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FARMING SYSTEMS RESEARCH UNIT IN BURKINA FASO

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I. INTRODUCTION

A. Program Goals

The goals of the Farming Systems Unit (FSU) are the following:

1) To identify the principal constraints to increased food production in Semi-Arid West Africa,
2) To identify technologies appropriate for farmers in Semi-Arid West Africa which can minimize the production constraints,
3) To develop and implement a multidisciplinary research method which can guide production technology and production research to directly address these production constraints,
4) To identify the elements of that method which can be implemented in national farming systems research programs, and
5) To train host country personnel to assume increasing responsibility in the continuation of this research.

B. Previous Findings

Burkinabe farmers, like most farmers throughout Semi-Arid West Africa, are largely subsistence farmers (FSU/SAFGRAD, 1982). They are risk averse and work on a deteriorating soil resource base and rainfall is minimal and unpredictable. Amelioration of the soil base is imperative if it is to continue to support the current population, particularly on the Central Plateau.

The preferred cereal crops, sorghum and maize, have greater yield variability than the principal cereal crop, millet. Risk is an obstacle to expanded culture of the preferred crops, particularly when cash imputs are required. Technologies should maximize the use of non-purchased inputs, still using minimal applications of purchased inputs. Technologies should be designed to minimize risk associated with the use of cash inputs.

Promising technologies include:

1) Construction of tied ridges[1] resulting in catchment basins to reduce rainfall runoff and thereby increase the amount of water available to the plants,

2) Application of chemical fertilizers and manure,

3) Culture of improved crop varieties.

Tied ridges can be constructed at various periods of the growing season. However, maximum yield effects would be expected if tied ridges were constructed at or immediately after planting, but farmers have said this conflicts with their planting strategies (planting of millet and sorghum as early in the season as possible and as soon as possible after a rain). Because of labor constraints and small plant size, farmers are generally reluctant to construct tied ridges prior to the second or final weeding. Construction of tied ridges at first weeding requires additional labor inputs at a time when labor is limited. Labor is slightly more available during the second weeding period, four to six weeks after planting (FSU/SAFGRAD, 1982).

A device devised by Jeff Wright, U.S. Peace Corps Volunteer with IITA, which can be attached to a butteur or ridger to construct the tied ridges during weeding, appears promising for farmer acceptance of the practice of tied ridging because it would reduce labor requirements. This may also promote the use of animal traction.

We have shown that tied ridges without fertilizer can result in positive economic returns for sorghum and maize which are generally grown on soils which are more productive than those on which millet is grown. Response to tied ridges without fertilization on millet has not been as promising as on sorghum and maize.

Volta phosphate plus urea without tied ridges on millet has not resulted in profitable economic returns. Cotton fertilizer, 14-23-15, plus urea on sorghum did result in profitable economic returns. However, sorghum yield response to fertilization alone is more variable and therefore involves the risk of losing the cash cost of the

1. The technique of tied ridging consists of creating a small depression between the crop rows either by hand tillage or animal traction. If done by hand tillage, depressions (32 cm long x 24 cm wide x 16 cm deep) are made between rows and spaced 1 1/2 meters apart. If done by animal traction, the cultivator must be equipped with a middle sweep to create a furrow, then followed by hand tillage to make a 16 cm high ridge perpendicular to the furrow every one to two meters.

fertilizer. The fertilization alone alternative is thus more risky than a tied ridging without fertilization alternative. The combination of tied ridging and fertilization consistently resulted in profitable economic returns (Lang, et al, 1983).

Tied ridging and fertilization are land substituting strategies which increase yields and labor utilization. Chemical fertilizer requires increased cash expenditures and therefore includes the risk of not covering the fertilizer cost. Tied ridges enable improved water conservation and when in combination with fertilization reduce the yield variability over the alternative of fertilization alone thus reducing the risk of losing the fertilizer cash costs.

By putting all the components of water retention, fertilization and animal traction together in a whole farm modeling analysis, substantial increases to household incomes can be shown (Roth and Sanders 1984). The combined effects of water retention, fertilization and animal traction were necessary. Introduction of these agronomic inovations creates a substantially improved environment in which there can be a high return to improved varieties of cereal grain crops. Because of the extensive acreage of millet in Semi-Arid West Africa, the whole-farm modelling analysis emphasized the importance of intensifying the search for improved agronomic technology for millet on the poorer soils (Roth and Sanders, 1984).

The necessity to introduce at least minimal quantities of purchased inputs to increase agronomic productivity suggested the need to determine the circumstances under which farmers could be expected to use cash inputs to intensify production. Indicators of the degree of commercialization of farmers include the amount of grain sales and cash cropping. The best predictor of grain sales, cash cropping and per capita grain consumption is, within a given agroclimatic zone, the number of hectares of crop land per capita in the household (Lang, et al, 1983). Managerial skill, land quality, level of farming effort and other factors undoubtedly contribute, but access to land and capital for expansion are the most critical determinants of commercial farming activity.

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The above findings have implications for design of agronomic trials and for economic research by FSU/SAFGRAD, and for land use policy in Burkina. Research on access to land and credit is needed to better understand farmers' options and therefore, the kinds of technologies that fit their circumstances. If farmers have access to both land and credit, they will extensify unless alternative technologies with intensification effects are competitive. Given existing intensification alternatives, the marginal return to extensification is higher and offers the expansion path that the rational farmer would logically follow. Farmers with access to credit but without access to land are more likely to find technologies, including tied ridges and fertilization, attractive (Lang, et al, 1983).

C. Objectives and Scope of Research Activities in 1984.

Agronomic and socio-economic research were conducted in five villages (Bangasse, Nedogo, Poedogo, Diapangou and Dissankuy) which represent a wide range of agroclimatic zones and agricultural productivity. Bangasse is 15 km northwest of Kaya, Nedogo is 30 km northwest and Poedogo is 130 km southeast of Ouagadougou. The three villages are on the densely-populated Central Plateau. There is very little animal traction at Bangasse whereas about half of the farmers in Nedogo and all of the farmers in Poedogo utilize donkey traction. Diapangou and Dissankuy are the most prosperous of the five villages. Diapangou is located 210 km east of Ouagadougou and is land abundant. Farmers in Diapangou practice shifting cultivation. Donkey and ox traction are widely utilized and some farmers practice cultivation manually. Dissankuy is 120 km north of Bobo-Dioulasso. Land is abundant and about half of the farmers practice manual tillage while the remainder use ox traction. Dissankuy is a net grain exporting village and produces cotton on about 15 percent of the cultivated land.

In each village, a census was taken to identify all households (Lang, et al, 1983). From this census, a random sample of 30 households was selected. This sample was used as the base for socio-economic surveys which were designed to identify production constraints and to understand the farmers' decision-making environment.

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In addition, questionnaires have been conducted to clarify possible constraints to increased production from the use of the technologies that FSU works with. In 1984, FSU conducted questionnaires on land-tenure and informal and formal credit. The questionnaires were in response to the findings in the 1983 FSU Annual Report that Farmers would extensify given available land and credit to purchase animals and equipment for traction. However when land becomes a limiting factor both in quantity and in quality as it is now on the Central Plateau, the alternatives are either migration or the use of intensive type technologies of the kind FSU works with. The purpose of the questionnaires were to explore the constraints that the present land tenure and credit systems may pose for the adoption of intensive type technologies.

A questionnaire was also conducted with the purpose of finding out what types of new technologies FSU farmer cooperators have adopted and the extent of the adoption. Farmers were also asked to comment on the benefits and problems with the new technologies.

Previous findings determined the agronomic research program for 1984. We repeated certain agronomic experiments which had been conducted in 1983 and 1982 to strengthen the data base from which to draw conclusions about the technologies. Agronomic experiments focused on evaluation of four types of technologies:

1) Water conservation by tied ridging to capture water and reduce rainfall runoff and thereby increase the amount of water available to the plants,
2) Amelioration of soil fertility by applications of minimal amounts of manure and/or chemical fertilizers,
3) Cereal-legume crop associations to reduce production risks and to benefit from the nitrogen fixed by the legume, and
4) Testing of new crop varieties.

We tested combinations of these four technologies in five farmer-managed and seven researcher-managed trials to determine the potential of the technologies under farmer-managed and/or researcher-managed on-farm conditions.

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II. AGRONOMIC TECHNOLOGY EVALUATION

A. General Crop Conditions

Total rainfall for 1984 at all villages was significantly below long-term seasonal average rainfall (Fig. 1). At Bangasse, the rains began early in the season and continued regularly until 15 August. Crops were seeded early, beginning at the end of May. Crop growth was good and symptoms due to low soil nitrogen were widely apparent in cereal crops. However, absence of rainfall after 15 August resulted in severe drought stress during flowering. Most maize fields produced no harvest. Based on discussions with farmers, millet yield was estimated by FSU field staff at 45% of normal and white sorghum yield was estimated at 65% of normal.

At Nedogo, rains arrived early in the season and some fields were seeded early, at the end of May. Throughout the season, rainfall was very limited but occurred regularly and was adequate for fair crop growth. Many fields were reseeded. Maize, millet and white sorghum yields were estimated at 35, 55 and 30% of normal, respectively.

Because of the absence of and the poor distribution of rainfall at Poedogo, seeding started late, at the beginning of June, and continued until mid-July. Fields which were seeded early, were subjected to severe drought during June and early July. Many maize plants did not survive. However, beginning mid-July, rainfall was excellent and continued until mid-October. Maize, millet and red sorghum yields were estimated at 40, 120 and 105% of normal, respectively.

At Dissankuy several early season rains occurred. However, no rainfall occurred for nearly a month in June, and many fields either were not seeded until July or had to be reseeded in early July. Maize, millet and white sorghum yields were estimated at 30, 70 and 80% of normal, respectively.

At Diapangou, rainfall was very infrequent until mid-July. Seeding of fields occurred from mid-June to mid-July and plant population densities were irregular and low in most fields. Small, but frequent rainfall during September and October resulted in normal millet yields. Maize and millet

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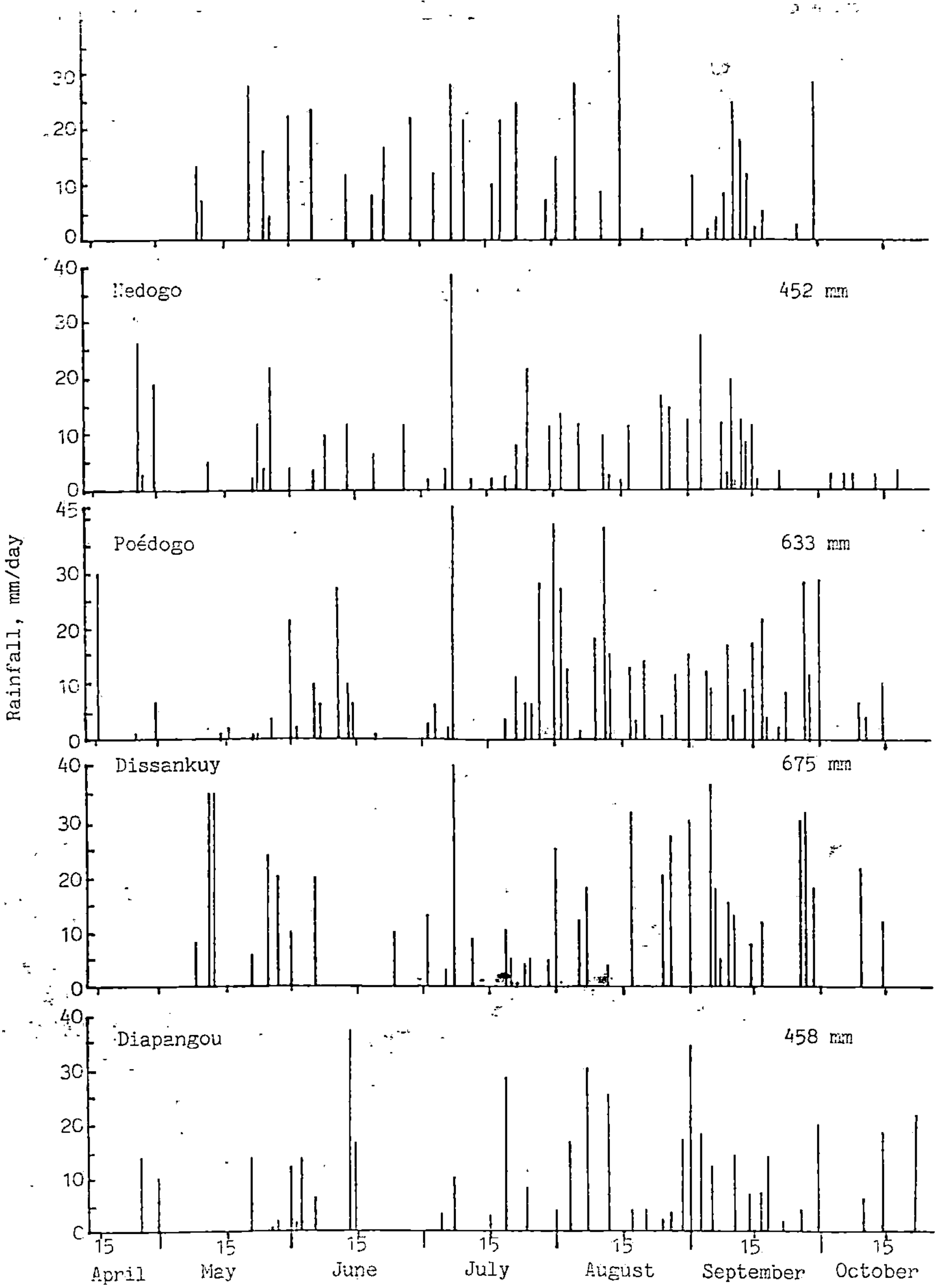

Fig. 1. Rainfall at five villages in Burkina in 1984. Total seasonal rainfall at each of the five villages is indicated near the right side of the figure. Average annual rainfall at data collection sites near the five villages (Bangasse, Nedogo, Poédogo, Dissankuy, Diapangou) are respectively (mm), the number of years of data until 1977 are in parentheses: Kaya, 703 (59); Pabre, 809 (24); Manga, 905 (29); Solenzo, 903 (18) and Fadà N'Gourma 865 (58) (ICRISAT, In Press).

yields were estimated at 10 and 100% of normal, respectively. In mid-October a severe wind storm caused most millet and sorghum plants to lie nearly flat. Some seeds sprouted in the spikes before harvest.

B. Farmer-Managed Trials

Methodology. Farmer-managed trials were designed to permit agronomic and economic analysis required to evaluate the adequacy and the profitability of technologies when used by farmers. The trials focused on three technology themes:

1) Construction of tied ridges to reduce surface runoff of rainfall and thereby increase the amount of water available for the plants,
2) Use of minimal amounts of fertilizers to improve soil fertility, and
3) Testing of new crop varieties.

Five experiments were conducted on fields of up to 25 randomly chosen farmers in each of one to five villages. The number of treatments for each experiment was five or less. Each treatment was randomly assigned to a parcel of the farmer's field. Parcel size ranged from 0.05 to 0.12 ha, depending upon the size of the farmer's field. The one parcel of each treatment in each farmer's field was considered as an observation.

The farmers managed and carried out the experiments and were responsible for all labor inputs. Prior to seeding, FSU field staff stationed in each village delineated each parcel with colored stakes and measured the area of all parcels. FSU field staff frequently visited the farmers to ensure that seeding, application of fertilizer, construction of tied ridges and other tasks were effected correctly and on time. Labor inputs by the farm families were recorded each week by FSU staff on a farmer-recall basis. Prior to harvest, FSU staff evaluated all parcels for general conditions of the crop. Farmers harvested all parcels. FSU staff weighed the harvest from all parcels.

