway by INERA (food crop fertilization project - Project Engrais Vivriers). The trials cover major agroclimatic zones, soil types, and the staple cereals. Different levels and sources of fertilizer and levels of manure are being tried. Economic analysis of the data will give rational fertilizer recommendations.

4.2.4. Organic fertilizers:

a) Manure and compost:

Application of manure and compost for soil improvement has been investigated and possibilities for on farm testing exist (Sedogo, 1981). The major limitation of manure indicated is the limited amount in the farms and problems associated with transport in the field (Pieri, 1985). However, ways can be found to resolve these limitations in stages. One such possibility is enclosure of animals therebye collecting good quality manure. This is linked to the overall issue of integrating crop/livestock enterprises. The fact that it is already a known practice to the farmers, requires little cash outlay and has other benefits to be gained from keeping livestock on the farm would suggest its feasibility. Certainly, manure can be more accessible to a larger number of farmers than purchased fertilizers. Compost making is increasing in the area with the encouragement of the extension department.

Benefits of compost and manure application with some mineral fertilizers on crop yields and soil improvement are recognized (Pieri, 1985, Sedogo, 1981). There is however, not much work reported on effect of manure applied over years and quantitative evaluation of feasibility on farms. Comparison of yield from compound fields, where manure is applied on a small area, with that from bush fields indicate highly positive effect (Prudencio, 1983).

b) Cereal/legume association:

Cereal/legume intercropping and cereal-legume rotations could have positive effect on soil fertility improvement. Some problems encountered with the technology have been noted (e.g. Pieri 1985). On-farm trials over several seasons would be required to note the effect. Like manuring and compost the technology is common in the area. What is lacking is identification of those combinations which improve soil fertility. Species, space and time arrangements for different agro-climate and farm resource condition need investigation both on station and on farm.

c) Use of perennial legume crops:

It is recognized that leguminous tree species could improve soil fertility as part of the other multiple advantages they offer. The same comments made for cereal/legume association are even more valid in this case.

4.3. Crop Selection.

There has been intensive work on crop improvement through breeding for higher yield, insect resistance and drought tolerance by IRAT, ICRISAT, IITA/SAFGRAD and, recently, INERA on the major food crops of the country. Some varieties that perform as well as the locals under traditional management but excell the locals at higher management levels have been identified (Table 5). It should be emphasized that local varieties that respond to inputs such as KANFIAGUI, for the Soudanian zone from the eastern region, are also available (INERA/SAFGRAD 1986 Annual Report).

Results of crop selection have not been as rewarding as would be expected from the level of effort exerted. There has been large gaps between yields of elite varieties on station, under improved management conditions, and those of the elite under the harsh environmental conditions of the farm (Matlon 1985). This is as expected but some precautions during the breeding program could have helped to identify varieties of intermediate performance but with more stable yields. Some of these considerations can be listed as:

- breeding for varieties more adopted to the environmental conditions of the farms than has been usually the case;
- better appreciation of the complexity of the farm environment and the diversity of farmers resources;
- more use of local breeding materials.

Under the degraded soil and the highly variable rainfall conditions a wider choice of technologies would be required to cope with the adversities. Simultaneously, work in crop variety will have to be supported with equally intense efforts to improve the soil medium. It is well appreciated that single technologies may not be sufficient to create impact under the conditions prevailing. Nevertheless, crop selection work in the area has enabled appreciation of the complexity of the environment.

4.4. Crop Association for Yield and Yield Stability:

Cereal/cereal, cereal/cashcrops and cereal/legume intercropping are commonly practiced in the area. There has been several years of on-station research work on cereal/legume intercropping (ICRISAT, IITA/SAFGRAD) and cereal/legume relay cropping (IITA/SAFGRAD). The advantages of these practices in terms of yield have been demonstrated under conditions of favorable rainfall and soil fertility. Under stress conditions a near full yield of the cereal crop with bonus yield of legume grain or forage can be obtained when the secondary crop is planted at a later date than the primary crop. Many of the advantages of intercropping are discussed by Fussel and Serafini (1985).

