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TECHNOLOGY EVALUATION, POLICY CHANGE AND FARMER ADOPTION IN BURKINA FASO

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Introduction

Purdue University began farming systems research in Burkina Faso in 1979 under the Semi-Arid Food Grain Research and Development project (SAFGRAD), a regional research coordinating program with major funding from the United States Agency for International Development (USAID). Among various research themes, the farming systems unit (FSU) stressed water conservation and soil fertility. This paper presents FSU's field trial and socio-economic program related to water conservation (tied ridges) and soil fertility (fertilization). The paper starts with background on Burkina Faso. Diagnostic and farming systems information are then presented leading to the description of the on-farm farmer-managed trials and the socio-economic program and presentation of the results. The evaluation of the technology interventions are then presented followed by the modifications that were made to the research program from the information gained in the preceeding field campaign. Linear programming is used to analyze the technology interventions in a whole farm context.

Background on Burkina Faso 1/

Burkina is situated in the zone known as the the semi-arid tropics and the climate is sudanian with the exception of the

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1/ Burkina Faso was formerly Upper Volta. The Background information on Burkina is a synthesis of several publications: World Bank, 1982; Jaeger, 1985; United States Department of State, 1984.

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northeast which is sahelian.2/ There are three distinct seasons: warm and dry from November to March, hot and dry during March through May and hot and wet from June to October. Daytime temperatures during the cooler November to March period average about 30 C and drop to 16 C at night with very low humidity. The temperature starts to climb in March and by May most daytime temperatures reach into the 40 C range. During the rainy agricultural season, daytime temperatures range between 27 C and 32 C. Once the rain stops in the fall, temperatures again begin to climb to the 40 C range during October until cooler weather sets in about mid-November. Long term average annual rainfall ranges from 500 mm in the northeastern Sahelian zone to 1400 mm in the extreme southwest. Isohytes tend to be horizontal except for the southwest where rainfall is heavier than in the southeast. Since the mid-sixties, annual rainfall has averaged 100 to 150 mm below the long term average within each of the isohyets.

The population of Burkina is estimated at 7.2 million (1987) with an annual growth rate of 2.6%. Most of the population lives on a plateau in the central part of the country referred to as the Mossi or Central Plateau. Population density is very high in this area approaching 48 per square kilometer in some locations

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2/ Burkina is a landlocked country in the center of West Africa bordered by Mali on the north and west, Ivory Coast, Ghana and Togo on the south and Benin and Niger on the east (Fig 1). The country is located between 9°20' and 15°5' latitude north and 2° 20' longitude east and 5°30' longitude west of the prime meridian. The land area of the country is 274,000 square kilometers of which an estimated one-half is arable. Eighty-five percent of the area is plains with an altitude of between 200 to 350 meters above sea level.

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as compared to 12 per kilometer in the north and east. Burkina is the largest supplier of emmigrant workers in West Africa. It is estimated that 25% of its work force, mainly better educated young single men, work in the Ivory Coast, Ghana, Mali and Senegal. This results in an annual net population growth rate of 1.7%. About 90% of the population live in rural areas with 83 % of the labor force engaged in agriculture. The literacy rate is 5%.

Food security continues to be an important problem for Burkina. Although increases in food availability (including imports) have kept pace with population growth allowing per capita consumption to remain constant, aggregate caloric intake is 85% and lipid consumption 50% of nutritionally recommended levels (Haggblade, 1984, p vii). The World Bank's average index of food production per capita dropped six percentage points between 1971 and 1981. Assuming the current increase in population growth, total food production will have to increase by 30% by 1990 to maintain the current consumption levels without greater reliance on imports (Singh, 1984, p. 5).

Diagnostic and Farming Systems Information

The major objectives of the farming system unit (FSU) were to identify the principal constraints to increased food production and to identify technologies appropriate for farmers which can overcome the production constraints (Ohm et al, 1985a, p.2). To achieve the objectives, FSU conducted on-farm researcher-managed and farmer-managed trials and collected base-

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line and socio-economic data in up to five villages. 3/ Villages were selected to represent different agro-climatic zones with different agricultural potential, differences in access to land, and represent, as far as possible, a complete range of tillage practices. The village of Bangasse has very few animal traction farmers whereas about one-half of the farmers in Nedogo use donkey traction. The Dissankuy and Diapangou sites have a complete range of manual, donkey and ox traction farmers. Dissankuy, which is just off the Mossi Plateau has the greatest agricultural potential followed by Diapangou, Nedogo and Bangasse all of which are on the Mossi Plateau. There is limited access to land in Nedogo and Bangasse.

Planting of crops begins with the first significant rains, some time between early May and late June. Labor constraints are most pressing at planting and at first weeding. Labor is less constraining during second weeding and the period that follows. The major staple crops grown are millet, white sorghum and maize. Small quantities of rice are grown in the bottom lands. In Nedogo, a red sorghum is grown for the making of local beer. Cash crops include peanuts, bambara nuts, and cowpeas. Cowpeas are usually intercropped with sorghum and millet. Other crops include okra, peppers and sesame. Cotton is a major crop grown in Dissankuy (FSU/SAFGRAD, 1983).

3/ The four villages of concern for this paper are: Nedogo - 30km northwest of Ouagadougou. Bangasse - 110km northeast of Ouagadougou and 15 km from the major center of Kaya. Diapangou - 210 km east of Ouagadougou and 15 km from the major center of Fada-nGourma and Dissankuy - 120 km north of Bobo-Dialasso (Fig 1). The ethnic group in Diapangou is Gourmantche, a mixture of Dioula and Mossi in Dissankuy and predominantly Mossi in the other villages.

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The soils are classified as alfisols and are red to reddish brown in color. Soil texture is predominantly sandy-clay with some sandy-loam soils at Bangasse, Nedogo and Diapangou. Soils are predominantly sandy-loam at Dissankuy. Sand, silt and clay content on the Mossi Plateau range from 60-70%, 20-30%, and 5-10% respectively (Vierich and Stoop, 1984). Table 1 presents the pH, fertility, and other characteristics of the soil by village location. The soils contain only weak aggregates and after a rain the soil surface dries and forms a crust which restricts water infiltration and aeriation and increases rainfall runoff (Kowal and Kassam, 1978). In the dry season the soils harden making pre-plant cultivation difficult and almost impossible by traditional methods until there is a major rain. Land quality deteriorates as one moves up the toposequence. Rainfall is highly variable and unpredictable and combined with the properties of the soil leads to water retention and soil erosion problems.