The economic analysis required labor data, prices of grains and fertilizers and agronomic data. The labor data requirements were the number of hours of labor it took to construct tied ridges and apply fertilizer. For tied ridges, the values of 100, 75 and 75 hours of labor per hectare were used for manual labor, donkey traction and ox traction respectively.

Because tied ridges are constructed in combination with a weeding operation, the above figures express the additional time necessary to tie the ridges above that required for the weeding operation. Fertilizer application required 20 additional hours of labor per hectare. The labor hour figures are all expressed on a man hour equivalent basis weighted as follows; one male hour ($\geq$ 15 yrs) = 1, one female hour ($\geq$ 15 yrs) = 0.75 and one child hour (< 15 yrs) = 0.5. The labor data are synthesized from FSU data from the years 1983 and 1984. The labor data, which was gathered on a farmer recall basis, showed a large variance and with the help of the field staff, the data was carefully screened to arrive at the figures. A 40 CFA/hr opportunity cost for farmers' labor is used in comparing the economic return/hr of the additional labor required to construct tied ridges and/or apply fertilizer. This figure represents a best estimate of the opportunity cost based on field staff observations. Grain prices are the official OFNACER prices in the fall of 1984. The prices are 92 CFA/kg for sorghum, millet and maize. The fertilizer prices are the official prices in the spring of 1984. The prices are 78 CFA/kg for 14-23-15, 66 CFA/kg for urea and 25 CFA/kg for volta phosphate.

EXPERIMENT 1: Effects of Tied Ridges and Fertilizer on Sorghum

Description. The objective was to estimate returns from the investment in the construction of tied ridges and fertilization on sorghum.

The experiment was conducted at Nedogo with manual traction and donkey traction, at Bangasse with manual traction, at Dissankuy with ox traction and at Diapangou with manual, donkey and ox traction. The four treatments were the following: traditional management practices including flat cultivation and no fertilization, the control; construction of tied ridges at one month after seeding and no fertilization; flat cultivation and 100 kg/ha of cotton fertilizer, 14-23-15, applied in a band 10-15 cm from the rows of sorghum two weeks after seeding plus 50 kg/ha of urea, applied in pockets 10-15 cm from the seed pockets one month after seeding; and construction of tied ridges as described above, plus fertilization as described above. Locally grown varieties of sorghum were utilized.

The experiment was conducted at Dissankuy for the first time in 1984. At Nedogo, Bangasse and Diapangou the experiment was grown in 1983, and in 1984, treatments were assigned to the same parcels as in 1983.

At Bangasse and Dissankuy, the experimental design was a randomized complete block. Farmer's fields were 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.

Results and Discussion. The relative responses of sorghum to the four treatments was consistent across the four villages; Nedogo, Bangasse, Dissankuy and Diapangou (Table 1). Treatments consisting of tied ridges to reduce surface runoff of rainfall, or fertilization to ameliorate the low soil fertility resulted in intermediate levels of sorghum yield. However, consistently the greatest yield response was achieved with the combination of tied ridges and fertilization.

Yields of sorghum were generally higher with animal traction than with manual traction (Figs. 2 and 3). However, at Nedogo, the difference was significant only for the combination of tied ridges and ferti-

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Table 1. 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 15 cm from the rows of sorghum two weeks after planting and 50 kg/ha urea was applied in pockets at 10 to 15 cm 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.

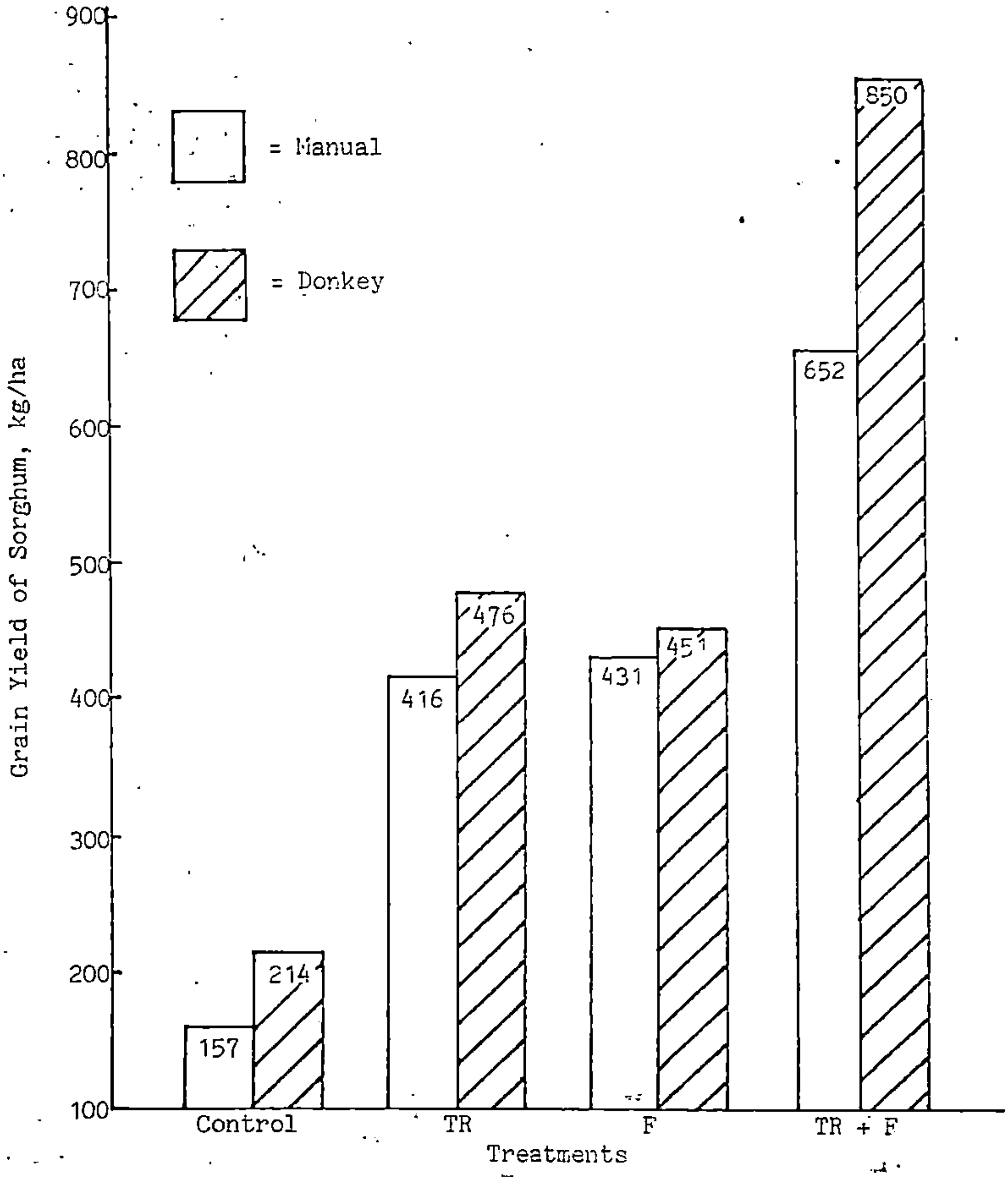

Fig. 2. Effects of tied ridges (TR) and fertilizer on yield of sorghum cultivated manually or with donkey traction at Nedogo in 1984. Treatments were as follows: no TR or F, the control; construction of TR one month after seeding and no F; F (100 kg/ha of 14-23-15 applied in a band 10 to 15 cm from the rows of sorghum two weeks after seeding plus 50 kg/ha urea applied in pockets 10 to 15 cm from the seed pockets one month after seeding) and no TR; and TR plus F as above. The standard error of the difference between the four treatment means is 75 kg/ha for manual traction and 63 kg/ha for donkey traction. The standard error of the difference between manual and donkey traction is 39.1 kg/ha. The number of observations of each treatment is 11.

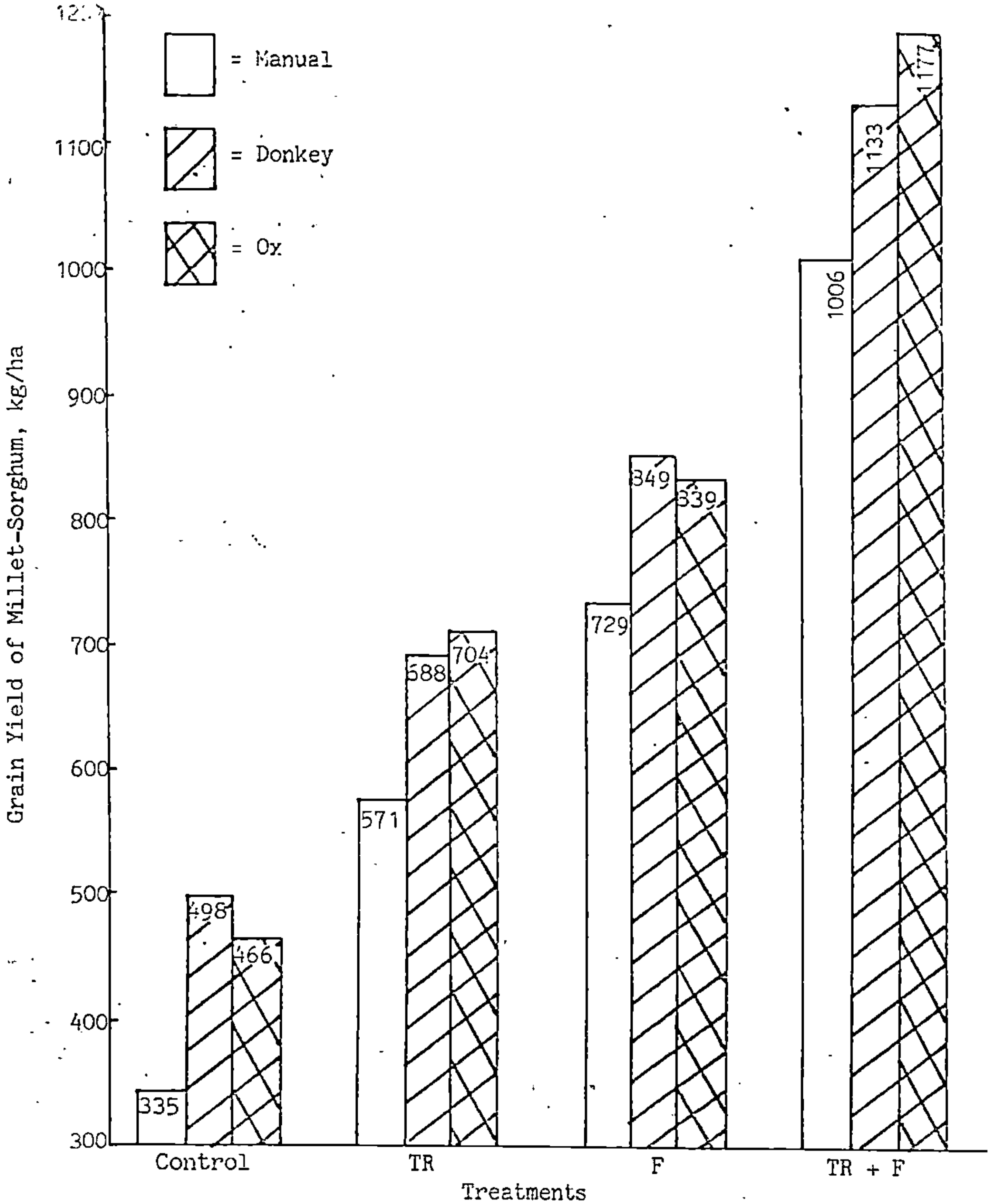

Fig. 3. Effects of tied ridges (TR) and fertilizer (F) on yields of millet (85%) - sorghum (15%) cultivated manually, with donkey traction or with ox traction at Diapangou in 1984. Treatments were the following: without TR or F, the control; construction of TR one month after seeding, without F; F (100 kg/ha 14-23-15 applied in a band at 10 to 15 cm from rows of millet-sorghum two weeks after seeding plus 50 kg/ha urea applied in pockets at 10 to 15 cm from seed pockets one month after seeding) without TR; and TR plus F. The standard error of the difference between two treatment means within manual, donkey, or ox traction are respectively: 48, 45 and 47 kg/ha. The standard error of the differences between the three types of traction is 40 kg/ha. The number of observations of each treatment is 19.

lization. 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 1984 especially in sandy soils with low organic matter.

The economic analysis (Table 2) shows that for the mean yield increases at all locations, the return/hr for labor inputs to construct tied ridges and/or to apply fertilizer is substantially above the 40 CFA/hr opportunity cost of labor. The combination of tied ridging and fertilization resulted in the largest net returns 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. With respect to risk, tied ridging alone carries no risk of losing cash. However, the fertilization alone treatment is moderately risky and some farmers would have lost cash at all locations. The use of tied ridging in combination with fertilization substantially reduces the farmers' risk of losing cash over the fertilization alone treatment. When tied ridges and fertilizer are combined, only 9% of the farmers at Nedogo with manual traction and 17% of the farmers at Bangasse with manual traction would have lost cash. Only at these two locations is the tied ridging-fertilization combination a greater risk than tied ridges alone. However, the low-risk tied ridging option results in substantially reduced net returns and labor returns/hr when compared with the tied ridging-fertilization combination.

EXPERIMENT 2: Effects of Tied Ridges on Maize.

Description. The objective was to evaluate the effects of tied ridges on the yield of maize grown on compound fields. Compound fields, on which maize is usually grown, are relatively well fertilized with manures and organic wastes, and rainfall is usually the most limiting constraint. The experiment was conducted at Nedogo with donkey traction, Bangasse and Poedogo with manual traction, Dissankuy with ox traction, and at Diapangou with manual and ox traction. Local varieties of maize were utilized.

The two treatments were the following: traditional management practices including flat cultivation (without tied ridges) and construction of tied ridges one month after seeding. It was planned that half of the farmers at Poedogo and Dissankuy (villages at which mulch was most available) were to apply mulch at 5 T/ha to one of the two parcels after construction of tied ridges. It was reasoned that farmers would have access to sufficient mulch for one-half of their compound maize field which is usually very small in area. However, only four farmers at Poedogo and two farmers at Dissankuy had access to sufficient mulch. We abandoned the application of mulch, although these six farmers did apply the mulch.

The experiment was grown at Poedogo and Dissankuy for the first time in 1984. At Nedogo, Bangasse and Diapangou the experiment was grown in 1983, and in 1984. In 1984, treatments were assigned to the same parcels as in 1983 to capitalize on residual soil water which might be present as a result of tied ridges in 1983.

At Nedogo, Bangasse, Poedogo and Dissankuy the experimental design was a randomized complete block. Farmers' fields were replications. At Diapangou, the experimental design was a split-plot with whole units (types of traction) arranged in a completely randomized design and treatments were the subunits. The statistical significance of differences between maize yield means of the two treatments (flat cultivation and tied ridges) was determined by the t-test on pairs of observations. A pair of observations, the yield for maize with flat cultivation and the

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

	Treatments 1/ C	TR	F	TR,F	S.E. of Difference Between 2 Treatment Means	Number of Farmers
		Nedogo, Manual Traction				
Grain Yield, kg/ha	157	416	431	652	75.1	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	664	280		
% Farmers Who Would Have Lost Cash	-	0	27	9		
		Nedogo, Donkey Traction				
Grain Yield, kg/ha	214	476	451	849	63.4	11
Yield Gain Above Control, kg/ha	-	262	237	635		
Gain in Net Revenue, CFA	-	24104	9871	46487		
Return/hr. of Additional Labor, CFA	-	321	494	489		
% Farmers Who Would Have Lost Cash	-	0	36	0		
		Bangasse, Manual Traction				
Grain Yield, kg/ha	293	456	616	944	145.0	12
Yield Gain Above Control, kg/ha	-	163	323	651		
Gain in Net Revenue, CFA	-	14996	17783	47959		
Return/hr. of Additional Labor, CFA	-	150	889	400		
% Farmers Who Would Have Lost Cash	-	0	8	17		
		Dissankuy, Ox Traction				
Grain Yield, kg/ha	447	588	681	855	35.1	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	480	270		
% Farmers Who Would Have Lost Cash	-	0	28	0		
		Diapangou, Manual Traction				
Grain Yield,kg/ha	335	571	729	1006	48.4	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	1216	415		
% Farmers Who Would Have Lost Cash	-	0	26	0		
		Diapangou, Donkey Traction				
Grain Yield, kg/ha	498	688	849	1133	45.6	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	1018	489		
% Farmers Who Would Have Lost Cash	-	0	21	0		
		Diapangou, Ox Traction				
Grain Yield, kg/ha	466	704	839	1177	46.8	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	1119	563		
% 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 20 additional hours/ha.