These include:

- higher land equivalent ratio
- better distribution of labor demand in the season
- more yield stability

The research work is relatively recent in the country and technologies suited to the specific farmer objectives, and environmental conditions are needed. Some on-farm testing has been conducted by FSU/SAFGRAD (Sawadogo et al, 1985) and ICRISAT FSR program (Matlon, 1984b). The profitability of improved cereal/legume intercropping on-farm trials has been shown but under conditions of low rainfall the farmers' traditional practice (e.g. low densities of legume) may be preferable. Need for more farmer managed trials is indicated (Sawadogo et al, 1985).

In contrast to cereal/legume intercropping, work on cereal/cereal association, cereal-legume rotation, and cereal/perennial crop intercropping ha not been initiated. Maize/cotton intercropping has been conducted by

IITA/SAFGRAD on station. Improvement of crop association can offer a way of intensifying the agricultural production in the area. For example, cowpea is rarely grown as monocrop in the area. Therefore, the way to encourage more cowpea production, for grain as well as forage production, is through association with cereals. This would offer a link mechanism for integration of grain production, animal feed source and soil restoration work.

4.5. Labor Bottlenecks and Low Productivity of Farm Implements:

Field study of farms in the Sudanian zone of Burkina Faso showed that animal traction was moderately profitable (Jaeger and Sanders, 1985) and that profitability of the practice could be increased with better management, use of several implements and animals in a better state. Some of the variations in the performance of animal traction is attributed to the time required for learning and the number of operations performed. Single operations such as ox plough alone were often not economical. According to the study prospects of using animal traction in the area look favorable.

There is little on-farm testing work destined to improve the performance of farm equipment. Implicitly agricultural intensification is perceived to be achieved using the rudimentary tools and implements. The most common animal traction implements are the cultivator, cart and plow. The range of tools is limited. Work on this area is done by ARCOMA (Attelier Régional Construction Materiel Agricole) and CNEA (Centre National d'Equipement Agricole). However, not much testing on-farms is conducted. Recently INERA has a department engaged in the area.

4.6. Cultural Practices.

Cultural practices such as recommended density of plants and timely operations of activities, planting and weeding, can increase crop yields. Due to the unpredictable rainfall pattern and labor shortages during parts of the season, however, timely operation of activities is often not realized. Similarly row planting of crops could help pave the way for intensification of crop production through better accessibility between rows for operations in the season. Not much work is done on chemical weed and insect control on-farm sites due to cost and/or inaccessibility of chemicals, except for cotton.

5. OBSERVATIONS ON ON-FARM RESEARCH EXPERIENCE

The work conducted on on-farm trials show the following characteristics among others:

- More dependency on technologies of short term impact nature as opposed to those with long term effect e.g. emphasis given to fertilizer and variety combination trials than for work on resource recycling such as mulching, manure application and arresting soil physical degradation. This is in contrast to the expressed concern with the degrading resource base of the area.

- Work done by narrow range of disciplines, often agronomy and socio-economics. Disciplines better equiped to tackle problems of soil conservation, animal production, farm machinery and implements, and forestry not participating. This reflects also the condition of research station work. There is serious lack of multidisciplinary tackling of an identified problem on the farm e.g. animal traction, land preparation, soil conservation etc.

- Emphasis on one or two elementary technologies. This may be attributed to the observation that farmers accept technologies in steps not packages. However, the conditions prevailing do not permit one or two elementary technologies to show appreciable impact. Any benefit is obscured by the variability in the environment.

- Project approach rather than sustained effort to alleviate the major constrainst of the area. This is more a condition imposed by funding source than lack of awareness on the part of researchers. It could be the reason for the emphasis on disciplinary research orientation too. Obviously the search for quick impact packages is not compatible with limited input of resources. High resource use over a short time may generate technologies with demonstrated effect on the farm, adequate resources over longer time would too, but not limited resources over short time.