Land quality, water retention ability and labor availability are the dominant factors in cropping decisions (Lang et al., 1983). Maize, which is less tolerant to drought and low soil fertility than either sorghum or millet is planted near the village compound. The compound area, ranging from .1 to .2 ha, is used to dump night soil, animal manure, stubble and other organic material. Thus the amount of land suited to growing maize is limited. Sorghum is planted on the more low lying areas where there is slightly more water accumulation and where the

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soils are more fertile than the poorer soils further up the toposequence (Stoop et al., 1982, p. 519). The poorer land is planted to millet, which is the most drought and disease tolerant crop. Farmers say that white sorghum is preferred because it stores twice as long as millet, however sorghum is more vulnerable to parasites (striga), drought and other diseases than is millet. Farmers say that in the worst rainfall years, some millet can always be harvested. The timing of rains also influences planting decisions, the later the rains, the more millet farmers plant. Also, farmers would plant more millet if not constrained by the labor supply in the planting, first weeding period. More cash crops such as peanuts would be planted but priority is given to the planting and first weeding of staple crops. A limited labor market exists for agricultural activities, particularly at planting and first weeding. Most farmers use their own household labor and little labor is hired in or out.

There is a distinction between collective fields of the household that provide the major subsistence crops and personal fields which individuals cultivate for private profit (Saunders, 1980, p. 5). Work on collective fields takes priority over work on private fields especially in peak labor periods. Both men and women have personal fields and plant cash crops.

In general, farmers' goals on the Mossi Plateau are subsistence oriented with the most immediate goal being that of meeting their staple food consumption needs (FSU/SAFGRAD, 1983). Commercialization is at a low level in all the villages with the exception of Dissankuy. Farmers in Dissankuy are more

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commercialized as a result of the cotton industry in their area.

Animal traction is the only major capital investment made by farmers. It is estimated that 10% of the farms in Burkina use animal traction. Most animal traction units are acquired under animal traction programs with built-in credit arrangements. Most formal credit for purchases of agricultural inputs such as fertilizers is obtained through membership (usually the household head) in a village credit group. When farmers are asked why they do not use more fertilizer, their response is that it is not readily available (outside the cotton growing area) and that they lack the credit (Ohm et al., 1985a).

The increased man-land ratio on the Mossi Plateau has caused a change in the traditional farming systems in many villages. Traditionally, farmers plant land for five to seven years and then it is fallowed for up to 20 years to restore the fertility. In Nedogo and Bangasse however, there is limited access to new land and virtually all land within the boundaries of the two villages has been cultivated continuously over the past ten years. Many of the fields have been planted without fallowing as long as the farmer can remember. The shorter fallow period in combination with the present farm management practice of burning or the removing of all plant material for household and animal feed exhausts the soil. The end result is that as more pressure is put on the land for food production, soil deterioration will increase, resulting in lower yields and lower food production.

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On-Farm Trials and Socio-economic Campaign

With regard to the factors of production, land quality (soil fertility) and labor requirements at planting and in particular at first weeding represent the most pressing constraints. The other most pressing constraint is water. If more water can be made available, the expected returns to several other factors of production (land, labor, fertilizer) will be substantially increased. A further constraint to exploiting some types of technologies is the farmers' present subsistence orientation and the low level of commercialization. Thus to start with farmers will only be able to use technologies that use a low level of cash inputs and exploit non-cash inputs such as labor wherever possible.

FSU's field trial campaign focused part of its efforts on soil fertility and water management (FSU/SAFGRAD, 1983, Lang et al., 1984, and Ohm et al., 1985a). Given the continuing deterioration of the soil, the limited supply of local organic matter, and the farmers' present level of commercialization, low levels of commercial fertilizers were incorporated into the field trials. The water management technique of tied ridging was also incorporated in the trials. 4/

4/ Tied ridges are small depressions made between the crop rows either by hand tillage or with a combination of animal traction and hand tillage. If done by hand, depressions 32 cm long x 24 cm wide x 16 cm deep are made between the rows and spaced 1 1/2 meters apart. If done with animal traction, the cultivator is equipped with a middle sweep to create a furrow which is then followed by hand tillage to make a 16 cm high ridge perpendicular to the furrow every one to two meters.

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In 1982, on-farm researcher-managed trials on sorghum were conducted using commercial fertilizer and tied ridges constructed 30-35 days after planting resulting in average yield increases of 195% over traditional practices (FSU/SAFGRAD, 1983). Based on the information of the on-farm researcher-managed trials, on-farm farmer-managed trials were then conducted in 1983 and 1984 with the objective of evaluating the agronomic characteristics and economic benefits from the construction of the water conservation technique of tied ridging in association with minimal amounts of fertilizer. The treatments of the trials in the four villages were as follows: 5/

1) traditional management practices (flat cultivation, no pre-plant ploughing, no fertilizer),

2) construction of tied ridges at 4 to 6 week after seeding and no fertilizer,

3) flat cultivation and 100 kg/ha 14-23-15 fertilizer applied in a band 10-15 cm from the rows of sorghum two weeks after seeding plus 50 kg/ha urea, applied in pockets 10-15 cm from the seed pockets 4 to 6 weeks after seeding, and

4) construction of tied ridges 4 to 6 weeks after seeding plus fertilization as described above.

5/ In 1983 and 1984 the trials were conducted on medium to good sorghum land at Bangasse (25 farmers with manual tillage), at Nedogo (25 farmers with manual tillage and 25 farmers with donkey traction) and at Diapangou (25 farmers each with manual, donkey and ox traction). In 1984, the trial was conducted for the first time in Dissankuy with 25 ox traction farmers. At Bangasse and Dissankuy, the experimental design was a randomized complete block with farmers' fields as replications. At Nedogo and Diapangou, the experimental design was a split plot with whole plots (types of traction) arranged in a completely randomized design and treatments were the subplots. Treatments were assigned to the same plots in 1984 as in 1983. Each treatment was randomly assigned to each plot. Plot sizes ranged from .05 to .12 ha with all plots in the same field of equal size. Locally grown varieties of sorghum were used. Planting in 1984 took place the week of June 1, May 25, May 15 and June 18 in Nedogo, Bangasse, Dissankuy and Diapangou respectively. Harvest started in October and continued into December.

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Rainfall in the villages was 574, 670, 666 and 668 mm in 1983 and 514, 452, 675, and 458 mm in 1984 in Bangasse, Nedogo, Dissankuy, and Diapangou respectively. The rainfall pattern in 1984 is presented in Figure 2. Both 1983 and 1984 rainfall are below the long term averages (Fig 2).

Socio-economic data collection included collection of labor times on farmers' fields for the principal agricultural activities and labor times for the two technological interventions of tied ridging and fertilization which are used in the budget analysis in Table 2. The mean man-hour equivalent labor required above weeding for tied ridging was set at 100, 75 and 75 hours/ha for manual, donkey, and ox traction. Fertilizer application required 75 and 20 man-hour equivalent hours/ha for application in the seed pocket and banding respectively. 6/

The ANOVA and economic budget analysis is presented in Table 2. Table 3 presents the means for effects of animal traction and/or tied ridges and fertilizer on sorghum yield for the 1984 campaign.