EXPERIMENT 2: Effects of Tied Ridges on Maize.

Description. The objective was to evaluate the effects of tied ridges on the yield of maize grown on compound fields. Compound fields, on which maize is usually grown, are relatively well fertilized with manures and organic wastes, and rainfall is usually the most limiting constraint. The experiment was conducted at Nedogo with donkey traction, Bangasse and Poedogo with manual traction, Dissankuy with ox traction, and at Diapangou with manual and ox traction. Local varieties of maize were utilized.

The two treatments were the following: traditional management practices including flat cultivation (without tied ridges) and construction of tied ridges one month after seeding. It was planned that half of the farmers at Poedogo and Dissankuy (villages at which mulch was most available) were to apply mulch at 5 T/ha to one of the two parcels after construction of tied ridges. It was reasoned that farmers would have access to sufficient mulch for one-half of their compound maize field which is usually very small in area. However, only four farmers at Poedogo and two farmers at Dissankuy had access to sufficient mulch. We abandoned the application of mulch, although these six farmers did apply the mulch.

The experiment was grown at Poedogo and Dissankuy for the first time in 1984. At Nedogo, Bangasse and Diapangou the experiment was grown in 1983, and in 1984. In 1984, treatments were assigned to the same parcels as in 1983 to capitalize on residual soil water which might be present as a result of tied ridges in 1983.

At Nedogo, Bangasse, Poedogo and Dissankuy the experimental design was a randomized complete block. Farmers' fields were replications. At Diapangou, the experimental design was a split-plot with whole units (types of traction) arranged in a completely randomized design and treatments were the subunits. The statistical significance of differences between maize yield means of the two treatments (flat cultivation and tied ridges) was determined by the t-test on pairs of observations. A pair of observations, the yield for maize with flat cultivation and the

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yield for maize with tied ridges, was obtained from each farmer's field. A t-test value at the 0.2, 0.05 or 0.001 level of probability indicates that one can be 80, 95 or 99% certain that the two treatment means are different.

Results and Discussion. Because of drought conditions which were particularly damaging to maize in 1984, several farmers in each village failed to construct the tied ridges and these fields were abandoned. This resulted in a limited number of observations for treatments. Although the number of observations was less than desired, the results show that at all villages, representing a wide range of yield levels, maize with tied ridges produced greater yields than maize without tied ridges (Table 3).

At Diapangou the experiment was grown with manual traction and with ox traction (Fig. 4). With both types of traction, yields of maize with tied ridges were significantly greater than yields of maize without tied ridges. Maize with ox traction produced significantly greater yields than maize with manual traction.

The economic analysis presented in Table 4 shows that in all trials, the mean yield increase from constructing tied ridges compared to that of flat cultivation results in labor returns/hr which are much greater than the 40 CFA/hr opportunity cost of labor. The percentage of farmers not covering their labor opportunity cost is moderately high at the Nedogo, Poedogo and Diapangou manual traction locations. Assuming farm labor can earn 40 CFA/hr in other employment opportunities, some farmers would have been better off doing so at all locations with the exception of ox traction at Diapangou. The results however do emphasize the value of water conservation by the construction of tied ridges on the fertile compound fields where maize is grown.

Table 3. Means for effects of animal traction and/or tied ridges on local maize varieties grown on compound fields at five villages in Burkina Faso in 1984.

Treatments	Mean Grain Yield				
	Nedogo	Bangasse	Diapangou	Pcedogo	Dissankuy
	kg/ha				
Traction					
Manual	—	—	584.6	—	—
Ox	—	—	1337.6	—	—
SE[1]			175.2		
Tied Ridges (TR)[2]					
Without TR	868.5	340.5	710.1	1338.9	564.3
TR	1305.2	465.9	1212.1	1952.6	725.1
SE[1]	91.9	101.9	273.4	351.3	35.4
CV%	26.1	61.9	75.3	42.7	15.5
N[3]	19	12	7	8	16

[1]Standard Error of the difference between two treatment means.

[2]Tied ridges were constructed one month after seeding.

[3]The number of farmers' fields (replications) on which the experiment was grown.

Table 4. Economic analysis of farmer managed trials of maize with tied ridges, 1984.

	Treatments 1/ C	TR	Number of Farmers
	Nedogo, Donkey Traction		
Grain Yield, kg/ha	869	1305**** 5/	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	
	Bangasse, Manual Traction		
Grain Yield, kg/ha	341	466****	12
Yield Gain Above Control, kg/ha	-	125	
Gain in Net Revenue, CFA	-	11500	
Return/hr. of Additional Labor, CFA	-	115	
% Farmers Not Covering Labor Opp. Cost		8	
	Poedogo Manual Traction		
Grain Yield, kg/ha	1339	1953*	8
Yield Gain Above Control, kg/ha	-	614	
Gain in Net Revenue, CFA	-	56488	
Return/hr. of Additional Labor, CFA	-	565	
% Farmers Not Covering Labor Opp. Cost		25	
	Dissankuy, Ox Traction		
Grain Yield, kg/ha	564	725****	16
Yield Gain Above Control, kg/ha	-	161	
Gain in Net Revenue, CFA	-	14812	
Return/hr. of Additional Labor, CFA	-	197	
% Farmers Not Covering Labor Opp. Cost		6	
	Diapangou, Manual Traction		
Grain Yield,kg/ha	445	724**	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***	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 grain 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 0.2, 0.05, 0.02, and 0.001 respectively for differences between treatments 85 and 86 as determined by the T-Test for paired observations.

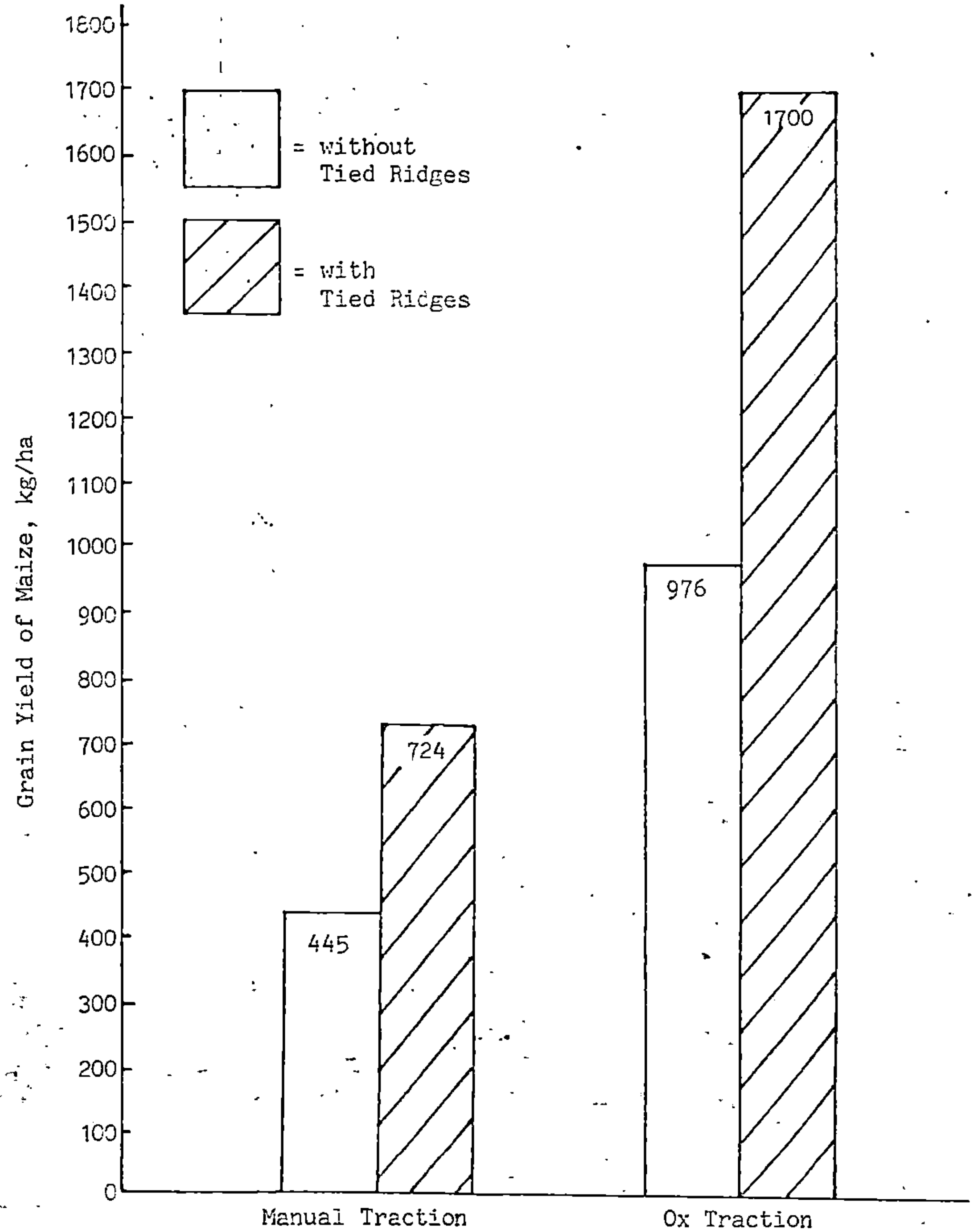

Fig. 4. Mean grain yield of maize grown on compound fields with manual and ox traction at Diapangou in 1984. Tied ridges were not constructed on 1/2 of field and tied ridges were constructed on other 1/2 of field. The difference between treatment means with manual traction is significant at the 0.05 level and with ox traction, at the 0.02 level (t-test). The number of pairs of observations with manual traction is 7 and with ox traction, 7. The standard error of the difference between manual traction and ox traction is 175.2 kg/ha.

EXPERIMENT 3. : Effects of Volta Phosphate and Tied Ridges on Millet.

Description. The objective was to evaluate the economic returns of two levels of fertilization and tied ridges on millet.

The experiment was conducted for the third year in 1984; at Nedogo and Bangasse with manual traction only. Local varieties of millet were utilized.

The five treatments were the following: traditional management practices including flat cultivation (without tied ridges) and no fertilization, the control (C); construction of tied ridges (TR) one month after seeding; F, consisting of 100 kg/ha of Volta phosphate (VP1) applied in the seed pocket plus 50 kg/ha urea applied in pockets 10-15 cm from the seed pockets two weeks after seeding, and construction of tied ridges one month after seeding; 2 F, consisting of 200 kg/ha of VP1 and 50 kg/ha urea applied together in a pocket 10-15 cm from seed pockets two weeks after seeding; and F, consisting of 100 kg/ha VP1 plus 50 kg/ha urea, but without tied ridges.

In 1984, treatments were assigned to the same parcels as in 1982 and 1983 to capitalize on the availability of phosphorus from VP1 applied in previous years.

At Nedogo and Bangasse, the experimental design was a randomized complete block. Farmers' fields were replications.

Results and Discussion. Grain yields of millet for the treatments, tied ridges in combination with fertilization or fertilization alone, tended to be greater than yields of millet without tied ridges or fertilization at Nedogo and Bangasse (Table 5). However, yield differences from that of the control were significant only for the combination of tied ridges and fertilization at Bangasse and for treatments consisting of tied ridges and/or fertilization at Nedogo. Responses from treatments involving fertilization were generally greater in 1984 than in 1983 (Lang, et al, 1983) or 1982 (FSU/SAFGRAD, 1982).

Tied ridges without fertilizer resulted in a significant yield increase compared to the control at Nedogo. This treatment requires

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no cash inputs, but this practice cannot solve the problem of soil fertility improvement over years.

Tied ridges in combination with fertilization resulted in the greatest yield of millet in 1984, which is consistant with our results in 1983 and 1982.

The mean yield increases at Nedogo for treatments which involve tied ridging and/or fertilization are adequate to cover the opportunity cost of labor (Table 6). In Bangasse, opportunity costs of labor are covered only for treatments which include tied ridging. When fertilizer is used alone, mean yield increases are not sufficient to cover the opportunity cost of labor, resulting in negative net revenues. At both locations, the percentage of farmers who would have lost cash is high for fertilization alone. At both locations, the combination of tied ridging and fertilization provided the largest net returns and highest return/hr of additional labor, emphasizing the gains which can be made by combining soil fertility and water conservation. It is important to note that millet response to improved soil-water management would likely be greater in the presence of a more soluble source of phosphorus.

Table 5. Means for effects of tied ridges (TR) and fertilization with volta phosphate (VP1) and urea on grain yield of local varieties of millet grown at Nedogo and Bangasse in 1984.

Treatments[1]	Mean Grain Yield	
	Nedogo	Bangasse
	kg/ha	
Traditional	107.0	220.3
TR	237.9	282.9
TR plus 100 kg/ha VP1 and 50 kg/ha Urea	348.8	468.9
200 kg/ha VP1 and 50 kg/ha Urea	227.6	250.9
100 kg/ha VP1 and 50 kg/ha Urea	194.9	273.3
SE[2]	30.5	40.3
CV%	32.0	39.2
N[3]	11	17

[1] Traditional management practices without TR or fertilization; TR constructed one month after planting; VP1 applied in the seed pockets; Urea applied in pockets at 10 to 15 cm from seed pockets two weeks after planting.

[2] Standard Error of the difference between two treatment means.

[3] The number of farmers' fields (replications) on which the experiment was grown.

Table 6. Economic analysis of farmer managed trials of millet with volta phosphate and tied ridges, 1984.

	Treatments 1/					S.E. of Difference Between 2 Treatment Means	Number of Farmers
	C	TR	TR,F	2F	F		
			Nedogo, Manual Traction				
Grain Yield, kg/ha	107	238	349	228	195	28.0	11
Yield Gain Above Control, kg/ha	-	131	242	121	88		
Gain in Net Revenue, CFA 2/	-	12052	16029	2209	1861		
Return/hr. of Additional Labor, CFA 3/	-	121	134	110	93		
% Farmers Who Would Have Lost Cash	-	0	0	55	55		
			Bangasse, Manual Traction				
Grain Yield, kg/ha	220	283	469	251	273	40.3	17
Yield Gain Above Control, kg/ha	-	63	249	31	53		
Gain in Net Revenue, CFA	-	5796	16673	-6071	-1360		
Return/hr. of Additional Labor, CFA	-	58	139	-	-		
% Farmers Who Would Have Lost Cash	-	0	6	59	59		

1/ C = control (no tied ridges or fertilizer); TR = tied ridges constructed one month after seeding; F = 100 kg/ha volta phosphate applied in the seed pocket and 50 kg/ha urea applied in pockets 10-15cm from seed pockets two weeks after seeding ; 2F = 200 kg/ha volta phosphate and 50 kg/ha urea applied together in a pocket 10-15cm from seed pocket two weeks after seeding.

2/ Net revenue = yield gain x grain price (92 CFA/kg) minus fertilizer cost; (25 CFA/kg for Volta Phosphate 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 traction requires 100 hours of additional labor/ha for tied ridging. Fertilizer application requires 20 additional hours/ha.

EXPERIMENT 4: Performance of Millet and Sorghum on Millet Land.

Description. The objectives were firstly to determine the response of millet to certain improved management practices and secondly, to determine whether or not sorghum is more profitable than millet under certain improved management practices on millet land.