- In general on-farm trials were conceived with assumptions of homogeneity of the environment, and as a diagnostic tool of farm constraints. Yet the hetrogeneity of the environment and the major constraints to production were well documented already. More active effort to generate technologies and demonstrate effect on productivity and promote environmental stability is needed. Diagnosis is necessary but not enough. The objective is generation of a range of technologies adapted to the farmer's needs. Sustained effort on a long term basis would be required to restore environment that took time to degrade.

- Avoiding traditional technologies. A wealth of traditional technologies exist: soil conservation measures are known to the farmers, limited use of supplementary irrigation from natural ponds is practised, experience on craftsmanship is available in the villages and integration of crop/livestock system is prevalent, to mention but a few. The rational for these practices have been known. Yet the existing practices are not often used as a launching form for improved technology generation. They are often acknowledged after the failure of the "improved" technologies. One such case is the emphasis on imported material for breeding at the sacrifice of locals. The scientific analysis bestowed on imported technologies could also be applied to improve the existing technologies.

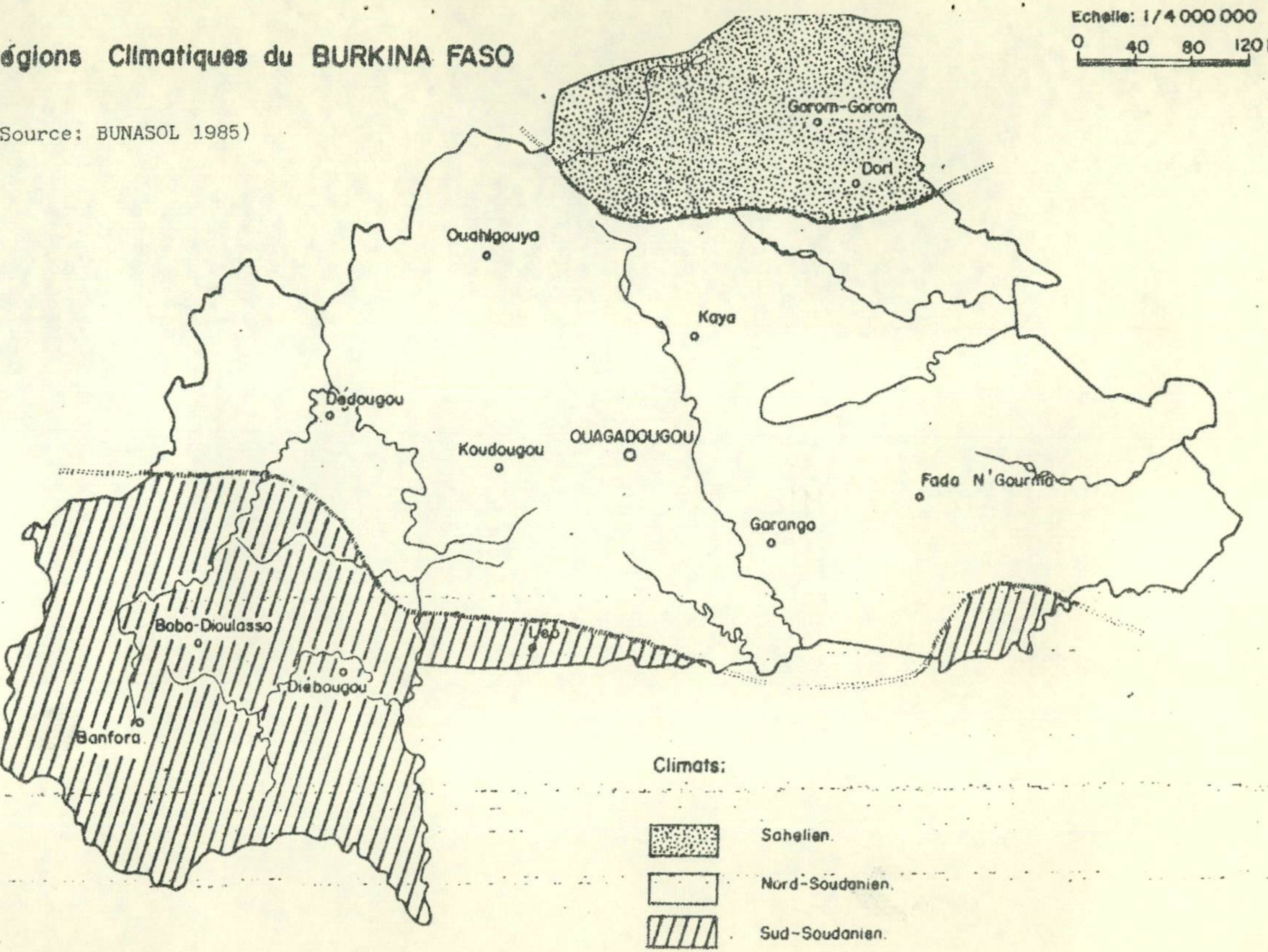
6. NEW ORIENTATION