6/ The labor data are synthesized from FSU data for the years 1983 and 1984. The labor data , which was gathered on a farmer recall basis, showed a large variance among farmers. Although part of the variance comes from the problems of a farmer recall method, there is a large difference between labor times of farmers as noted by the field staff and time and motion studies carried out on a select group of farmers. For example, the additional time above weeding to tie ridges by donkey ranged from 50 to 125 hr/ha. The labor times used for the budget analysis in Table 2 represent that of a good farmer. For purposes of the economic budget analysis presented in Table 2, a composite labor figure was calculated using the following weights: one male hour ($\geq$ 15 yrs) = 1, one female hour ($\geq$ 15 yrs) = .75 and one child hour ($<$ 15 yrs) = .5.

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A survey of technology adoption by FSU cooperator farmers was conducted at the end of the 1984 campaign (Ohm et al., 1985a, p. 105). The objective of the survey was to determine the extent to which FSU cooperator farmers adopted the technologies of tied ridging, new varieties and fertilizer on their own fields. A further objective was to identify some of the key variables that distinguish adoptors of technologies from non-adoptors. The results (Tables 4 and 5) indicate that adoption rates and the average hectares of technology adoption are low. Farmers commented that the primary reason for not constructing more tied ridging was lack of sufficient labor. The financial conditions of not having the cash or not being able to obtain credit were their primary reason for not using fertilizer. Fertilizer availability was also cited as a problem. Farmers were generally hesitant about trying new varieties until they could give them a good appraisal - either on a demonstration plot or on another farmer's field.

The characteristic that consistently showed the strongest relationship to adoption in all three technology cases was farm size. Other characteristics of adoptors were cash crop area and good management skills which both exhibited a positive relationship. Farmers (households) controlling larger than average size land holdings are associated with adopting the technologies. Perrin and Winklemann (1976) found similar results with respect to farm size and the adoption of new varieties in countries where new variety introductions were recent. Underlying the size effect are the factors of economies of size

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in transactions costs of evaluating and acquiring new technologies, differences in prices for inputs and products and differences in land productivity (Perrin and Winklemann, 1976). Ruttan and Binswanger (1978, P. 387) indicate that while there were differencial rates of adoption by farm size and tenure for the adoption of HYV's in green revolution countries at the start, differences in the adoption rates for different farm size and tenure categories disappeared after a few years. The data collected and analyzed in the FSU adoption of technology survey corresponds to the vary early stages of the typical "S" shaped adoption curve and the results agree with Perrin and Winklemann and with Ruttan and Binswanger. The widespread use of new technologies in Burkina has not taken place and it is yet to be determined whether the differences in adoption rates for different farm size categories will disappear after a few years as they did in the green revolution countries.

Technology Evaluation

Evaluation Criteria

The criteria for the evaluation of the technologies of fertilization and tied ridging were as follows: 1) technical feasibility, 2) profitability/risk, 3) the "fit" of the technology within the farming system, and 4) the intra-household and inter-household relationships.

The first criteria involves answering the question of " Is the technology agronomically or technically superior to existing farm practices? ". Simple budgeting analysis is used for the

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second criteria and the percentage of farmers who would have lost cash from any of the treatments is used as an indicator of risk. With respect to the third criteria of fit, given that the technology is technically and economically feasible, it must be established whether there are other constraints in the farming system that hold back the use of the technology i.e., land (quality, quantity), labor availability, credit and the like (Sanders and Roth,1985). The fourth criteria concerns changes in intra-household and inter-household relationships from the technology intervention (McKee, 1984). Three intra-household relationships require analysis: 1) changes in the allocation of family labor, 2) intra-household resource control, and 3) the incentive structure: who benefits from and controls the output from the new technology (whether it be cash, agricultural output or more free time). Questions pertaining to inter-household dynamics involves asking whether or not the technology intervention is accessible to all households and what are the possible income distribution consequences from the adoption of the technology.

The methodology used in criteria 3 is that of linear programming (LP) which is a whole-farm modeling technique. Simple budgeting of costs and returns (criteria 2) is generally employed to evaluate the results of field trials. However, these evaluations are limited in two ways (Roth et al., 1984). First, the explicit values of land and labor in Burkina are unknown and are generally included in an ad hoc manner. Secondly, the budgeting analyses are partial, hence they ignore the

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substitutibility of inputs on the farm and how they are allocated based on the fixed endowments and implied prices of resources. New technology needs to be considered in a whole farm context (as in linear programming) to account for the effects of constraints on availabilities of land, seasonal labor, purchases of modern inputs and other interactions.

Evaluation of the Technologies

Technical Feasibility. The relative responses of sorghum yield to the four treatments were consistent across the four locations over the two years (Table 2). Treatments consisting of tied ridges to reduce surface runoff of rainfall, or fertilization to ameliorate the low fertility resulted in increased levels of sorghum yield. The analysis of variance indicated that when tied ridges were used in combination with fertilizer, statistically significant yield increases over the control were recorded at all locations for both years. 7/

Yields of sorghum were generally higher with animal traction than with manual traction. However, at Nedogo the difference was significant only for the combination of tied ridging and fertilization (Table 3). At Diapangou, sorghum yields with ox traction were not superior to those with donkey traction. It is possible that the deeper cultivation during weeding with ox traction, compared to donkey traction, accentuated the severe drought conditions in both years, especially in sandy soils with

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7/ Had new varieties been included in the treatments, the criteria would also include seedling establishment, yield stability, and yield component analysis (Matlon, 1985).

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low organic matter. In sandy soils, there exists the problem of the ties washing away under heavy rains and thus requiring extensive repair during the growing season.

The conclusions to be drawn are that the use of tied ridging alone or fertilization (at the treatment levels) alone can result in superior yields but that when used in combination, the sorghum yields are always superior. Tied ridges may not be suitable in the more sandy soils and should only be recommended in areas with soils that do not wash away easily. 8/

Profitability/Risk. The partial budget analysis (Table 2) shows that for the mean yield increases at all locations over the two years with the exception of Nedogo manual in 1983, the return/hr for labor to construct tied ridges and/or to apply fertilizer was positive. With the exception of the 1983 Treatment F in Bangasse, net returns were the largest for the combination of tied ridging and fertilization at all locations. Net returns were larger for fertilization alone than for tied ridging alone at Bangasse and for the three types of traction at Diapangou in both years. In 1984, the return/hr of additional labor for the combination of tied ridging and fertilization were larger than the return/hr of additional labor for the other treatments at Bangasse and for the two types of animal traction at Diapangou while in 1983, the return/hr was largest for fertilization at Bangasse and all Diapangou locations. With respect to the farmers' risk of losing their cash outlay, the fertilization

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8/ Of a total cultivated area of 2,005,000 hectares in Burkina Faso, it is estimated by local agronomists that about 40% is suitable for tied ridging based on land quality and rainfall levels.