The experiment was conducted at Nedogo with donkey traction, at Bangasse with manual traction and at Dissankuy with ox traction on fields on which the farmer would normally plant millet. The three treatments were the following: local varieties of millet grown with traditional management practices including flat cultivation (tied ridges were not constructed) and no fertilization; local varieties of millet with improved management practices, 100 kg/ha cotton fertilizer, 14-23-15, applied in a band 10 to 15 cm from the rows of millet two weeks after seeding plus 50 kg/ha urea applied in pockets 10 to 15 cm from seed pockets one month after seeding, and construction of tied ridges one month after seeding; and local varieties of sorghum with improved management practices.

The experimental design was a randomized complete block at each of the three villages. Farmers' fields were replications.

Results and Discussion. Millet and sorghum grown with improved management practices produced more grain yield than did millet grown without improved management practices except for the case of sorghum at Dissankuy (Table 7). At Bangasse and Dissankuy millet with improved management produced greater yields than did sorghum.

At Dissankuy particularly, rainfall amounts and infrequency at seeding (Fig. 1) resulted in poor emergence and seedling establishment of sorghum. Total seasonal rainfall at Dissankuy was greatly reduced in 1984 compared to long-term average rainfall. Most millet soils near Dissankuy are more productive than at many other locations on the Central Plateau and one would expect a greater response of sorghum in most years compared to 1984. At Bangasse most millet land is very sandy and droughty. Because of frequent rainfall during the growing season until mid August plant growth was extensive. Immediately prior to flowering drought stress became severe and it was more severe for sorghum than for millet.

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At Medogo, six of the 13 farmers who conducted the experiment, achieved good to excellent establishment of sorghum as well as millet seedlings. All but one of these farmers are good to excellent managers with respect to quality and timeliness of field operations. Data from this sample of six fields in which good seedling establishment was achieved were analyzed separately (Table 7). Millet and sorghum with improved management practices produced at least twice as much yield as did millet without fertilizer and tied ridges. Also, with improved management sorghum produced at least as much yield as did millet.

Millet and white sorghum are the dominant cereals throughout the Central Plateau of Burkina. Farmers consistently say that white sorghum is highly valued because it can be stored twice as long as millet and under desirable soil and rainfall it yields more grain and flour per hectare than millet.

However, white sorghum requires better land and more consistent rainfall than does millet. Millet is more drought tolerant and has fewer disease problems than white sorghum. If rains do not come early enough to plant sorghum, millet may be planted instead. Farmers say that even in the worst of years, some millet can always be harvested. Thus, in comparison to millet, white sorghum is viewed as a more desirable grain but a more risky crop.

During personal interviews, farmers repeatedly state that land quality is the dominant factor in their cropping decisions. Asked whether price affects his decision regarding what to plant, the farmer's most common response was "the land tells me what to plant" (Lang, et al, 1983). Because soil quality continues to deteriorate, millet accounts for an increasing share of cereal acreage.

Sorghum is commonly grown on soils which are lower along the toposequence, soils which are more fertile and less droughty than " millet land" which is generally on the upper part of the toposequence and has poorer soil structure. Since soil fertility and availability of soil moisture are two important distinguishing factors between sorghum land and millet land, it was reasoned that the better millet land could be

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upgraded to sorghum land by amelioration with fertilizer and tied ridges to reduce surface runoff of rainfall. The farmers were very interested in conducting the experiment.

The economic analysis (Table 8) indicates that at all locations, the average net returns from using fertilizer and tied ridges on millet covered the opportunity cost of the additional labor. However the percentage of farmers who would have lost cash from fertilizer purchases is moderately high at all locations. Given the poor rainfall levels and poor rainfall distribution, 1984 provided a very good test of the technologies. One would however not expect this type of year to be repeated with any great frequency and in years with more desirable rainfall patterns, the percentage of farmers losing cash would be greatly reduced. But when given the realities of the "survival-first" attitudes of the farmers, even one bad year in ten is a concern that must be addressed before one would expect farmers to adopt the technologies.

There are however encouraging results from the farmer-managed trials of millet with volta phosphate and tried ridges (Tables 5 and 6). At Nedogo and Bangasse, the percentage of farmers who would have lost cash under a fertilizer-tied ridging combination is zero and 6% (one farmer) respectively. These results warrant further testing of using improved management practices on millet.

In the trials of sorghum grown on millet land with fertilizer and tied ridges, the average net returns only covered the opportunity cost of the additional labor at Nedogo. The percentage of farmers who would have lost cash from fertilizer purchases is very high at Bangasse and Dissankuy and moderately high at Nedogo. At Nedogo, one farmer out of the six (17%) who achieved good to excellent establishment of sorghum would have lost cash. In contrast, two farmers out of the six (33%) would have lost cash in the millet trial. This points out the economic value to farmers of having a sorghum variety that can establish itself given the weather patterns of 1984. The Nedogo experiment indicates that given good plant establishment, sorghum can compete with millet on millet land in terms of yield, net returns, and risk when fertilizer and tied ridges are used.

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Table 7. Mean grain yield of millet and sorghum with tied ridges and fertilizer and grown on millet land at three villages in Burkina Faso in 1984.

Treatment[1]	Mean Yield
	kg/ha
Nedogo	
A. Millet, without tied ridges (TR) or fertilization (F)	294
B. Millet, with TR and F	600
C. Sorghum, with TR and F	529
SE[2]	62
CV%	34
N[3]	13
Nedogo selected[4]	
A. Millet, without TR or F	355
B. Millet, with TR and F	707
C. Sorghum, with TR and F	748
SE[2]	109
CV%	31
N[3]	6
Bangasse	
A. Millet, without TR or F	291
B. Millet, with TR and F	544
C. Sorghum, with TR and F	411
SE[2]	49
CV%	44
N[3]	27
Dissankuy	
A. Millet, without TR or F	435
B. Millet, with TR and F	626
C. Sorghum, with TR and F	459
SE[2]	36
CV%	25
N[3]	23

[1] A) Local varieties of millet grown with traditional management practices including flat cultivation (tied ridges were not constructed and no fertilization; B) local varieties of millet with improved management practices, 100 kg/ha cotton fertilizer 14-23-15, applied in an band 10-15 cm from the rows of millet two weeks after seeding plus 50 kg/ha urea applied in pockets 10-15 cm from seed pockets one month after seeding, and construction of tied ridges one month after seeding; and C) local varieties of sorghum with improved management practices as in treatment B.

[2] Standard error of the difference between two treatment means.

[3] The number of farmers' fields (replications) on which the experiment was grown.

[4] Data from a group of 6 of the 13 farmers who achieved good to excellent seedling establishment for millet and sorghum.

Table 8. Economic analysis of farmer managed trials of millet and sorghum on millet land, 1984.

	Treatments 1/			S.E. of Difference Between 2 Treatment Means	Number of Farmers
	M,C	M,I	S,I		
	Nedogo, Manual Traction				
Grain Yield, kg/ha	294	600	529	61.9	13
Yield Gain Above Control, kg/ha	-	306	235		
Gain in Net Revenue, CFA 2/	-	16219	9687		
Return/hr. of Additional Labor, CFA 3/	-	135	81		
% Farmers Who Would Have Lost Cash	-	23	31		
	Nedogo, (Sub-sample) 4/				
Grain Yield, kg/ha	354	707	748	109.4	6
Yield Gain Above Control, kg/ha	-	353	394		
Gain in Net Revenue, CFA	-	20543	24315		
Return/hr. of Additional Labor, CFA	-	171	203		
% Farmers Who Would Have Lost Cash	-	33	17		
	Bangasse, Manual Traction				
Grain Yield, kg/ha	291	544	411	49.1	27
Yield Gain Above Control, kg/ha	-	253	120		
Gain in Net Revenue, CFA	-	11343	-893		
Return/hr. of Additional Labor, CFA	-	95	-		
% Farmers Who Would Have Lost Cash	-	30	63		
	Dissankuy, Ox Traction				
Grain Yield, kg/ha	435	626	459	36.4	23
Yield Gain Above Control, kg/ha	-	191	24		
Gain in Net Revenue, CFA	-	5639	-9725		
Return/hr. of Additional Labor, CFA	-	59	-		
% Farmers Who Would Have Lost Cash	-	43	65		

1/ M = Millet; C = control (no tied ridges or fertilizer); I = Improved management (100 kg/ha of 14-23-15 plus 50 kg/ha urea and tied ridges); S = Sorghum.

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 20 additional hours/ha.

4/ A sub-sample of six Nedogo manual traction farmers who were able to achieve good to excellent sorghum plant establishment.

EXPERIMENT 5: Red Sorghum Variety Trial

Description: The objective was to evaluate the performance of the red sorghum variety, Framida.

The experiment was conducted at Poedogo with donkey and ox traction. The four treatments were the following: local red sorghum variety, traditional management practices without tied ridges or fertilizer; local red sorghum variety with 100 kg/ha cotton fertilizer, 14-23-15, applied in a band 10-15 cm from the rows of sorghum two weeks after seeding plus 50 kg/ha of urea applied in pockets 10-15 cm from seed pockets one month after seeding and with tied ridges constructed one month after seeding; Framida without tied ridges or fertilization; Framida with fertilizer and tied ridges as above.

The experimental design was a randomized complete block. Farmers' fields were replications.

Results and Discussion. Although both local varieties and Framida responded significantly to improved management, grain yield of Framida was less than that of the local variety (Table 9). Early in the season there was significant spittle-bug damage on many parcels of Framida. Spittlebug damage was particularly severe on the parcels of Framida which were not fertilized. Also, seed set of Framida was greatly reduced due to flower blast caused by sorghum midge. Damages from spittlebug and sorghum midge were small or negligible in parcels of the local varieties which were adjacent to the parcels of Framida in this experiment.

Framida has performed very well in other trials (ICRISAT, 1983). However, data from this experiment does point out two potential problems which may occur with the variety Framida; yield loss due to spittlebug and sorghum midge.

In our trials in 1983 Framida was well-liked by farmers at Poedogo. Farmers prefer its taste, ease of grinding and large kernels compared to local red sorghum varieties.

Table 9. Mean grain yield of local red sorghum varieties and the variety Framida with and without tied ridges and fertilization at Poedogo in 1984.

Treatment[1]	Mean yield
	kg/ha
Local variety, without tied ridges (TR) or fertilization (F)	1152
Local variety with TR and F	1580
Framida without TR or F	595
Framida with TR and F	1199
SE[2]	170
CV%	35
N[3]	11

[1]Local red sorghum varieties grown with traditional managment practices and without tied ridging (TR) or fertilization (F); local red sorghum varieties with 100 kg/ha cotton fertilizer, 14-23-15, applied in a band at 10 to 15 cm from the rows of sorghum two weeks after planting plus 50 kg/ha of urea applied in pockets at 10 to 15 cm from the seed pockets one month after seeding and construction of TR one month after seeding; the red sorghum variety Framida without TR or F; Framida with tied ridging and fertilization.

[2]Standard Error of the difference between two treatment means.

[3]The number of farmers' fields (replications) on which the experiment was grown.

SUMMARY

Five experiments with millet, sorghum and maize were each conducted in one to five villages. The purpose of the trials was to determine the potential of water conservation and fertilization technologies under on-farm, farmer-managed conditions in Burkina. These trials were designed to maximize the use of non-purchased inputs, still using minimal applications of purchased inputs, because most farmers are currently subsistence oriented and they have little cash available for purchased inputs.

The agronomic results indicated that significant yield increases of sorghum and millet can be obtained by applying minimal amounts (as described above) of fertilizer and/or by construction of tied ridges. Tied ridges may be beneficial because of effects in addition to reduction of surface runoff of rainfall. Depressions in the soil surface resulting from tied ridging collect tree leaves and crop residues during the dry season. Also, during the rainy season because of reduced rainfall runoff, loss of accumulated residues is reduced allowing them to be incorporated into the soil during cultivation. However, tied ridges alone cannot solve the soil fertility problem over years. This may not be as serious on village maize fields as on sorghum and millet fields. On village fields which are usually well-fertilized, maize yields can be significantly increased with construction of tied ridges without fertilization. Yield levels of sorghum and millet are highest when both fertilizer and tied ridges are utilized indicating that soil fertility and water become constraints in turn.

The economic analysis indicated that for most of the farmer-managed trials, the mean yield increases from tied ridging and/or fertilization gave rise to a return per hour for the additional labor involved above that of the opportunity cost for labor. Tied ridges alone or in combination with fertilizer are more economically attractive and less risky with respect to losing cash costs, than a fertilizer alone alternative. The combination of tied ridges and fertilizer results in the largest net returns.

C. Researcher-Managed Trials

Methodology. Technologies tested in researcher-managed trials are those which have shown promise based on trials under experiment station conditions. These trials are conducted on farmers' fields and are managed by FSU staff. In 1984, these trials focused on four technology themes:

1) Construction of tied ridges to reduce surface runoff of rainfall and thereby increase the amount of water available to plants,
2) Fertilization with chemical fertilizers and manure to improve soil fertility,
3) Cereal-legume crop associations, and
4) Testing of new varieties.

Seven experiments were conducted in each of one to five villages. The standard experimental designs, randomized complete block and split-plot, were used. The number of treatments ranged from four to 11. Each experiment with three to four replications was conducted in one carefully chosen farmer's field in each village.

Treatments were randomly assigned to a parcel (plot) within each block (replication). Plots consisted of six rows spaced 75 cm apart and 8 m long. Data were collected from the center four rows. (The center three rows of cowpeas when intercropped with a cereal). Crops were manually seeded soon after a rainfall and without prior tillage of the seedbed--practices similar to those by most farmers. Construction of tied ridges was accomplished by manual labor.

EXPERIMENT 1: Maize-Cowpea Relay and Association.

Description. The objective was to determine the performance of the maize variety Safita-2, the early-maturing (determinate) and up-right cowpea variety TVX 3236, local varieties of maize and local (indeteminate) varieties of cowpeas when intercropped.

The experiment was conducted at Poedogo and Nedogo. The experimental design was a randomized complete block with three blocks. Treatments consisted of combinations of maize and cowpea varieties with traditional (TP) and improved management practices (IMP). In all parcels, rows of cowpeas were planted between rows of maize. Cowpeas were planted in pockets 40 cm apart in the row, and when tied ridges were present, the pockets were near the top of the cross ties which were 40 cm apart. Two weeks after planting, cowpeas were thinned to two plants per pocket. Under TP maize was planted in pockets 40 cm apart in the row and under IMP 20 cm apart in the row. When maize seedlings were 10 cm tall, the population was thinned to two plants per pocket if pockets were 40 cm apart and 1 plant per pocket if pockets were 20 cm apart. Maize was planted on 29 June at Nedogo and on 8 July at Poedogo. The six treatments were the following:

1) Local maize and local cowpeas with TP which included neither tied ridging nor fertilization, cowpeas were planted on the same date as maize at Nedogo and 3 weeks later than maize at Poedogo,
2) Local maize and cowpeas with IMP which included tied ridges constructed before planting, 200 kg/ha cotton fertilizer, 14-23-15, applied in a band at 10 to 15 cm from the rows of maize at planting and 50 kg/ha of urea applied in pockets at 10 to 15 cm from maize seed pockets one month after planting, cowpeas were planted on the same date as maize at Nedogo and 3 weeks later than maize at Poedogo;
3) Safita-2 and TVX 3236 with TP, cowpeas planted one week after maize was at 50% silk at Nedogo, but at Poedogo because of the late date of maize planting, the cowpeas were planted 4 weeks after maize was planted;
4) Safita-2 and TVX 3236 with IMP as in Treatment 2, cowpeas planted one week after maize was at 50% silk at Nedogo and 4 weeks after

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maize was planted at Poedogo,

5) Safita-2 and local cowpeas with TP, cowpeas planted three weeks after maize at Nedogo and Poedogo;

6) Safita-2 and local cowpeas with IMP as in Treatment 2, cowpeas planted three weeks after maize at Nedogo and Poedogo.