The lack of wide range of technologies for on-farm testing in Sub-Sahara Africa is discussed by Spencer (1985). This is the case in Burkina Faso. Hence the primary client of the INERA/NFSR should be to provide feedback to research organizations on the farm conditions so as to promote technology generation. On-farm testing is considered as part of a continum in a chain of activities from research station up to the farm. To be effective a multidisciplinary approach to tackling major production constraints of the area with integration of crop/livestock/agroforestry enterprises is necessary. An outcome of this undertaking is the benefit to be acquired in intensifying agriculture by taking advantage of the complementarity effect of the different enterprises in meeting the needs of the farm community and promote environmental stability. The stnategy is to concentrate efforts on few representative sites on the Central Plateau and work with adequate number of sample farmers over a prolonged period to note impact of integrated technologies. Advantage will be taken of the previous experience of the on-farm work to improve the program. The fact that the program is part of the national institute can be expected to assure continuity of activities and facilitate collaboration with national research and development workers.

More emphasis on long term natural resources restoration is required. Activites conducted in 1985, 1986 indicate prospects for improving agricultural productivity in the area (INERA/SAFGRAD Annual Report 1985, 1986). The findings are preliminary but confirm aspects of the results of FSU/SAFGRAD, and ICRISAT and IITA/SAFGRAD. Newer dimensions of the program are expected to reveal results with time.

Régions Climatiques du BURKINA FASO

(Source: BUNASOL 1985)



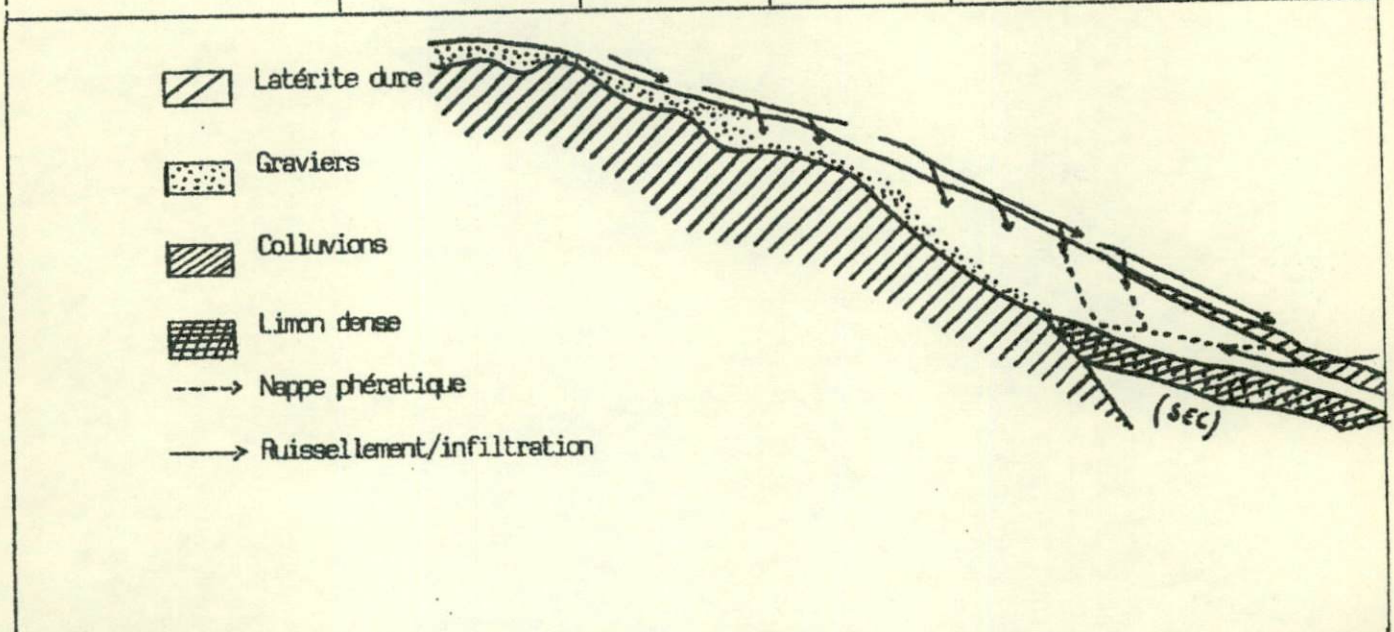
Type de terroir	Plateau	Haut de Pente	Mi-pente	Bas de pente/ bas-fonds	Marais
					