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alone treatment is high at Nedogo and moderately risky at all other locations and some farmers at each location would have lost cash. The use of tied ridging in combination with fertilization substantially reduces the farmers' risk of losing cash as opposed to the fertilization alone treatment. Because tied ridging uses household labor, the tied ridging treatment does not carry the risk of losing a cash outlay. However, this option results in substantially reduced net returns when compared to the tied ridging fertilization combination and although this practice controls erosion, it cannot solve the low soil fertility problem.

The conclusions to be drawn are that tied ridging alone or fertilization alone can be profitable; however, fertilization alone carries a high risk of losing the cash outlay. Only when in combination do the two technologies provide substantial net return and return/hr of additional labor at a level of risk of losing the cash outlay that may be acceptable to farmers.

Technology "Fit". Linear programming was used to analyze the technology interventions within a whole farm context. 9/ Three models were constructed representing the three types of tillage practices on the Mossi Plateau: manual only tillage, donkey

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9/ Briefly, the linear programming (LP) farm model has the option of performing tillage operations under one of three types of tillage practices: manual, donkey and oxen. A farmer possesses four types of resources: land of various quality, family labor, animal traction, and modern inputs. Land is divided into four types: high fertility compound land, two types of sorghum land with one having better fertility and water retention capability and the fourth, the lower quality millet land. Stocks and flows of labor are dissaggregated into weekly time periods to capture the critical labor constraints at planting and first weeding. Information on the technical aspects of the tied ridging and fertilization technologies from the on-farm trials and socio-economic surveys are included in the LP model.

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traction, and ox traction. The technology interventions of tied ridges and fertilization were incorporated into the models. Tied ridging was given as an option on maize compound land and tied ridging and fertilization were options on the two types of sorghum land and on the millet land. On-farm researcher-managed trials indicated a significant maize yield response from tied ridges alone but little additional response when fertilizer was added in combination with tied ridges on compound land (Lang et al., 1984). Thus only the tied ridging option is available for maize on compound land.

Models were run for all three types of tillage. Results are only shown for the donkey traction model given the option of using the two technologies in combination and not separately (Table 6). The results of the manual tillage model indicated that the hectarage devoted to the technologies was very low. The labor constraint and the lower yields associated with manual traction precluded a significant area from being devoted to the technologies. The ox traction model showed similar results to that of the donkey traction model. When the tied ridging alone alternative is modeled, the lower yields associated with this technology as compared to the yields when used in combination with fertilizer precluded a significant hectarage from being brought into the solution. The alternative of modeling fertilizer alone was not considered because of the high risk of losing the cash outlay.

Table 6, column 1 presents the results of the donkey traction model under traditional management practices and column

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2 presents the results with the technology interventions of tied ridging (ridged with donkeys but tied by hand) and fertilization. 10/ The results indicate that tied ridges are constructed on maize on compound land and tied ridges and fertilization are used on all the red sorghum land (high quality sorghum land) and a small portion of the white sorghum land (lower quality sorghum land). The results also indicate that the new technologies do not completely displace the total hectarage under traditional management practices because of the labor constraint. Total per capita cereal production increases from 150 kgs to 186 kgs and net farm income per worker increases from 30.8 thousand CFA to 36.2 thousand CFA.

The model was run with several tied ridging labor times to examine the sensitivity of the results and take into consideration that labor times vary from farmer to farmer (as was indicated by the labor data collected in the field). Scenarios were also run with the yields of the new technologies increased by 10%. The results are presented in figure 3 showing net farm income under a range of tied ridging labor times. The results indicate that farmers who are able to construct tied ridges with

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10/ The basic structure and data of the model is outlined in Roth et al., 1984. The traditional management yields in kgs/ha and those obtained under the technology options in the donkey traction model are as follows: maize on compound land (1090 to 1730), red sorghum on high quality sorghum land (672 to 1236), white sorghum on lower quality sorghum land (472 to 913), and millet on poorer quality millet land (320 to 660). The yields are based on FSU field trial data (Lang et al, 1983 and Ohm et al, 1985).

the least amount of labor time obtain a significantly higher net return. For example, the results from the model indicate that when it takes 125 hrs/ha to construct tied ridges, no white sorghum land is devoted to the technologies and red sorghum land technology adoption is decreased to .5 ha.

The conclusions to be drawn from the LP model are that the two technologies can fit into the production system of animal traction farmers but that a labor constraint still prevents the technologies from being adopted on all the hectarage. The results also indicate that manual tillage farmers would adopt the technologies to a lesser extent than animal traction farmers.

Intra-household and Inter-household Relationships. Under traditional cultivation, men, women, and children are involved in planting, and first and second weeding. The technology interventions of constructing tied ridges and fertilization requires additional labor. The labor data collected during the field campaign indicated that the gender distribution of labor for the new tasks generally followed that of the distribution of labor for the traditional activities of planting, and first and second weeding. Thus the gender distribution of labor with the introduction of tied ridges and fertilization does not appreciably change, however the additional labor must be pulled from other tasks or leisure and/or there must be a rearrangement of tasks to fit the labor profiles. The linear programming results indicate that with traditional donkey tillage the binding labor constraints are during planting and first weeding. There is, however, some available labor in the model during second

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weeding and this labor is used for making tied ridges. Thus, the additional labor for tied ridging is pulled from non-production activities or leisure.

The technological intervention of fertilization requires a cash outlay and the fertilizer is often bought through credit. Credit is usually obtained through village credit groups whose members are predominantly male household heads (Ohm et al., 1985a) Admittance to the group requires group approval and an entrance fee. This may preclude the use of fertilizer alone or in combination with tied ridging on both men's and women's personal fields. The degree to which other economic and social features constitute barriers to entry into village credit groups requires further study. Labor is also controlled in the household. The extent to which labor would be taken away from other tasks or from work on personal fields by tied ridging and fertilization of the main fields which has priority on labor requires further study.

The main output from the technology intervention is increased agricultural output which may be used for consumption or marketed. The household heads who control the resources of production on the main fields also control the output. Other members of the household may benefit indirectly through increased consumption or cash income, but this depends on the distribution of the new production. Whether the increased output will be distributed as in the past according to current goals and objectives of the household, or will benefit only a small minority of the family remains unknown.

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Changes in inter-household distribution of income may occur from the adoption of the technology interventions. The LP results indicated that animal traction farmers will be the adoptors of the technologies to a greater degree than manual tillage farmers primarily because of the labor constraint. Manual tillage farmers may however adopt the technologies but on a smaller hectarage. Income distribution changes may also occur if all households do not have access to credit.