Cowpeas were sprayed at budding with DECIS at the rate of 1 l/ha and at 10 to 14 days after budding with Thiodan at the rate of 1 l/ha to minimize insect damage to flowers and pods.

The plot area was gently sloping at Poedogo and at Nedogo. At both villages, the plot area was considered by the farmer-cooperators to be average "sorghum land" and at Nedogo the plot area was variable in soil color.

Results and Discussion. At both Poedogo and Nedogo maize grain yield consistantly was significantly greater with IMP than with TP (Table 10). Also, total grain yield from maize and cowpeas was significantly greater with IMP than with TP. Cowpea yield was not consistantly greater with IMP than with TP, but it was at least as high with IMP as it was with TP. The greater plant growth of maize with IMP probably resulted in increased shading of the cowpeas, particularly when planting of cowpeas was delayed as in treatment 3 to 6, compared to that with TP. One would have expected the cowpeas in association with Safita-2, Treatments 5 and 6, to yield higher than those in association with the local maize variety, Treatments 1 and 2, because Safita-2 is shorter and earlier-maturing than the local maize varieties, but this was not the case at Poedogo or Nedogo. However, cowpeas in Treatments 5 and 6 were planted 3 weeks later than the maize and may have been adversely affected by shading early in their growth, and by the end-of-season drought later in their growth.

Intercropping of cowpeas and maize tended to suppress maize yields. Generally, maize yields with IMP were greatest when cowpeas were planted 4 weeks after maize or one week after 50% silk, intermediate when cowpeas were planted three weeks after maize was planted, and maize yields were least when cowpeas were planted on the same date as maize. When cowpeas are planted one week after 50% silk, one would expect little or no reduction of maize yield compared to yield of maize in pure stand because the

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maize would be nearly mature before it encountered appreciable competition from the cowpeas.

TVX 3236 yielded poorly compared to the local cowpea variety at Poedogo and it produced no yield at Nedogo when planted on the 6th of September one week after 50% silk.

Early in the season, the maize canopy probably retarded growth of TVX 3236, as it did for the local cowpea. However, the determinate cowpea, TVX 3236, initiated flowering early, when the plants were small, and although rainfall continued at Poedogo to mid-October and more light reached the cowpea plants as maize senesced, the determinate cowpea could not capitalize on these improved conditions because it could not resume growth and flowering. At Nedogo, although TVX 3236 was planted one week after 50% silk and should have been able to capitalize on the improved light conditions as the maize senesced, rainfall ended by mid-September and the cowpeas were severely damaged by lack of rain. Climatic constraints and variabilities at Poedogo and Nedogo in 1984 are not uncommon in the central plateau of Burkina, emphasizing the importance of the stability of production offered by indeterminate cowpea varieties compared to determinate varieties.

Very little of the nitrogen fixed by the legume, cowpeas, would have been available for the maize, particularly for those treatments in which planting of cowpeas was delayed. Possible benefits from nitrogen fixed by the legume, should be determined in 1985 by experimentation.

Table 10. Means for performance of maize and cowpeas intercropped at Poedogo and Nedogo in 1984.

Treatments[1]	Mean Grain Yield		
	Maize	Cowpeas	Maize + Cowpeas
	kg/ha		
Poedogo			
LM and LC, TP, 3 wk	36.2	944.5	980.7
LM and LC, IMP, 3 wk	1909.6	1583.5	3493.1
Safita-2, TVX 3236, TP, 4 wk	72.9	676.2	749.1
Safita-2, TVX 3236, IMP, 4 wk	2302.1	592.8	2894.9
Safita-2, LC, TP, 3 wk	53.3	907.2	960.5
Safita-2, LC, IMP, 3 wk	2156.3	1051.3	3207.6
SE[2]	159.6	263.4	206.1
CV%	17.9	33.6	11.9
Nedogo			
LM and LC, TP, same	402.9	259.5	662.4
LM and LC, IMP, same	666.7	351.4	1018.1
Safita-2, TVX 3236, TP, Silk	597.1	0	597.1
Safita-2, TVX 3236 IMP, Silk	1125.0	0	1125.0
Safita-2, LC, TP, 3 wk	236.2	259.7	495.9
Safita-2, LC, IMP, 3 wk	722.1	333.5	1055.6
SE[2]	243.8	75.0	283.4
CV%	47.8	45.7	38.4

[1] LM = local maize varieties, LC = local cowpea varieties, which have an indeterminate flowering period, TP = traditional management practices which include neither tied ridging nor fertilization, Same = maize and cowpeas were planted on the same date, IMP = improved management practices which include tied ridges constructed prior to planting and 200 kg/ha 14-23-15 applied in a band at 10 to 15 cm from the rows of maize at planting and 50 kg/ha of urea applied in pockets at 10 to 15 cm from maize seed pockets one month after planting, Safita-2 is an early variety of maize and TVX 3236 is a variety of cowpeas with determinate flowering, both varieties developed at IITA, Silk = cowpeas planted one week after maize was at 50% silk, 3 wk = cowpeas planted 3 weeks later than maize.

[2] Standard error of the difference between two treatment means.

EXPERIMENT 2: Tied Ridges and Fertilizer on Maize.

Description. The objective was to determine the effects of tied ridges constructed prior to planting and one month after planting and with fertilization on maize.

The experiment was conducted at Poedogo, Nedogo, Diapangou and Dissankuy. The experimental design was a split-plot with four blocks (replications) at each village. The two treatments, no fertilization and fertilization, were randomly assigned to the whole plots. Fertilization consisted of 100 kg/ha of 14-23-15 applied in a band at 10 to 15 cm from the rows of maize at planting and 50 kg/ha of urea applied in pockets at 10 to 15 cm from seed pockets one month after planting. The three treatments, flat cultivation (without tied ridges), construction of tied ridges prior to planting and construction of tied ridges one month after planting, were randomly assigned to the subplots. There were six treatment combinations.

Local varieties of maize were grown. For plots in which tied ridges were constructed prior to planting, seed pockets were placed near the top of the ridges. Maize was planted in pockets 40 cm apart in the rows. When seedlings were 10 cm in height the plant population was thinned to two plants per pocket.

The maize was planted on 27 July at Poedogo; 9 July, but 1/3 of population was reseeded 19 July at Nedogo; 19 July at Diapangou; and 3 August at Dissankuy. From farmer-experience, it is preferable to plant maize by mid-July. Because of undesirable rainfall patterns in 1984, this trial was seeded very late at Poedogo and Dissankuy.

At Poedogo the experiment was conducted on a gently sloping (5% slope) field which the farmer considered sorghum land of average productivity. The field at Nedogo was slightly sloping (3 to 5% slope) and considered by the farmer to be good sorghum land. Soils at Diapangou and Dissankuy on which the experiment was grown, were very good sorghum land, but the late planting and low rainfall in 1984 severely limited maize yields. The field was slightly sloped (3 to 5%) at Diapangou and at Dissankuy the field was level.

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Results and Discussion. Maize yields were generally very low at all villages (Table 11). Fertilization was most effective at Poedogo where rainfall was good during August and September (Fig. 1). At Diapangou, and Dissankuy particularly, low rainfall during late August and September severely limited maize yields.

Tied ridges were most effective at Poedogo where the field was sloped and there was sufficient rainfall for maize growth. Tied ridges were also very effective at Diapangou where the field was sloped, the soil was productive and rainfall was sufficient to result in good plant response to the increased water from tied ridging compared to flat cultivation. Although rainfall was limited at Diapangou, it was sufficiently frequent to prevent severe stress. Tied ridges were least effective at Dissankuy where the field was level and rainfall runoff was not a problem.

At Poedogo, tied ridges constructed prior to planting tended to result in greater yields than tied ridges constructed one month after planting. At Nedogo, Diapangou and Dissankuy tied ridges constructed one month after planting tended to result in higher yields than those constructed prior to planting. One would expect effects like those realized at Poedogo because tied ridges constructed prior to planting would capture rainfall early in the season thereby enhancing seedling growth.

At Poedogo there was sufficient rainfall during germination and seedling emergence to result in good plant establishment for all plots, including those in which tied ridges were constructed prior to planting and seed pockets placed near the top of the ridges. At Nedogo, moisture was limited subsequent to the first date of planting, 9 July, and seedling emergence was poor in plots with tied ridges. Good plant establishment was achieved in these plots after replanting on 19 July, but because of the delay in planting, grain yield from these plots was reduced compared to that from plots in which good seedling establishment was achieved after the first date of planting.

There was a significant fertilization X tied ridging interaction at Poedogo, Nedogo and Diapangou (Fig. 5). At Poedogo, the fertilizer was utilized more fully as additional water was made available to the plants by tied ridging one month after planting. The difference in maize yield between unfertilized and fertilized plots was greatest when tied ridges were cons-

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tructed prior to planting, likely because the tied ridges resulted in more water available to the plants beginning early in the season. At Dissankuy the lack of rainfall during late September when the maize was in the flowering and early filling stages of growth probably limited yields to about 700 kg/ha.

The very large response to fertilization with tied ridges constructed prior to planting accounted for much of the interaction effects at Poedogo. At Nedogo the necessity to reseed the plots in which tied ridges were constructed early contributed to the poor performance of maize on the treatment. The differences between grain yields with and without fertilization were small at Dissankuy.

Table 11. Means for performance of maize with tied ridges and fertilization at Poedogo, Nedogo, Diapangou and Dissankuy in 1984.

Treatments[1]	Mean Grain Yield			
	Poedogo	Nedogo	Diapangou	Dissankuy
	kg/ha			
Fertilization				
Without Fertilizer	169.2	597.2	798.8	531.2
Fertilized	633.8	968.8	1062.5	708.3
SE[2]	77.5	60.8	103.3	26.7
Tied Ridges (TR)				
Without TR	237.9	650.8	692.5	580.8
TR, at Planting[3]	542.9	786.7	1031.2	632.9
TR, One Month After[4]	423.3	911.7	1067.5	645.8
SE[2]	96.7	127.9	152.5	73.3
CV%	48.0	32.7	32.8	23.7

[1]Fertilization consisted of 100 kg/ha of 14-23-15 applied in a band at 10 to 15 cm from the rows of maize at planting and 50 kg/ha of urea applied in pockets at 10 to 15 cm from seed pockets one month after planting.

[2]Standard error of the difference between two treatment means.

[3]Tied ridges were constructed at planting.

[4]Tied ridges were constructed one month after planting.

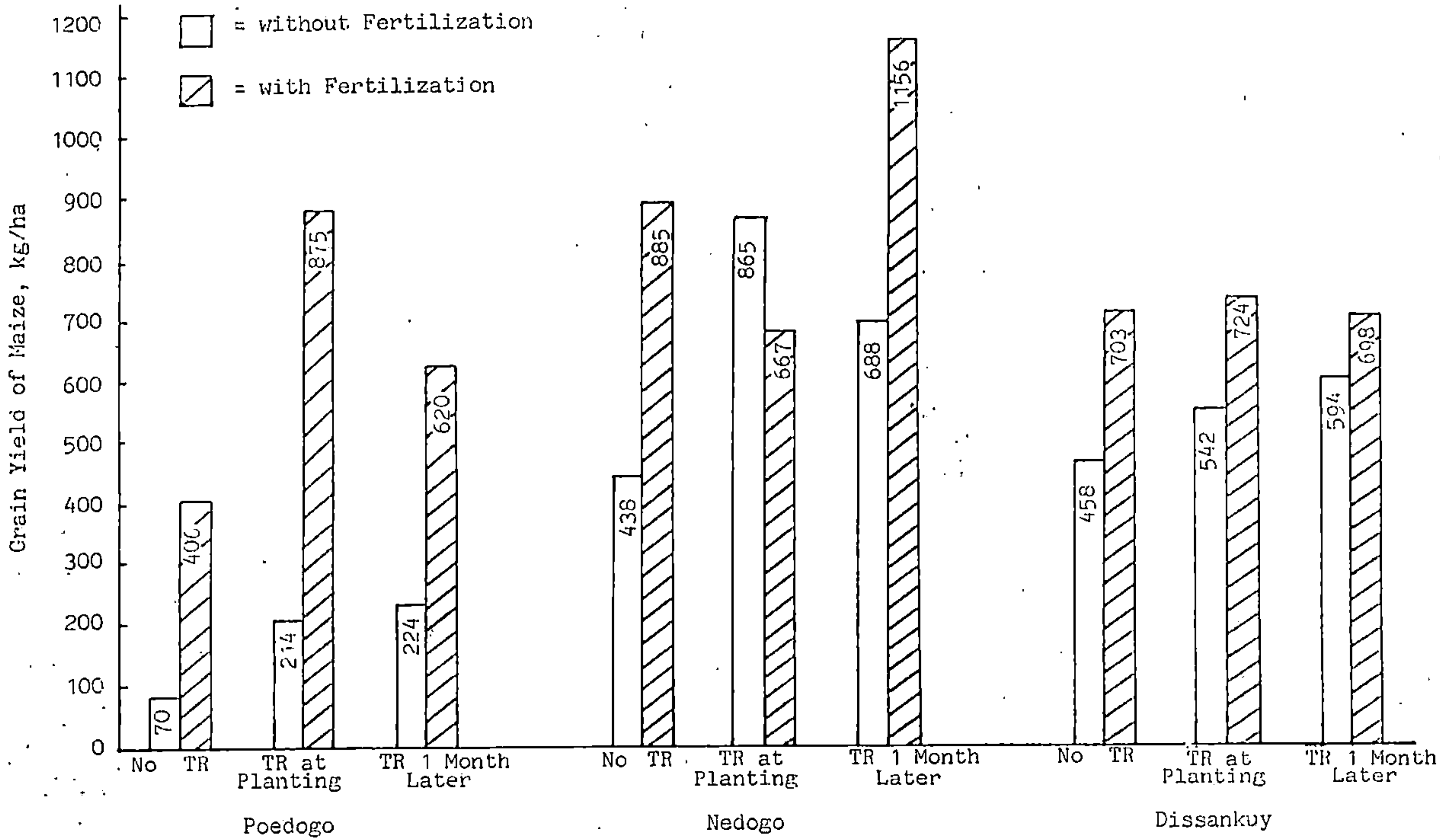

Fig. 5. Interaction effects of fertilization and tied ridging on grain yield of maize grown at three villages in Burkina Faso in 1984. The standard errors of the difference between any two treatment means are, respectively 136, 160 and 89 kg/ha for Poedogo, Nedogo and Dissankuy.

EXPERIMENT 3: Tied Ridges and Fertilizer on Sorghum.

Description. The objective was to determine the effects of tied ridges constructed prior to planting and one month after planting and with fertilization on sorghum.

The experiment was conducted at Poedogo, Nedogo and Bangasse. The experimental design was a split-plot with four blocks (replications) at each village. The two treatments, no fertilization and fertilization, were randomly assigned to the whole plots. Fertilization consisted of 100 kg/ha of 14-23-15 applied in a band at 10 to 15 cm from the rows of sorghum at planting and 50 kg/ha of urea applied in pockets at 10 to 15 cm from seed pockets one month after planting. The three treatments, flat cultivation (without tied ridges), construction of tied ridges prior to planting and construction of tied ridges one month after planting were randomly assigned to the subplots. There were six treatment combinations.

Local varieties of red sorghum were grown at Poedogo and local varieties of white sorghum were grown at Nedogo and Bangasse. For plots in which tied ridges were constructed prior to planting, seed pockets were placed near the top of the ridges. Sorghum was planted in pockets 40 cm apart in the rows. When seedlings were 10 cm in height the plant population was thinned to two plants per pocket.

The sorghum was planted on 13 June at Poedogo, 6 June at Nedogo, and 22 May at Bangasse. The plot area at the three villages was gently sloping.