Couleur de la couche arable	brun à brun foncé	brun foncé	brun jaune foncé	brun gris foncé	-
Texture de la couche	limon sableux	limon sableux	limon sableux	limon fin	-
Profondeur du profil sur la latérite (cm)	35	80	> 120	-	-
Profondeur du profil sur la couche de limon fin dense (cm)	-	-	> 100	95	-
Profondeur de la nappe phératique	-	-	-	variable (inondations rares)	variable (inondations périodiques)
Culture dominante	mil	mil	mil/sorgho	sorgho/maïs	riz
Classification des sols	plinthustalf	Paleustalf oxique	paleustalf oxique	tropaquept	-

Figure 1 : Présentation schématique des conditions de sol, des mouvements de l'eau dans les sols et les cultures le long de la toposéquence.

Fig. 2. Schematic presentation of soil types, soil moisture movement, and crops along the toposequence at Kamboinsé (Sudanian zone).

Source Van Staveren and Stoop in "L'Agronomie Tropicale" 1986, 41-3-4.

Table 1. Sorghum grain yield (kg/ha) mean of 4 years data 1982-84, 86.

Location	Land preparation		
	Control	Plowing (exen) beginning of season	Plowing + Ridging 1 MAP + Tying 2 MAP
SARIA :			
Upland*	1437 (100)	2060 (143)	2112 (147)
Midland*	1361 (100)	1765 (130)	2378 (175)
GAMPELA*	1448 (100)	2223 (154)	2621 (181)

* SARIA and GAMPELA are in the Sudanian zone (700-900 mm).

SARIA upland = Gravelly shallow soil with compact layer at 30 cm.

SARIA midland and GAMPELLA; deeper clay soil with concrecations at 70-80 cm.

Source: Nicou et al 1987, P. 33.

Table 2 . Economic analysis of farmer managed trials of sorghum with fertilizer and tied ridges, 1984.

	Treatments[1]				S.E[4]	CV[4]	Number of Farmers
	C	TR	F	TR,F			
	Nedogo, Manual Traction						
Grain yield, kg/ha	157	416	431	653	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	733	63.4	44	18
Yield gain above control, kg/ha	-	252	182	600			
Gain in net revenue, CFA	-	23184	4811	43268			
Return/hr. of additional labor, CFA	-	309	51	255			
% Farmers who would have lost cash	-	0	50	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 woul 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 riging 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.

* Nedogo and Diapangou on the Sudanian zone seasonal rainfall 452 and 458 mm respectively.

Source: Adapted from Ohm et al, 1985.

Table 3 . Economic analysis of farmer managed trials of maize with tied ridges, 1984.