Modifications to the Research Program

The LP model results, the questionnaire on the adoption of technologies and farmer interviews throughout the three years of field trials clearly indicated that if the labor requirement for tied ridging could be decreased, more hectarage would be devoted to the technology. This had been communicated to other researchers within SAFGRAD and in the Fall of 1983, a Peace Corps volunteer with IITA/SAFGRAD in Burkina (Jeff Wright) started work on a prototype mechanical device to tie the ridges. The mechanical device is attached to an animal drawn cultivator with one large middle sweep and either ties the ridges as they are made or ties the ridges after the field has been ridged by making a second pass with the mechanical ridge tier attached to the cultivator. The device is essentially a paddle wheel (45 cm in diameter) with four paddles, one scraping the ground building up earth until it is tripped by the operator every 1 1/2 to 2 meters to create the tie in the ridge. When oxen are used, the ridging and tieing with the mechanical ridge tier can be done in one

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operation. Donkeys can do both operations at one time but only if they are managed well, healthy and in good condition and the soil is loose or moist. Preliminary cost estimates of the mechanical ridge tier is between 10,000 and 15,000 CFA (as compared to a cultivator at a cost of 20,000 to 25,000 CFA).

With FSU collaboration, the mechanical ridge tier is part of the national farming systems on-farm field program of Burkina. A trial with a similar protocol to the farmer-managed sorghum with tied ridges and fertilization experiment is being conducted. The treatments are as follows: 1) a control (no tied ridges), 2) tied ridging with the ridge being tied by hand, 3) tied ridging with the mechanical ridge tier at second weeding, and 4) tied ridging with the ridge tier at both first and second weeding. All treatments are fertilized with 100 kg/ha 14-23-15 and 50 kg/ha urea applied at the same times as the farmer managed sorghum trials. Yield data are not yet available but field observations indicate that they will be similar to yields obtained when the ridges are tied by hand. Labor times have been collected from the field. Ridging and tieing with the mechanical ridge tier at the same time (one pass) adds only a minimal amount of time over that of just ridging. In the model, two hrs/ha are given to this activity. If the donkey cannot do the operation in one pass, the additional time it takes to make the second pass to tie the ridges takes between 7 to 15 hrs/ha. Two people usually work with the donkey, thus the actual labor hours are doubled. In the model, 20 hrs/ha are used for a second pass. In the trials, urea is banded and covered by the ridger at second weeding instead of

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being put into pockets thus decreasing the labor requirement from 75 hr/ha to 20 hr/ha.

The LP model results using the mechanical ridge tier at second weeding are presented in Table 6. Column 3 presents the results when two passes are required (ridging first followed by tieing with the mechanical ridge tier). All the red sorghum and white sorghum land are ridged and tied including a small proportion of millet land. Column 4 presents the results when only one pass is used to ridge and tie and results in a greater proportion of millet land devoted to the technologies. Figure 4 presents net farm income under a range of labor times using the mechanical ridge tier in two passes along with two yield scenarios. The one pass option under the two yield scenarios is also presented. Substantial net farm income can be gained if the donkey is able to do the operation in one pass or if the hrs/ha it takes to do two passes can be decreased to 10 hrs/ha.

The mechanical ridge tier requires animal traction and thus similar concerns to those already expressed about the adoption of tied ridges and fertilization by manual tillage versus animal traction farmers and the intra-household and inter-household questions are relevant. However, the mechanical ridge tier may make animal traction more profitable thus more practical for adoption by present manual tillage farmers. At present, animal traction is land using allowing farmers to do more weeding and hence increase the area farmed. But through the use of the mechanical ridge tier in combination with fertilizer, animal traction can be land augmenting in that increased production can

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be obtained from increased yields/ha. This type of technology intervention is required in those areas where access to land is limited or in areas where extensification with animal traction leads farmers to farm more marginal land (Roth and Sanders, 1984).

Conclusions and Policy Recommendations

The water retention and fertility research results indicate that the combination of tied ridging and fertilizer (14-23-15 and urea) is both technically and economically superior to traditional management practices. When only one of the technologies is used, yields are constrained by the absence of the other and in the case of fertilizer alone, the risk of losing the cash outlay is very high as observed by the results in Table 2. When the two technologies are used in combination, the next constraint is labor availability. While manual farmers may adopt the two technologies on a small portion of their land, animal traction farmers are in a better position to be adoptors because they can construct tied ridges faster and better (resulting in higher yields) than manual tillage farmers. However, labor is still a constraint for animal traction farmers when the ridges are tied by hand. The results indicate that the mechanical ridge tier can decrease the labor constraint to the point where most of the staple crop land is under tied ridges.

Before farmers will adopt the tied ridges and fertilization package on a large scale and before the technologies are fully recommended, several issues must be dealt with. The first issue

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is that the technology package will be adopted to a greater extent by animal traction farmers and those animal traction farmers who have access to credit for fertilizer and the mechanical ridge tier. At present, not all members within a household or all households have access to credit or animal traction. The policy implications are that credit and animal traction programs are required to make access more readily available to those involved in agricultural production. Also, the mechanical tied ridger can make animal traction more profitable thus giving the opportunity to increase the use of animal traction in Burkina. This however would require animal traction programs on a large scale to train animals and to train farmers in management and maintenance and make animals, equipment, and credit available. At present, there are also problems of fertilizer availability outside of the cotton growing area and strategically placed distribution centers are required before fertilizer use by farmers will increase.

The field trial results indicated that tied ridges do not work as well in sandier soils especially in the more northern areas. Recommendations as to the soil types and areas that are suitable for tied ridging as well as other water retention methods (diguettes) and soil tillage practices need to be made.

The LP results indicate that tied ridging and fertilization technologies would have a better chance of being adopted if yields can be improved through plant breeding. For example, the shift in the yields by 10% in figures 3 and 4 demonstrate a significant increase in net returns. In the near future, it

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cannot be expected that farmers will be able to provide high levels of management within which the improved varieties to date do their best. The FSU research has shown that the use of an intermediate level of inputs such as tied ridging and minimal amounts of fertilizer can be profitable using local varieties. In addition to screening varieties under high management levels, it is within this intermediate input level environment that screening for better plant varieties would have the most immediate payoff.