Results and Discussion. The trial at Poedogo was excellent and the significant response to fertilization (Table 12) was very apparent throughout the season. The response of sorghum to fertilization was significant at Nedogo and Bangasse but it was not as dramatic as at Poedogo. At Nedogo rainfall varied significantly throughout the area. The plot area for this trial was missed by several rains which occurred in other areas near Nedogo and consequently the sorghum was severely drought stressed as reflected by the low yields in Table 12. Response to fertilization at Bangasse was more apparent early in the season than the data in Table 12 indicate. Early in the season rainfall was adequate and crop growth was very good. However,

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during late August when the sorghum was in the flowering and early grain filling stages of growth, lack of rain caused severe drought stress. Because of greater plant growth on fertilized plots than on non fertilized plots, sorghum on fertilized plots was stressed more severely than on non fertilized plots.

Tied ridges constructed prior to planting resulted in a significant sorghum yield increase at Poedogo (Table 12). The early season benefits of tied ridges constructed early were realized in this experiment at Poedogo because rainfall was adequate for germination and seedling emergence even when the seed pockets were near the top of the tied ridges. However, later in the season 80 to 90% of the plants in plots in which tied ridges were constructed prior to planting were lodged or leaning because soil had eroded away from the base of the plants. Few or none of the plants were lodged in plots with no tied ridges or when tied ridges were constructed one month after planting.

At Bangasse, seedlings did not emerge in approximately 25 and 5% of the seed pockets in plots respectively with tied ridges constructed prior to planting and in plots without tied ridges at planting. The sorghum was not reseeded in these plots. Although the difference is not significant, the numerically lower yields of sorghum with tied ridges constructed prior to planting, 862 kg/ha, compared to that with tied ridges constructed one month after planting, 1015 kg/ha, is a consequence of the reduced plant population. Also, the generally frequent and adequate rainfall until mid-August at Bangasse minimized the beneficial effects of tied ridges constructed early and the late-constructed tied ridges were in place prior to the drier part of the season after mid-August.

The fertilization X tied ridging interaction effects were significant at Poedogo and Nedogo (Fig. 6). At Poedogo the response of sorghum to fertilization was greater with tied ridging than without tied ridging. At Nedogo the response to fertilization was greater when tied ridges were constructed early than without tied ridges or when tied ridges were constructed late. However, the treatment means were low in the experiment at Nedogo.

Because of the greater potential of lodging and increased difficulty to achieve seedling emergence by planting near the top of the ridges, it would be preferable to place the seed pockets approximately half-way down one side of the ridges or construct tied ridges as soon as possible after seedling emergence.

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Table 12. Means for performance of sorghum with tied ridges and fertilization at Poedogo, Nedogo and Bangasse in 1984.

Treatments	Mean Grain Yield		
	Poedogo	Nedogo	Bangasse
	kg/ha		
Fertilization			
Without Fertilizer	1158.8	100.8	661.2
Fertilized[1]	3012.9	194.6	913.3
SE[2]	132.1	35.0	110.0
Tied Ridges (TR)			
Without TR	1803.3	93.8	484.4
TR, at Planting[3]	2307.5	177.1	862.0
TR, one Month After[4]	2147.1	171.7	1015.6
SE[2]	230.4	88.8	131.1
CV%	22.1	58.3	33.3

[1]Fertilization consisted of 100 kg/ha of 14-23-15 applied in a band at 10 to 15 cm from the rows of sorghum at planting and 50 kg/ha of urea applied in pockets at 10 to 15 cm from seed pockets one month after planting.

[2]Standard error of the difference between two treatment means.

[3]Tied ridges were constructed at planting.

[4]Tied ridges were constructed one month after planting.

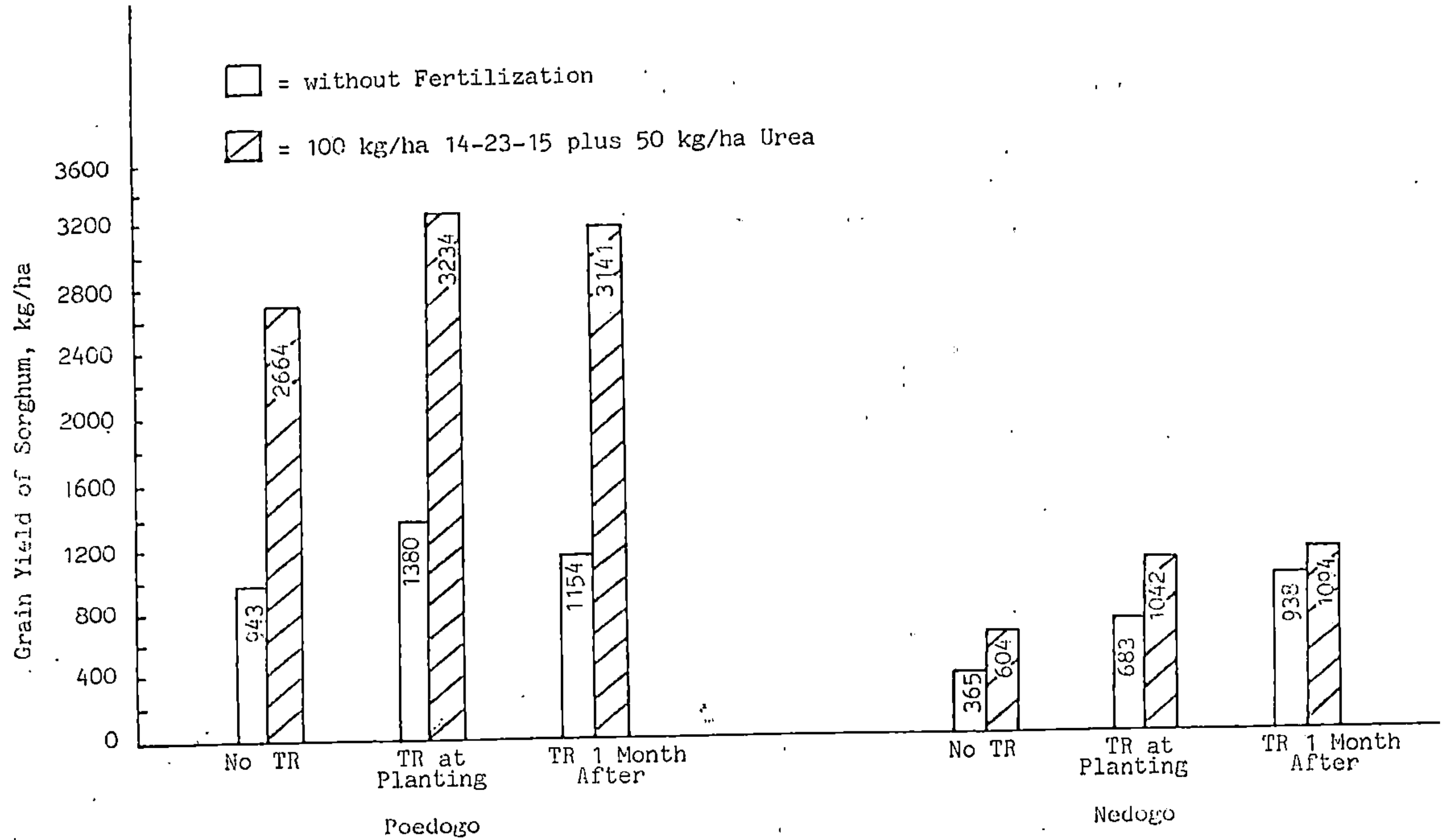

Fig. 6. Interaction effects of fertilization and tied ridging on grain yield of sorghum grown at two villages in Burkina Faso in 1984. The standard errors of the difference between any two treatment means are, respectively 297 and 108 kg/ha for Poedogo and Nedogo.

EXPERIMENT 4: Millet-Cowpea Association.

Description. The objective was to evaluate the performance of millet and cowpeas when grown in association.

The experiment was conducted at Poedogo and Bangasse. At each village the experimental design was a randomized complete block with four blocks (replications) and seven treatment combinations. Local varieties of millet were grown at two population densities in association with the Ouahigouya local (indeterminate flowering) cowpea variety at three population densities, and in association with TVX 3236 (determinate flowering) cowpea at a high population density. The seven treatments were the following:

1) Millet at a population density of 31,250 plants/ha,
2) Millet at 31,250 plants/ha and local cowpeas at 7,800 plants/ha,
3) Millet and local cowpeas, both at 31,250 plants/ha,
4) Millet at 31,250 plants/ha and local cowpeas at 62,500 plants/ha,
5) Millet and local cowpeas, both at 62,500 plants/ha,
6) Millet at 31,250 plants/ha and TVX 3236 at 62,500 plants/ha,
7) Millet and TVX 3236, both at 62,500 plants/ha.

Millet and cowpeas were planted on 15 June at Poedogo and on 3 June at Bangasse. Millet was seeded in pockets which were 40 cm apart in the rows. When seedlings were five to 10 cm tall, millet was thinned to one plant per pocket for treatments 1, 2, 3, 4 and 6 (31,250 plants/ha) and to two plants per pocket for treatments 5 and 7 (62,500 plants/ha). For treatment 2, cowpeas were planted in rows between every second row of millet. In the rows of cowpeas, seed pockets were 80 cm apart. For treatment 3, cowpeas were planted in rows between rows of millet and cowpea seed pockets were 40 cm apart in the row. For treatments 4, 5, 6 and 7, cowpeas were planted in rows between rows of millet and cowpea seed pockets were 20 cm apart in the row. At 10 days after planting, cowpeas were thinned to one plant per pocket.

Fertilizer was not applied. Cowpeas were sprayed at budding with DECIS at the rate of 1 l/ha and at 10 to 14 days after budding with Thiodan at the rate of 1 l/ha to minimize insect damage to flowers and pods.

At both villages the plot area was nearly level with a 1 to 3% slope.

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Seedling emergence of millet and cowpeas was very good at both villages.

Results and Discussion. At Poedogo the general lack of rainfall during the first six weeks of growth resulted in severe drought stress. Millet plants in plots with cowpeas were visibly shorter than in plots with pure stand millet. Plant height was progressively shorter with increased populations of millet and particularly with increased populations of cowpeas. Although rainfall was much greater beginning mid-July, the millet plants in association with cowpeas remained shorter and their inflorescences were smaller than millet in pure stand. These relationships were reflected in the grain yield of millet at Poedogo (Table 13). Fertilization may have increased yields by enabling plants to respond to increased rainfall later in the season, but the most limiting constraint to production was the limited rainfall early in the season. Cowpea grain yields were high relative to millet yields probably because the sparse millet canopy resulted in ample light to the cowpeas. Total yield was respectable compared to average millet yields in the area.

Millet at 31,250 plants/ha in association with cowpeas at 7,800 plants/ha, Treatment 2, resulted in the greatest total grain yield and was significantly greater than millet in pure stand. Near Poedogo farmers traditionally practice association cropping with plant populations of 31,000/ha of millet and 3,000 to 8,000/ha of cowpeas. In Treatment 2 the cowpea yield more than compensated for the loss in millet yield compared to pure stand millet yield.

For all other treatments the cowpea yield only compensated for the respective losses in millet yield, resulting in total grain yields similar to yield of millet in pure stand. However, cowpea grain has a much greater percentage of protein than does millet grain.

The indeterminate Ouahigouya local variety of cowpea produced greater yields than did TVX 3236. TVX 3236 a determinate flowering type of cowpea could not capitalize on the favorable rainfall later in the season. Because of the severe drought early in the season, the plants of TVX 3236 were small and produced few flowers. The indeterminate variety resumed growth after the drought ended and by flowering, beginning mid-September, the plants were large and productive. TVX 3236 began flowering at mid-August.

At Bangasse, because of favorable rainfall early in the season, cowpeas in association with millet did not depress millet grain yields (Table 13). Millet yields were highest at the high population and millet yield of the treatment with millet and cowpea populations both at 62,500 plants/ha was significantly greater than yield of millet in pure stand with a population of 31,250 plants/ha.

The early-flowering, determinate cowpea variety, TVX 3236, produced greater yields than the indeterminate variety, Ouahigouya local (Table 13) at Bangasse. TVX 3236 developed good growth early in the season because of favorable rainfall, and began flowering on 27 July and the seeds were well-filled by mid-August when the drought stress began. The indeterminate cowpea variety began flowering at mid-August.

Total grain yields of cowpeas in association with millet were significantly greater than grain yield of millet in pure culture (Table 13) at Bangasse. As at Poedogo, millet at 31,250 and cowpeas at 7,800 plants/ha resulted in the highest total grain yield.

At the two villages, representing a sharp contrast in rainfall patterns, total grain yields of cowpeas in association with millet were at least as great as grain yield of millet in pure culture. Millet at 31,250 and cowpeas at 7,800 plants/ha produced the greatest total grain yield. Perhaps with fertilization, millet and cowpeas at higher populations would produce the greatest yields.

Table 13. Means for the performance of millet and cowpeas intercropped at Poedogo and at Fangasse in 1984.

Treatments[1]	Mean Grain Yield		
	Millet	Cowpeas	Millet+Cowpeas
	kg/ha		
	Poedogo		
LM, 31,250	958.3	-	958.3
LM, 31,250; LC, 7,800	705.8	541.7	1247.5
LM, 31,250; LC, 31,250	427.1	615.6	1042.7
LM, 31,250; LC, 62,500	419.2	666.7	1085.9
LM, 62,500; LC, 62,500	390.8	621.7	1012.5
LM, 31,250; TVX 3236, 62,500	599.2	302.2	901.4
LM, 62,500; TVX 3236, 62,500	630.0	302.2	932.2
SE[2]	59.2	57.2	92.4
CV%	14.2	15.9	11.9
	Bangasse		
LM, 31,250	192.7	-	192.7
LM, 31,250; LC, 7,800	234.4	220.8	455.2
LM, 31,250; LC, 31,250	286.5	143.1	429.6
LM, 31,250; LC, 62,500	239.6	98.6	338.2
LM, 62,500; LC, 62,500	286.5	98.6	385.1
LM, 31,250; TVX 3236, 62,500	218.8	169.4	388.2
LM, 62,500; TVX 3236, 62,500	369.8	152.8	522.6
SE[2]	66.1	43.9	78.8
CV%	35.8	42.2	26.9

[1]LM = Local variety of millet; 7,800, 31,250, 62,500 = number of plants/ha; LC = Local variety (indeterminate flowering) of cowpeas; TVX 3236 is a early, determinate flowering cowpea variety developed by IITA.

[2]Standard error of the difference between two treatment means.

EXPERIMENT 5: Response of Sorghum and Millet to Fertilizers.

Description. The objective was to determine the response of sorghum and millet to several types of fertilizer and rates of fertilization.

The experiment was conducted at Nedogo, Bangasse, Dissankuy, Diapangou and Poedogo, but the sorghum was not harvested at Poedogo. The white sorghum line E2S50, developed by ICRISAT was grown at Nedogo, Bangasse and Dissankuy. At Diapangou, a mixture of a local millet variety (85%) and a local sorghum variety (15%) were grown because this type of mixture is widely grown by farmers near Diapangou.

At each village, the experimental design was a randomized complete block with four blocks. The eleven treatments were the following:

1) Neither tied ridges nor fertilization (for the remaining 10 treatments, tied ridges were constructed prior to planting),
2) No fertilization,
3) 100 kg/ha volta phosphate (VP1) applied in the seed pocket, below, the seed and not in contact with the seed,
4) 100 kg/ha of partially acidified rock phosphate (UV5) applied in the seed pocket, below the seed and not in contact with the seed,
5) 50 kg/ha urea applied in pockets at 10 to 15 cm from seed pockets one month after planting,
6) 100 kg/ha 14-23-15 applied in a band at 10 to 15 cm from seed rows at planting,
7) 200 kg/ha 14-23-15 applied as in Treatment 6,
8) 100 kg/ha VP1 applied as in Treatment 3 plus 50 kg/ha urea applied as in Treatment 5,
9) 100 kg/ha UV5 applied as in Treatment 4 plus 50 kg/ha urea applied as in Treatment 5,
10) 200 kg/ha UV5 applied as in Treatment 4 plus 100 kg/ha urea applied as in Treatment 5,
11) 100 kg/ha VP1 and 50 kg/ha urea applied as a mixture in a pocket at 10 to 15 cm from seed pockets one week after planting,

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The experiment was planted on 8 July at Nedogo, 29 June at Bangasse, 12 July at Dissankuy, and 3 June at Diapangou. The sorghum and millet were seeded in pockets which were 40 cm apart in the rows. When seedlings were 5 to 10 cm tall the population was thinned to two plants per pocket.