	Treatments[1]			Number of Farmers
	C	TR	CV[6]	
	Nedogo, Donkey Traction			
Grain yield, kg/ha	869	1305****[5]	26	19
Yield gain above control, kg/ha	-	436		
Gain in net revenue, CFA[2]	-	40112		
Return/hr. of additional labor, CFA[3]	-	535		
% Farmers not covering labor opp. cost[4]	-	21		
	Diapangou, Manual Traction			
Grain yield, kg/ha	445	724**	69	7
Yield gain above control, kg/ha	-	279		
Gain in net revenue, CFA	-	25668		
Return/hr. of additional labor, CFA	-	257		
% Farmers not covering labor opp. cost	-	29		
	Diapangou, Ox Traction			
Grain yield, kg/ha	976	1700***	46	7
Yield gain above control, kg/ha	-	724		
Gain in net revenue, CFA	-	66608		
Return/hr. of additional labor, CFA	-	888		
% Farmers not covering labor opp. cost	-	0		

1/ C = control (no tied ridges or fertilizer); TR = tied ridges constructed one month after seeding.

2/ Net revenue = yield gain x gain price (92 CFA/kg)

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

4/ A 40 CFA/hr. opportunity cost of labor is used.

5/ **, *** and **** indicate a level of significance of 0.05, 0.02, and 0.01 respectively for differences between treatments C and TR as determined by the T-Test for paired observations.

6. CV% = coeficient of variation.

Nedogo and Diapangou = sites on Sudanian zone.

Source: Adapted from Ohm et al 1985.

Table 4 . Percent of farmers adopting tied ridges (TR), fertilizer and new varieties by village, 1984.

Village	Years[1]	Number of farmers	Percent of farmers adopting		
			TR	Fertilizer[2]	Varieties
Nedogo	5	69	25	10	10
Bangasse	3	53	23	0	0
Poedogo	2	27	4	33	41
Dissankuy	2	60	2	97[2]	0
Diapangou	3	61	25	8	8

1. Number of years FSU in villages; 1984 was the first year for farmer-managed trials at Poedogo and Dissankuy.

2. The figures relate only to land sown to cotton. Small amounts of fertilizers are used on cereals.

Table . Average hectares of technology adoption, 1984.

Technology	Village				
	Nedogo	Bangasse	Poedogo	Dissankuy	Diapangou
	ha				
Tied Ridges	.32	.03	.11	.03	.18
Fertilizer	.46	0	3	3	.34
Varieties	.33	0	.12	0	.04

All villages in the Sudanian zone.

Source: Ohm et,al,1985.

Table 5 . White sorghum grain yield (kg/ha) at two levels of management and four locations in Kamsaoguin (1986). Researcher managed trials.

Variety	Location 1			Location 2			Location 3			Location 4		
	CONT.	TR + F	MEAN	CONT.	TR + F	MEAN	CONT.	TR + F	MEAN	CONT.	TR + F	MEAN
LOCAL	1046	3061ab	2053ab	1024bc	2172a	1598bc	617a	1375b	996b	774	1277	1026
IRAT 277	766	1883c	1325c	890c	2040a	1465c	227b	649c	438c	313	961	637
KANFIAGUI	1239	2453b	1846b	1571a	2373a	1973a	807a	1261b	1034b	544	705	625
ICSV 1002	1258	3547a	2403a	1477ab	2180a	1829ab	821a	1966a	1394a	333	1086	710
Mean	1077b	2736a		1241b	2192a		618b	1313a		491a	1007a	
LSD Mngt.	568			651			449			666		
Sign level	$P < 0.01$			$P < 0.05$			$P < 0.05$			$P < 0.01$		
LSD Variety	390			327			221			406		
Sign level	$P < 0.01$			$P < 0.05$			$P < 0.01$			n.s.		
LSD Variety for same mngt.	551			463			412			574		
C.V.	19.5%			18%			21.7%			52%		
Mean			1907			1716			966			755

Location: Village site (Kamsaoguin) - Sudanian zone, long term mean annual rainfall 790 mm, seasonal rainfall 663 mm.

1. and 2. Mid slope, relatively fertile soils
3. Lowland, temporal water logging problem
4. Mid slope, poor soil

Treatments : CONT = Traditional management, flat planting without fertilizer input
TR + F = Tied ridging (TR) one month after planting plus fertilizer (F), 100 kg/ha NPK (14-23-15) and 50 kg/ha urea.