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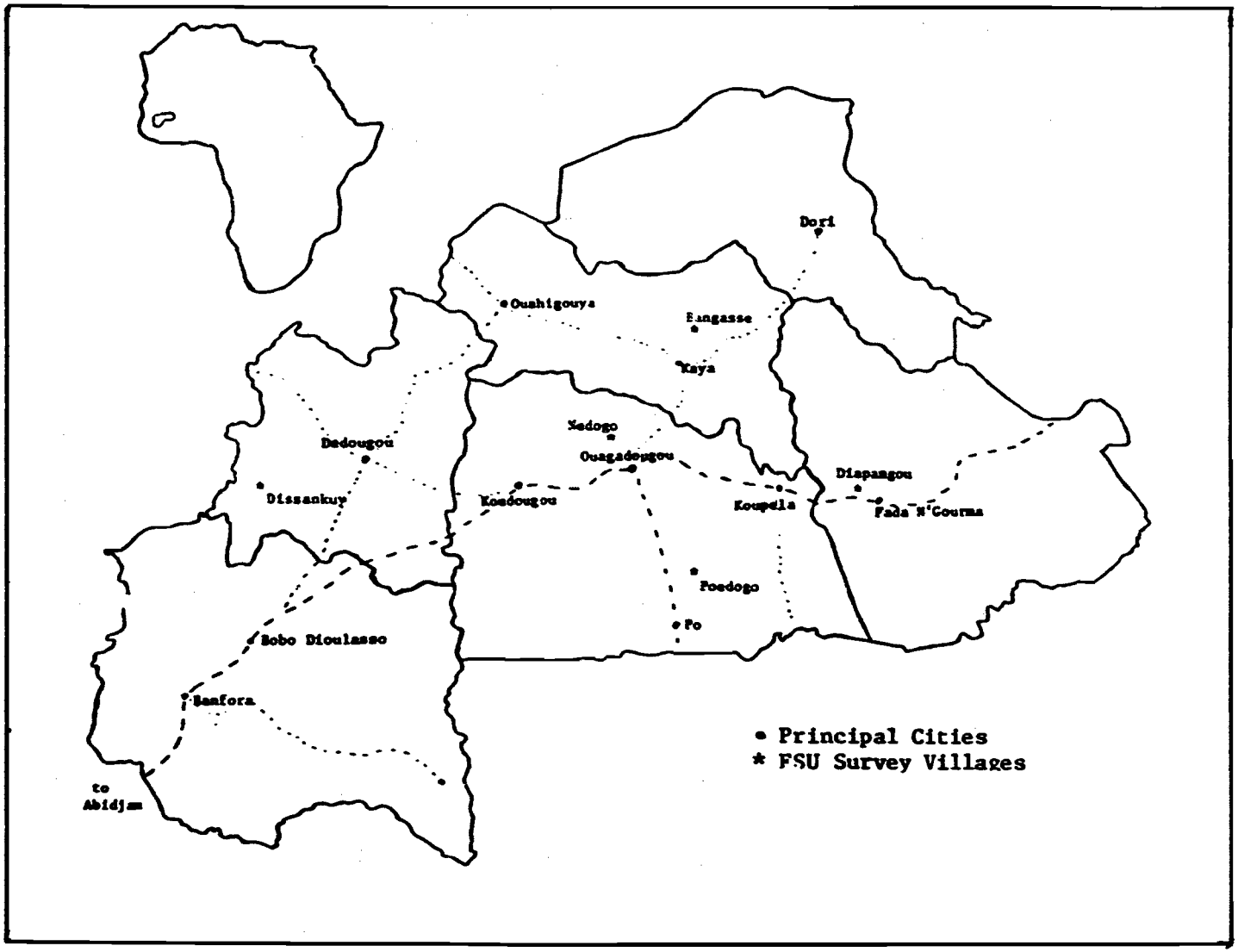

Figure 1: Map of Burkina Faso

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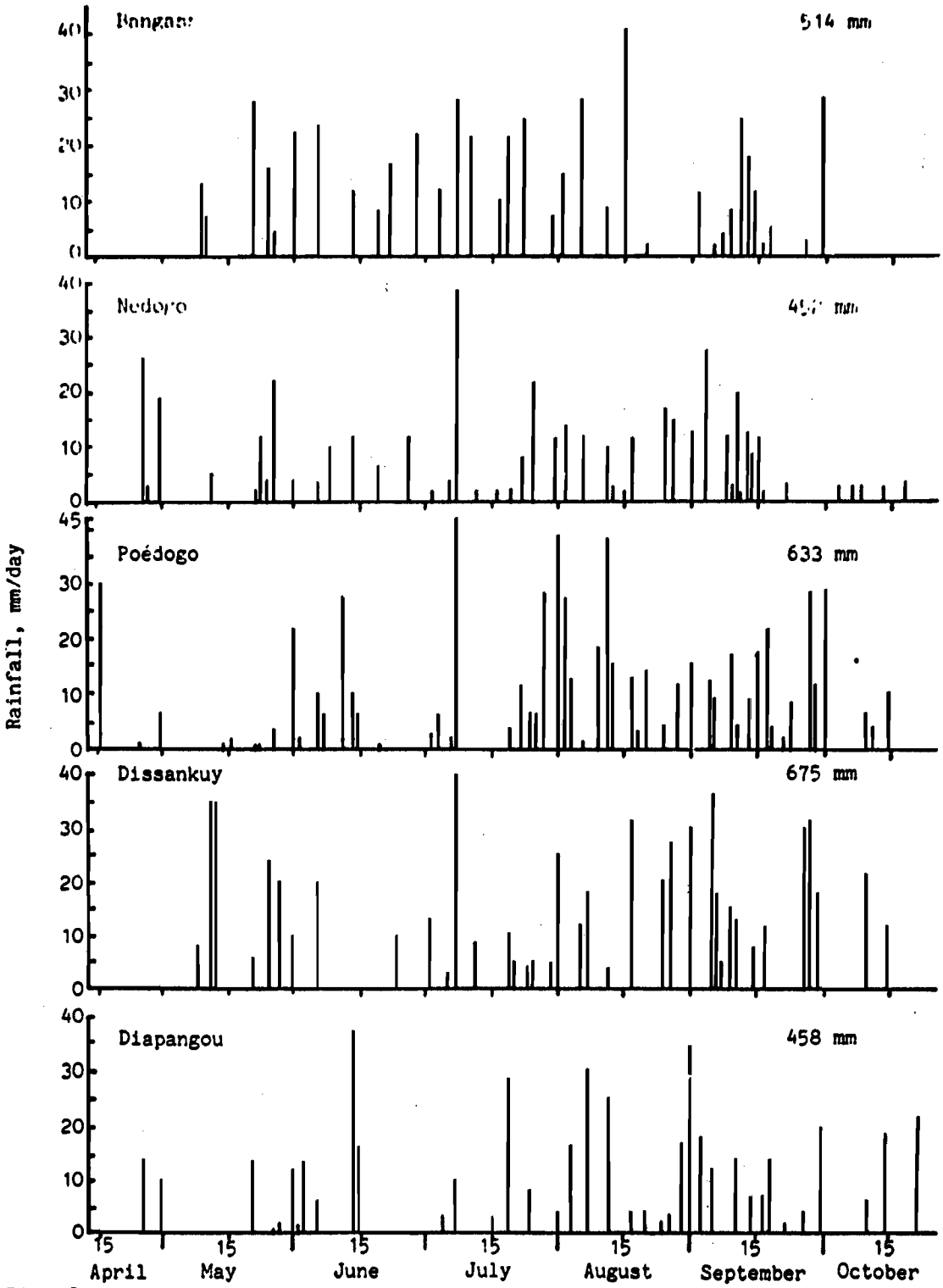

Fig. 2. Rainfall at five villages in Burkina in 1984. Total seasonal rainfall at each of the five villages is indicated near the right side of the figure. Average annual rainfall at data collection sites near the five villages (Bangasse, Nedogo, Poédogo, Dissankuy, Diapangou) are respectively (mm), the number of years of data until 1977 are in parentheses: Kaya, 703 (59); Pabre, 809 (24); Manga, 905 (29); Solenzo, 903 (18) and Fada N'Gourma 865 (58) (ICRISAT, In Press). (Source Ohm et al., 1985a)

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Table 1. Soil Characteristics of Five FSU Villages in Burkina Faso.