Results and Discussion. Seedling emergence and establishment was excellent at all locations except for the control treatment at Nedogo and Bangasse. Seedlings in approximately 25% of the seed pockets did not emerge from the soil in plots of the control treatment at Nedogo and Bangasse, and these plots were not reseeded.

At Nedogo there was little response to fertilization with VP1, UV5 or urea alone (Table 14). Moisture stress was persistent throughout the growing season and the plants were severely stressed during flowering and early grain filling during early and mid-October. Sorghum fertilized with 14-23-15 or with a mixture of VP1 and urea, flowered on 26 to 29 August and thus was not as severely drought stressed during flowering and early grain filling as was sorghum with the other treatments which flowered eight to 10 days later.

The ample and frequent rainfall early in the season at Bangasse resulted in significant responses to fertilizers (Table 14). The greatest response was achieved with 14-23-15. However sorghum response to UV5 both alone and with urea was excellent at Bangasse. Fertilization with VP1 and urea also resulted in significant yield increases compared to the control or tied ridges alone.

At Dissankuy the plot area for this experiment was sloped at 2 to 5%, although most of the cultivated fields near Dissankuy are nearly level. The combination of sloped plot area and the rainfall pattern of several large but infrequent rains at Dissankuy (Fig. 1) resulted in a very large response from tied ridging (Table 14). As at Bangasse, there was a good response to UV5 plus urea. As at Nedogo and Bangasse the highest yields were achieved with 14-23-15. Sorghum on plots fertilized with 14-23-15 flowered the earliest, on or about 15 September. Sorghum with other treatments flowered from three days (UV5 plus urea) to two weeks later (VP1 alone and TR alone).

At Diapangou, the millet was well-established but was subjected to periodic severe stress throughout the season because of the large and infrequent rains (Fig. 1). The greatest grain yield was achieved with 14-23-15, and UV5 in combination with urea.

At Poedogo the grain yield of most plots was zero because of late planting, 27 July. However, differential plant responses to fertilizations were apparent throughout the season, as they were at the other four villages. Plants with the greatest growth and those which flowered the earliest were fertilized with 14-23-15. As at Nedogo, we did not observe a positive response to UV5 or urea at Poedogo.

A good response to fertilization with cotton fertilizer, 14-23-15, was consistently achieved at all of the five test sites. Responses to VP1, UV5 and urea were inconsistent. Cotton fertilizer contains small amounts of sulphur and calcium and we suggest that low concentrations of certain elements in addition to N, P and K may restrict yields of cereals in certain areas of Burkina. Soil samples from fields and plot areas near the five villages are being analyzed.

Table 14. Means for the performance of sorghum and millet with fertilization and tied ridges at Nedogo, Bangasse, Dissankuy and Diapangou in 1984.[1]

Treatments	Mean Grain Yield[2]			
	Nedogo	Bangasse	Dissankuy	Diapangou
	kg/ha			
Control[3]	135.4 a	265.8 a	1010.4 a	677.1 a
TR[4]	145.8 a	229.2 a	1843.8 b	708.3 a
TR, 100[5] VP1[6]	156.2 a	1177.1 bc	2510.4 bc	843.8 ab
TR, 100 UV5[7]	239.6 a	1250.0 bc	2385.4 bc	677.1 a
TR, 50 Urea[8]	166.7 a	1067.5 bc	2635.4 bc	854.2 ab
TR, 100 14-23-15[9]	812.5 cd	1083.3 bc	3156.3 c	864.6 ab
TR, 200 14-23-15	1000.0 d	1474.2 c	3166.7 c	1000.0 b
TR, 100 VP1, 50 Urea	447.9 ab	1120.0 bc	1995.0 b	677.1 a
TR, 100 UV5, 50 Urea	145.8 a	1093.8 bc	2937.5 c	958.3 b
TR, 200 UV5, 100 Urea	187.5 a	1484.2 c	2437.5 bc	937.5 b
TR, 100 VP1,50 Urea,Mixed[10]	635.4 bc	900.8 b	2312.5 bc	822.9 ab
SE[11]	145.4	207.9	393.3	84.6
CV%	55.5	27.0	23.2	14.5

[1]The white sorghum line, 82S50, developed by ICRISAT, was grown at Nedogo, Bangasse and Dissankuy. A mixture of local millet (85%) and local white sorghum (15%) was grown at Diapangou.

[2]Means within a column which are followed by a similar letter are not significantly different at the 5% level by Duncan's New Multiple Range Test (Steel and Torrie, 1960).

[3]Neither tied ridges nor fertilization.

[4]Tied Ridges constructed prior to planting.

[5]Numbers are the number of kg/ha of fertilizer applied.

[6]Volta phosphate applied in the seed pocket, below and not in contact with the seed.

[7]Partially acidified rock phosphate applied in the seed pocket, below and not in contact with the seed.

[8]Urea applied in a pocket at 10 to 15 cm from the seed pocket one month after planting.

[9]Cotton fertilizer applied in a band 10 to 15 cm from the seed rows at planting.

[10]The VP1 and urea were applied as a mixture in a pocket at 10 to 15 cm from seed pockets one week after planting.

[11]Standard error of the difference between two treatment means.

EXPERIMENT 6: Sorghum and Millet Fertilized with Manure.

Description. The objective was to evaluate the responses of sorghum and millet to fertilization with minimal amounts of manure placed near the plants and manure in combination with urea and partially acidified rock phosphate (UV5).

The experiment was conducted at Nedogo, Bangasse, Diapangou and Dissankuy. Local varieties of millet were grown at Bangasse and Diapangou and the white sorghum line, 82S50 developed by ICRISAT, was grown at Nedogo and Dissankuy.

At each village the experimental design was a split-plot with whole plots (application of no urea or 50 kg/ha urea) arranged in a completely randomized design and manure treatments were the subplots. There were two observations of each of the two whole-plots. The four subplot treatments were the following:

1) No application of manure, the control,
2) 3.1 T/ha manure applied in the seed pocket below and not in contact with the seed,
3) 3.1 T/ha manure applied in pockets at 10 to 15 cm from seed pockets at planting,
4) mixture of 3.1 T/ha manure and 100 kg/ha UV5 applied in the seed pocket below and not in contact with the seed.

The cattle manure was thoroughly sundried, ground and uniformly mixed, and then distributed to the four villages for the trials. Urea was applied in pockets at 10 to 15 cm from seed pockets one month after planting. The sorghum and millet were planted in pockets which were 40 cm apart in the rows. Seeding was done on 8 July at Nedogo; 25 May at Bangasse; 6 June at Diapangou, but 1/3 of the population was re-established by transplanting seedlings during thinning; and 7 July at Dissankuy. Tied ridges were constructed prior to planting for all plots. Seed pockets were placed near the top of the ridges. When seedlings were 5 to 10 cm tall the population was thinned to two plants per pocket.

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Results and Discussion. The response to urea was significant in trials at Nedogo and Bangasse but not at Dissankuy and Diapangou (Table 15). Because of the ample rainfall at Bangasse early in the season, symptoms indicative of nitrogen deficiency were widely apparent and response of millet to urea in this trial was particularly apparent. The significant response to urea is not surprising because manure supplies only small amounts of nitrogen. Manure generally contains respectively 5, 10 and 5% of N, P and K.

As we found in Experiment 5, response to UV5 was location-specific. At Bangasse, manure plus UV5 resulted in a significant yield increase compared to millet yield without fertilization whereas manure alone did not result in a significant yield increase (Table 15). The treatment, manure plus UV5 also resulted in the highest sorghum yield at Dissankuy, but there was no response to UV5 at Nedogo or at Diapangou.

The significant urea X manure interaction at Nedogo and Dissankuy was primarily due to the large response to urea when UV5 was present (Fig. 7).

We recognize that 3 T/ha is certainly a minimal amount of manure from which to expect a significant cereal yield increase. But we argue that farmers do not have access to sufficient amounts of manure to apply even 3 T/ha over a substantial portion of their crop area. It will be more important to determine the beneficial effects of manure in subsequent years and the effects of minimal applications in successive years. Beneficial effects include improved soil structure from increased organic matter which may result in increased rates of water infiltration and increased water holding capacity.

Table 15. Means for the performance of white sorghum or millet fertilized with manure, partially acidified rock phosphate (UV5) and urea at four villages in Burkina Faso in 1984.

Treatments	Mean Grain Yield			
	Nedogo	Bangasse	Diapangou	Dissankuy
	kg/ha			
Urea				
Without Urea	697.9	562.5	828.3	807.5
50 kg/ha Urea	906.2	716.2	981.2	1476.6
SE[1]	21.2	8.3	44.5	130.4
Manure (M)[2]				
Without M	510.4	432.3	802.1	984.2
M in Seed Pockets	906.2	604.2	859.2	1104.2
M Beside Seed Pockets	895.8	666.7	963.3	1166.7
M + UV5 in Seed Pockets	895.8	854.2	995.0	1312.5
SE[1]	197.5	105.4	90.4	227.5
CV%	34.8	23.3	14.1	28.2

[1]Standard error of the difference between two treatment means.

[2]Dried cattle manure at 3 T/ha applied in the seed pockets, below and not in contact with the seed, or in pockets at 10 to 15 cm from the seed pockets, UV5 at 100 kg/ha.

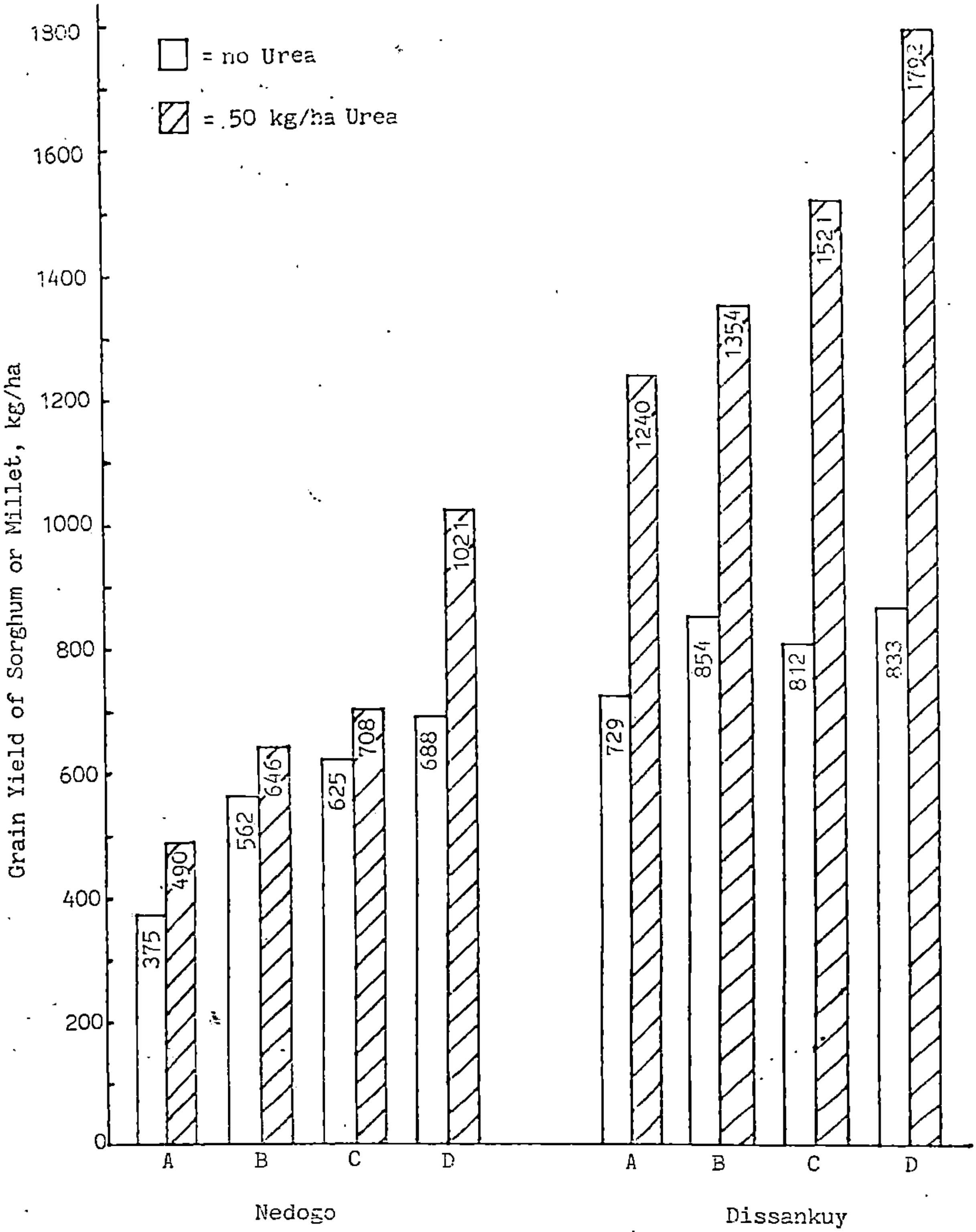

Fig. 7. Mean grain yields for urea X manure interactions at Nedogo and Dissankuy in 1984. A = 0 manure, B = 3.1 T/ha dry manure in seed pockets below seed and not in contact with seed, C = 3.1 T/ha manure in pockets at 10 to 15 cm from seed pockets at seeding, D = 3.1 T/ha manure plus 100 kg/ha UV5 in seed pockets.

EXPERIMENT 7: Early-Maturity White Sorghum Variety Trial.

Description. The objective was to determine grain productivity of the white sorghum varieties, Kanfiagui and 82S50 with fertilization. Kanfiagui is a local variety grown near Diapangou and 82S50 was developed by ICRISAT.

The experiment was conducted at Nedogo. The experimental design was a randomized complete block with four blocks. The four treatments were the following:

1) Kanfiagui without fertilization,
2) Kanfiagui with 100 kg/ha 14-23-15 applied in a band at 10 to 15 cm from the rows of sorghum two weeks after planting, plus 50 kg/ha urea applied in pockets at 10 to 15 cm from seed pockets one month after planting,
3) 82S50 without fertilization,
4) 82S50 with fertilization as in Treatment 2.

Planting was done on 9 July. Sorghum was planted in pockets which were 40 cm apart in the rows. When seedlings were 5 to 10 cm tall the population was thinned to two plants per pocket.

Results and Discussion. Similar population densities were achieved for the two varieties, 72 seedlings/plot for Kanfiagui and 78 for 82S50 (Table 16). For both varieties seedlings failed to emerge in approximately 25% of the seed pockets. Plant height at maturity was 2.6 m for Kanfiagui and 1.4 m for 82S50. Although there was no lodging, 82S50 had a more substantial stem than Kanfiagui. Both varieties were taller with fertilization than without fertilization.

Kanfiagui produced significantly more grain yield than 82S50 under both fertilization and nonfertilization. The relatively poor yield of 82S50 was primarily because it flowered 10 days later (4 October) than Kanfiagui (25 September). The last significant rain at Nedogo occurred on 16 September. Having reached 50% flowering on 25 September, enabled Kanfiagui to achieve a high percentage seed set and begin grain filling

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before drought stress became severe. Comparison of Kanfiagui and 82S50 for number of seedlings per plot and number of spikes harvested demonstrates the significance of the drought stress during flowering of 82S50. 82S50 develops many more kernels per panicle than Kanfiagui. The kernels of 82S50 are also larger than those of Kanfiagui.