Variety - Local - farmers' own variety; IRAT 277 = IRAT improved variety recommended for the area; ICSV 1002 = ICRISAT variety; KANFIAGUI = local from the easter region.

Comments: - Marked effect of TR + F (+ 76 - 150 %). - Variety difference les pronounced than management effect. - Yield level location dependent.

Source: INERA/SAFGRAD FSR Program 1986 results.

Table 6a. Effects of rock bunding and sorghum variety ICSV 1002 on grain yield (kg ha^{-1}) in farmers' fields in four villages in two agroclimatic zones, Burkina Faso, 1985.

Yield and other aspects	Agroclimatic zone			
	Sudanian		Guinean	
	Kolbila	Ononon	Koho	Sayero
Number of fields	8	7	8	8
Rainfall in 1985 (mm)	514	487	922	715
Fields receiving heavy runoff	5	1	0	1
Fields receiving moderate runoff	2	5	2	1
Sorghum grain yield (kg ha^{-1}) with bunding and ICSV 1002	730	350	670	1010
Control	230	160	650	600
SE	±118	±67	±206	±233

Table 6b. Effect of earthen contour bunds on sorghum and pearl millet grain yield (kg ha^{-1}) from farmers' fields in 25 villages, Burkina Faso, 1982/84.

Treatment	Crop		Region		
	Sorghum	Pearl millet	North	Central	Southeast
Plots within bund system	740	300	180	590	580
Control plots outside bund system	570	210	130	430	440
Percentage yield increase over contour plots	+30	+40	+38	+37	+32
SE	±68	±21	±22	±56	±53
Number of observations	100	234	126	100	105

Source: ICRISAT Annual Report 1985,P. 308-309.

Based on work by ICRISAT/BURKINA FASO - Economics Program.

Table 8. Summary of state of technologies in Burkina Faso.

Topic	Research station work	On-farm testing	Practice traditionaly	Constraints to adoption (technical)	Research needs
1. Tillage	Adequate	Limited (socio-economic)	Few farmers	- Weak animals - Limited equipment - Not enough training	- Draft power improvement - Implement development - Training
2. Tied ridging	Adequate	Fair	Rarely practiced (tuber crops) - South West	- Similar to and presupposes, tillage	- Same as for tillage
3. Contour bunds	None	Limited (FEER, ICRISAT OXFAM)	Well spread (North)	- Lack of construction materials - Labor requirement	- Design criteria - Search for materials - Reduction of labor requirement
4. Supplementary irrigation	None	Rare	Wide spread on small scale (Gardening)	- Know how - lift power - equipment	On station - runoff collection design criteria - irrigation optimization - economic evaluation, on-farm to village scale
5. Mulching	Adequate	Rare	Known to farmers (small scale)	- Lack of mulch material - Transport requirement	- In situ mulch - Test alternative mulch materials
6. Cover crop	Limited	- Some devlpt work	- Not aware of	- Knowhow	A lot of work required
7. Alley cropping	None	Recent (INERA)	Known to farmers	- Knowhow	- All aspects of agroforestry for soil conservation

Table 8 . Summary of state of technologies in Burkina Faso.

Topic	Research station work	On-farm testing	Practice traditionaly	Constraints to adoption (technical)	Research needs
8. Mineral fertilizer	Substantial	Substantial	- Small no. of farmers (cotton) and in humid zones	Risky	- Recommended doses for cereals/soil/climate matrix - Alternative sources
9. Organic farming:					
a) Manure	Some	Developt. work	Well spread	- Not enough manure - Transport	- Modes of crop/animal integration
b) Cereal/lugume association	Some	Some	Well known	- Narrow range of combination spécies - Moisture supply	- Search for species/time/space combination to restore resources
c) Cereal/Perennial legume	None	some investigation work	Common	- Knowhow	- A lot of work on annual/perennial combination
10. Variety selection	Substantial	Substantial	Common	- Harsh environment	- More use of local materials
11. Implement development	Limited	Limited	-	- Narrow choice of implements	Intensive, multidisciplinary work needed

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1987-09

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