Village Location[1]	pH Water	Organic Matter	Base Saturation	P	K	Ca	Mg	Cation Exchange Capacity
		%		kg/ha				
Diapangou	6.7	1.07	74.6	20	307	1968	409	5.9
Dissankuy	5.9	1.79	56.7	7	230	1190	357	8.1
Bangasse	5.9	1.09	61.9	5	228	988	305	5.8
Poedogo	6.4	0.73	71.3	24	318	1250	321	4.3
Nedogo	6.3	1.01	62.3	12	273	1168	232	4.3

Source: Ohm et al. 1986. Soil nutrient content in Burkina Faso. Purdue University Research Bulletin. Forthcoming.

[1]Soil Samples taken from on-farm farmer-managed control plots in each village.

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

	Treatments 1/				4/	4/	Number of
	C	TR	F	TR.F	S.E	CV	Farmers
Nedogo, Manual Traction							
Grain Yield, kg/ha	157	416	431	652	75.1	43	11
Yield Gain Above Control, kg/ha	-	259	274	495			
Gain in Net Revenue, CFA 2/	-	23828	13275	33607			
Return/hr. of Additional Labor, CFA 3/	-	238	140	172			
% Farmers Who Would Have Lost Cash	-	0	27	9			
Nedogo, Donkey Traction							
Grain Yield, kg/ha	173	425	355	773	63.4	44	18
Yield Gain Above Control, kg/ha	-	252	182	600			
Gain in Net Revenue, CFA	-	23184	4811	43267			
Return/hr. of Additional Labor, CFA	-	309	51	255			
% Farmers Who Would Have Lost Cash	-	0	50	0			
Bangasse, Manual Traction							
Grain Yield, kg/ha	293	456	616	944	145.0	62	13
Yield Gain Above Control, kg/ha	-	163	323	651			
Gain in Net Revenue, CFA	-	14996	17783	47959			
Return/hr. of Additional Labor, CFA	-	150	187	246			
% Farmers Who Would Have Lost Cash	-	0	8	17			
Dissankuy, Ox Traction							
Grain Yield, kg/ha	447	588	681	855	35.1	19	25
Yield Gain Above Control, kg/ha	-	141	234	408			
Gain in Net Revenue, CFA	-	12972	9595	25603			
Return/hr. of Additional Labor, CFA	-	173	101	151			
% Farmers Who Would Have Lost Cash	-	0	28	0			
Diapangou, Manual Traction							
Grain Yield,kg/ha	335	571	729	1006	48.4	23	19
Yield Gain Above Control, kg/ha	-	236	394	671			
Gain in Net Revenue, CFA	-	21712	24315	49799			
Return/hr. of Additional Labor, CFA	-	217	256	255			
% Farmers Who Would Have Lost Cash	-	0	26	0			
Diapangou, Donkey Traction							
Grain Yield, kg/ha	498	688	849	1133	45.6	18	19
Yield Gain Above Control, kg/ha	-	190	351	635			
Gain in Net Revenue, CFA	-	17480	20359	46487			
Return/hr. of Additional Labor, CFA	-	233	214	273			
% Farmers Who Would Have Lost Cash	-	0	21	0			
Diapangou, Ox Traction							
Grain Yield, kg/ha	466	704	839	1177	46.8	18	19
Yield Gain Above Control, kg/ha	-	238	373	711			
Gain in Net Revenue, CFA	-	21896	22383	53479			
Return/hr. of Additional Labor, CFA	-	292	236	315			
% Farmers Who Would Have Lost Cash	-	0	5	0			

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

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

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

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

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Table 2 (con't). Economic analysis of farmer managed trials of sorghum with fertilizer and tied ridges, 1983.

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

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

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

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

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

Table 3. Means for effects of animal traction and/or tied ridges and fertilization on grain yield of sorghum grown at five villages in Burkina Faso in 1984[1].

Treatments	Mean grain yield			
	Nedogo	Bangasse	Dissankuy	Diapangou
	kg/ha			
Traction				
Manual	414.3	—	—	660.2
Donkey	497.6	—	—	792.1
Ox	—	—	—	797.0
SE[2]	39.1	—	—	72.9
TR[3] F[4]				
Control[5]	185.5	293.1	447.0	433.0
TR	446.1	456.0	587.7	654.5
F	441.2	615.8	680.8	805.6
TR and F	750.9	943.6	855.4	1105.6
SE[2]	78.1	145.2	35.1	51.7
CV%	56.8	61.6	19.3	36.8
N[6]	11	12	25	19

[1]Local varieties of white sorghum at Nedogo, Bangasse and Dissankuy, and a mixture of local millet (85%) and local white sorghum (15%) at Diapangou.
[2]Standard Error of the difference between two treatment means.
[3]TR = tied ridges, constructed one month after planting.
[4]F = fertilization, 100 kg/ha cotton fertilizer, 14-23-15, was applied in a band at 10 to 15cm from the rows of sorghum two weeks after planting and 50 kg/ha urea was applied in pockets at 10 to 15cm from seed pockets one month after planting.
[5]Without tied ridges or fertilization.
[6]The number of farmers' fields, replications, on which the experiment was grown.

Source: Ohm et al., 1985a, p. 12.

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	Varieties
Nedogo	5	69	25	10	10
Bangasse	3	53	23	0	0
Poedogo	2	27	4	33	41
Dissankuy	2	60	3	97[2]	0
Diapangou	3	61	25	8	8

[1]Number of years FSU in village; 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.

Source: Ohm et al, 1985b.

Table 5. 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

Source: Ohm et al., 1985b.

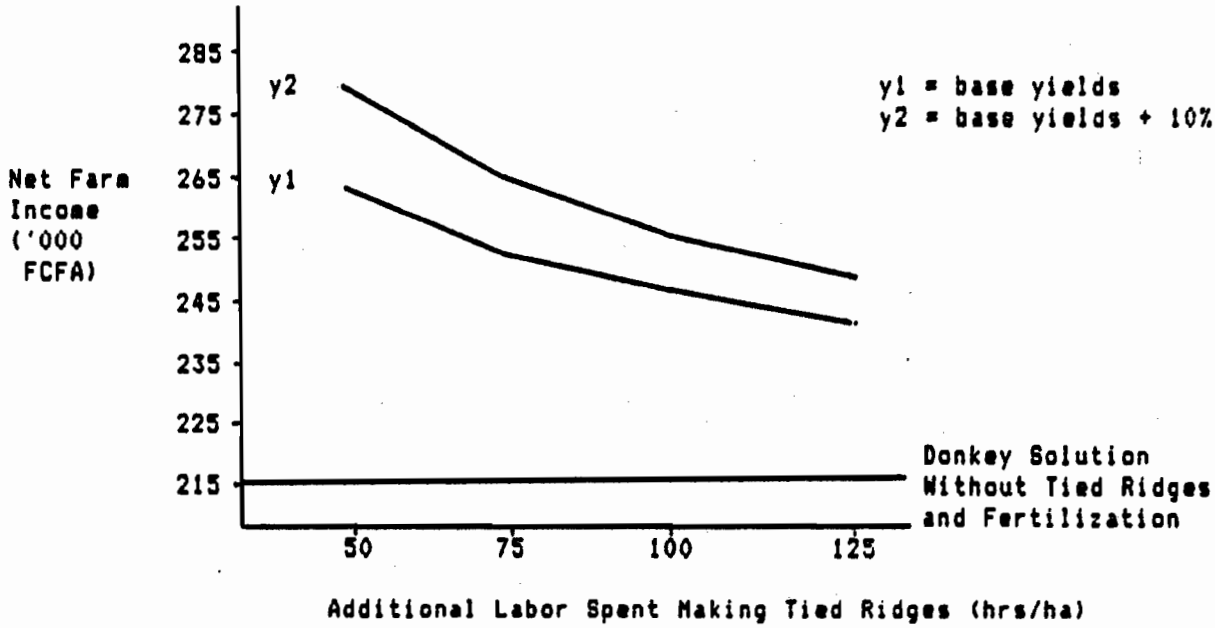

Figure 3. Effect of various yields and labor spent on tied ridging by hand on net revenue of the farm on the Central Plateau.

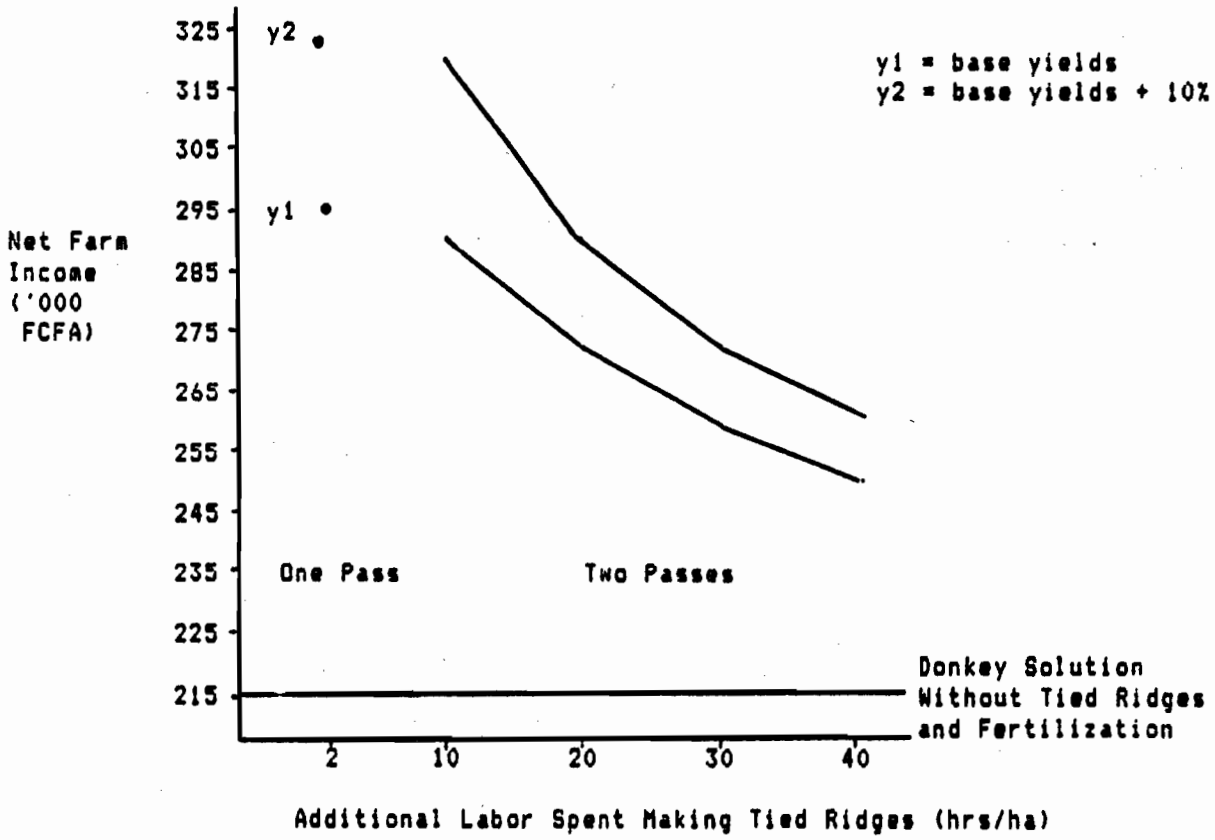

Figure 4. Effect of various yields and labor spent on tied ridging with machine on net revenue of the farm on the Central Plateau.

Table 6. Effect of Tied Ridging Technologies with Donkey Traction on Area Cultivated, Production and Net Farm Income Estimates, Central Plateau

Variable	Traditional Management (Donkey)	Tied-Ridging Technology a/		
		Tied by Hand	Tied With Machine	
			Two Passes	One Pass
Total Area Cultivated (ha)	5.5	5.6	5.7	5.6
Maize				
Traditional	.20			
With Tied Ridges		.20	.15	.15
Red Sorghum				
Traditional	.60			
With Tied Ridges		.60	.68	.60
White Sorghum				
Traditional	.80	.70		
With Tied Ridges		.10	.80	.95
Millet				
Traditional	3.18	3.15	3.18	1.88
With Tied Ridges			.05	1.27
Peanuts	.76	.86	.79	.71
Fertilizer (kgs/farm)				
Urea		45	84	149
Cotton Fertilizer		90	168	298
Total Cereals Production (kgs)				
Per Household	2103	2604	2970	3354
Per Resident b/	150	186	212	240
Net Farm Income ('000 FCFA) c/				
Per Household	215.3	253.2	273.2	296.4
Per Worker d/	30.8	36.2	39.0	42.3

a/ Based on 50 kg/ha Urea and 100 kg/ha Cotton Fertilizer, labor times of 75 hrs/ha for Tying the Ridges by Hand, 20 hrs/ha for Machine--Two Passes, and 2 hrs/ha for Machine--One Pass. Yield estimates are given in text.
b/ Based on 14 residents/household.
c/ Annualized cost of 4,400 FCFA for Tied-Ridging Machine subtracted in columns 3 and 4.
d/ Based on 7 active workers/household.