Table 16. Means for the performance of the white sorghum varieties Kanfiagui and 82S50 with fertilization at Nedogo in 1984.

Treatments	Means				
	Seedlings per plot	Plant Height	Grain Yield	Spikes Harvested	Grain/ Panicle
	number	m	kg/ha	number	gm
Varieties					
Kanfiagui (K)	72	2.6	713.5	97	17.6
82S50	78	1.4	328.1	33	23.8
SE[1]			78.5		
Fertilization					
Without Fertilizer			312.5		
Fertilized[2]			729.2		
SE[1]			78.5		
Combinations					
K without Fertilizer	68	2.3	468.8	78	14.5
K with Fertilizer	76	3.0	958.3	116	20.6
82S50 without Fertilizer	78	1.2	156.2	24	15.8
82S50 with Fertilizer	79	1.6	500.0	41	31.7
SE[1]			111.1		
CV%			30.2		

[1]Standard error of the difference between two treatment means.

[2]100 kg/ha of 14-23-15 applied in a band at 10 to 15 cm from the rows of sorghum two weeks after planting, plus 50 kg/ha urea applied in pockets at 10 to 15 cm from seed pockets one month after planting.

Summary

Seven agronomic trials were conducted by FSU/SAFGRAD staff on farmers' fields near one to five villages throughout the central plateau of Burkina Faso. The trials were designed to focus on the following four technology themes: construction of tied ridges to reduce surface runoff of rainfall and thereby increase the amount of water available to plants; fertilization with chemical fertilizers and manure to improve soil fertility; cereal-legume intercropping; and new varieties of cereals and the legume, cowpeas.

Tied ridging alone and fertilization with certain types and rates of fertilizers alone usually resulted in significant increases in cereal (millet, sorghum and maize) grain yield and cowpea yields. However, the greatest yields almost always were achieved with combinations of tied ridging and fertilization which emphasizes that available water for plants and soil fertility are both serious constraints to crop production throughout the central plateau.

To minimize difficulties of seedling emergence due to dry conditions after seeding and to minimize lodging due to erosion of tied ridges, the tied ridges should be constructed after seeding or the seed pockets should be placed half way down one side of the ridges. Tied ridges should be constructed as soon as possible after seedling emergence, recognizing constraints due to plant size and available labor.

Significant yield increases from fertilization were most consistently achieved with 100 to 200 kg/ha of 14-23-15. The inconsistent responses of cereal crops across the central plateau to VP1, UV5 and urea alone or in combination, and the fact that 14-23-15 contains small amounts of sulphur and calcium suggest that low concentrations of certain elements in addition to N, P and K may restrict yields of cereal crops in certain areas of Burkina.

Although the amount of manure available for fertilization is currently very limited, its application should certainly be encouraged. Long-term benefits from manure include the improvement of soil structure to increase rate of water infiltration.

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Intercropping of cowpeas and the cereals maize and millet, tended to reduce cereal yields compared to yields of sole-cropped cereals. However, total cereal-plus-legume grain yields were almost always as large and in some cases, significantly larger than yields of the sole-cropped cereal.

The variable climatic constraints across the central plateau in 1984 emphasized the importance of the stability of production offered by indeterminate cowpea varieties.

The variety trial comparing the two varieties of white sorghum, Kanfiagui and ICRISAT 82S50, emphasized the importance of drought stress during flowering and grain filling as a production constraint.

III. SOCIO-ECONOMIC RESEARCH

In 1984 FSU socio-economic research focused on three areas: credit, land tenure and stocks and transactions. Additionally information was gathered on farmers'perceptions of and their adoption of certain technologies.

The data base for all the socio-economic analysis comes from a sample of 30 households in each of the five villages that FSU works in. The 30 households were randomly selected based on a village census. In Diapangou, although randomly selected, all households are animal traction households. This was to accomodate an animal traction study (Jaeger, 1985). This sample was conserved in 1984.

In 1983, FSU conducted an analysis to identify the factors that explain economic performance and the general welfare of individual farmers (FSU/SAFGRAD, 1983). The factors associated with economic performance and farmer well-being for a given household are per capita grain consumption, per capita cereal and livestock sales, cash crop hectares per capita and the number of hectares per capita of cultivated land. Of these, the number of hectares per capita was found to be the major factor explaining economic performance and farmer well-being.

The area cultivated by a household is a function of the active labor force and tillage technology utilized. It is also determined by the access to land and the desire to expand land area. Thus access to land and capital to invest in animal traction and other inputs determines the expansion path farmers will take to increase their economic well-being. Given access to land and credit, most farmers will likely choose to extensify. Extensification offers a greater return than intensification and less risk of losing the cash cost from technologies like fertilizer. Increasing the cultivated area of a household however does not preclude farmers from adopting intensive type technologies. Farmers who want to increase their welfare but who do not have access to land but have access to credit will most likely try to intensify and adopt technologies that FSU works with.

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However, the extensification option is not a long term solution for increasing farmers'welfare especially on the Mossi plateau. The net population growth rate of 1.7 percent has increased the man-land ratio and is causing a change in traditional farming practices. To increase food production, there is a shortening of the fallow rotation period required to restore the soil which is very low in organic matter and fertility. The shortening of the fallow period in combination with the present farm management practice of the removal or burning of all plant material is very exhaustive on the soil. In the northern areas of Burkina, desertification of cultivated land is also becoming a serious problem.

As access to land becomes more limiting and more pressure is put on the land for food production, soil deterioration will increase resulting in lower yields and food production and increased outmigration. Part of the solution to overcoming these problems lies in changing the present farming system by using intensive type technologies that increase the productivity of the land. The work by FSU with tied ridges, organic and inorganic fertilizers, new varieties and mulch explores the type of intensive technologies that increase land productivity.

Since access to land which is determined by the land tenure system and utilization of formal and informal credit play an important role in shaping farmers' decisions with respect to intensification and extensification options, studies in the two areas were undertaken in 1984. Section A presents the study on credit and the study on land tenure is presented in section B.

The collection of stocks and transactions data was continued in 1984. The data was analysed and published in monthly reports. In addition, stocks and transactions data has been used for a masters student thesis (Ann Bukowski, in process) and two publications on marketing (Mahlon Lang, in press). Section C presents a summary analysis of data collected from December 1983 to November 1984.

A survey of cooperator-farmers was conducted to evaluate their perceptions about the technologies that FSU works with. The hectarage and number of cooperator-farmers using the technologies outside of the FSU trials were tabulated. An analysis of the difference in farm-specific characteristics between adoptors and non-adoptors was also undertaken. The analysis is presented in section D.

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A. Credit.

In 1984, research in the area of credit was undertaken. The study began in April, just prior to the beginning of the cropping season, and continued through 7 January, 1985. The study was designed to encompass both the formal and informal credit systems.

The objectives were to:

1) describe the structure of the informal credit system

2) determine the uses of formal and informal credit

3) evaluate the costs of informal credit.

Thirty households in each of the five study villages (150 households in total) were interviewed during a period of 9 months coinciding with the agricultural season. At the start of the survey, all households were asked to provide data on their current borrowing and lending position. They were also interviewed regarding their perceptions as to their access to agricultural credit in the informal sector, and their use of formal credit.

In the months that followed, the evolution of the informal credit transactions of each household was monitored. Beginning in May, the credit interviews were combined with the monthly stocks and transactions questionnaire. This approach proved to be satisfactory for several reasons. The stocks and transactions interviews provided a natural starting point for the credit interviews, due to the importance of grain in household economies. The combined interviews resulted in a reduction in emphasis on credit per se and provided a better environment within which to discuss the sensitive issue of credit. Consideration of credit transactions also improved the quality of the stocks and transactions data collected.

The credit data include information on loans outstanding at the time the interviewing was initiated, as well as all those loans which took place during the study period. Services provided on credit and credit purchases of non-cereal commodities are not included. Prevailing market prices were used to determine the value of in-kind lending and borrowing.

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Informal credit.

Farmer Lending.

Within the informal credit system, farmers act as both lenders and borrowers. Table 17 provides a breakdown of the incidence of informal credit in each of the five villages studied. The proportion of households involved in lending varied widely across villages, ranging from a high of 73 percent in Poedogo to a low of 40 percent in Nedogo and Bangassé. Except for Poedogo, the villages located on the Central Plateau showed a lower incidence of lending by farmers.

Table 17 also presents the average value of all loans extended, but due to the large variation in value, no definitive conclusions are possible. Loan size can vary over a wide range. In this data set values of loans extended ranged from 100 to 100,000 CFA.

On the borrowing side the situation was similar. Approximately equal proportions of households borrowed during the study as lent. The grain surplus villages (Poedogo, Dissankuy, and Diapangou) showed a higher incidence of borrowing. This suggests that informal borrowing may be used for productive purposes in those villages, a hypothesis to be tested later on. The mean values for borrowing show the same large variation as those for lending.

In work undertaken previously in the Eastern ORD, Tapsoba (1981) found that farmers reported far greater numbers of loans extended than loans received. He postulated that shame related to borrowing may have been responsible for this discrepancy.

In terms of loan value, lending was in balance with borrowing in Dissankuy (Table 17). In Nedogo, Bangasse, Poedogo and Diapangou, the total value of lending exceeded the value of borrowing by a ratio of 1.6, 2.1, 1.8 and 3.6, respectively. The value for Diapangou, located in the Eastern ORD, compares favorably with the 3.9 observed by Tapsoba, and is partly attributable to the presence of two farmer-traders in the sample. These households were responsible for a large share of the value of loans extended, but borrowed very little themselves. In addition, the Diapangou sample was composed entirely of animal traction households who might be expected to participate to a greater extent in lending activity. Indeed,

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Table 17. Incidence of informal credit by village.[1]

Village	Lending: Percent of Sample Households	Lending: Average Value of Loan	Borrowing: Percent of sample	Borrowing: Average Value of Loan	Lending-Borrowing Ratio
		CFA		CFA	
Nedogo	40.0	5,[illegible]46 (4,564)[2]	43.3	3,650 (3,041)	1.6
	12[3]	26[4]	13	24	
Bangasse	40.0	6,710 (20,446)	36.7	3,916 (2,761)	2.1
	12	22	11	18	
Poedógo	73.3	4,343 (6,251)	66.7	5,589[5] (9,865)	1.8
	22	127[6]	20	54	
Dissankuy	63.3	5,738 (8,162)	56.7	10,689 (33,030)	1.0
	19	65	17	35	
Diapangou	70.0	16,975 (23,361)	66.7	13,924 (22,210)	3.6
	21	106	20	36	

[1]Includes credit outstanding at the beginning of the study.

[2]Standard deviation of the mean.

[3]Number of households.

[4]Number of observations.

[5]Excludes two borrowings for a total value of 3,300,000 CFA.

[6]One observation missing.

Tapsoba (1981) found that animal traction households in the Eastern ORD lent more than non-traction households, but borrowed less.

In Bangasse, the ratio of lending to borrowing is influenced considerably by one loan for 100,000 CFA extended in 1982. The presence of this one large loan, for which no reimbursements have been made, may indicate a reluctance on the part of farmers to drop loans from their portfolios. This could help to explain the discrepancy between borrowing and lending. Indeed, the lending/borrowing ratio in Bangasse drops from 1.6 to 0.68 when this loan is excluded, and pre-1984 loans accounted for 76% of the value of loans extended.

- Beneficiaries of Farmer Lending.

In order to assess the relative importance of informal lending to various sectors in the rural economy, several beneficiary/lender categories were developed. These included village groups, household and family members and traders.

Table 18 presents a breakdown by beneficiary of the total value of loans extended during the study and outstanding at the start of the agricultural season. In Dissankuy and Diapangou, persons in the village (other than members of the lender's household or extended family, or traders) received the largest proportion of loan funds extended by farmers, accounting for 60 percent and 46 percent of the total, respectively. At Bangasse, one loan was made to a trader outside the village. This credit represented 68 percent of the loan funds extended by Bangasse farmers. When this loan is removed, other persons in the village accounted for 46 percent of the total, while family and household members together received 28 percent of loan funds.

In Diapangou, the proportion of loans extended to traders was influenced by the inclusion in the sample of two large farmer traders. These two households were responsible for a large share of funds lent, including the entire amount lent to traders. Their lending to "other persons in the village" was important; it comprised 42 percent of the value of their combined lending.

Household and family members are important in Poedogo and in Nedogo as beneficiaries of farmer lending. These two categories received 21 percent and 29 percent respectively of funds lent by farmers.

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Table 18. Beneficiaries of farmer lending by village, April 1984 to January 1985.[1]

Village	Persons Within Village: Household Member	Family Member[2]	Village Groups	Other Persons[3]	Traders	Non-Village: Traders	Other Persons[4]	Undetermined
	(Percent of Total Value)[5]							
Nedogo	13.6	7.7	18.3	26.3	-	-	34.2	-
n	6	2	1	8			9	
Bangasse	4.9	5.6	-	14.8	-	67.7	6.9	-
n	2	7		8		1	4	
Poedogo	12.2	16.4	-	22.6	-	7.6	41.0	.3
n	11	14		48		7	47	1
Dissankuy	-	14.5	-	59.5	-	13.4	12.6	-
n		14		43		1	7	
Diapangou	.2	9.0	-	45.9	12.2	13.0	19.2	.6
n	2	17		68	3	2	13	1

[1]Includes loans outstanding at the beginning of the study.

[2]Extended family.

[3]Includes all those not previously mentioned in village except traders.

[4]Includes all those outside village except traders.

[5]Percentages do not sum to 100 due to rounding.

Persons outside the village (excluding traders) were an important beneficiary group in Nedogo and Poedogo. In the former village, this group received 34 percent of the total amount lent. These recipients were persons residing in other villages located from 5-90 km from the lenders. Non-traders outside the village received 41 percent of the total value of lending by Poedogo farmers. Most of these recipients were located within 25 km of the farmer-lenders, although one beneficiary of a large loan (50,000 CFA) was located in Abidjan.

In summary, the data indicated that farmer lenders provide loan funds most often to beneficiaries either in or near their villages. Traders did not comprise a significant beneficiary group for farmer-extended loans.

Sources of Farmer Borrowing.

If the majority of farmer lending takes place among villagers, what can be said about the sources of loan funds for farmer investments? Table 19 shows the proportions of loan funds provided by different lender categories. Although results varied from village to village, some generalizations can be made.

In Nedogo and Bangasse, household and family members together provided the largest proportion of funds for farmer investments. Family members were also important sources of borrowing in Diapangou and Dissankuy.

Village groups have been established as farmer organizations for extension and self-help purposes. These groups are involved in the administration of cereal banks and formal credit programs. Other activities may include the provision of informal credit. In Nedogo, for example, a village group provided 20 percent of the total amount of borrowed funds. These credits, however, represented loans made to only one household (the traditional chief) between 1979 and 1983. In 1984, no loans were received from village groups in Nedogo. In both Bangasse and Diapangou, one loan was provided by a village group in 1984 and 1981 respectively. In Diapangou the loan was received by a large grain trader. In Poedogo, the village group was active in making in-kind loans during the hungry period.

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Table 19. Source of informal farmer borrowing by village, April 1984 to January 1985.[1]

Village	Persons Within Village: Household Member	Family Member[2]	Village Groups	Other Persons[3]	Traders	Non-Village: Traders	Other Persons[4]	Undetermined
	(Percent of Total Value)[5]							
Nedogo	21.1	37.8	20.3	16.3	-	-	4.6	-
n	7	6	3	6			2	
Bangasse	11.4	39.0	10.6	18.4	-	-	20.6	-
n	3	7	1	4			3	
Poedogo	10.1	-	8.3	30.6	10.8	7.4[6]	32.5	.3
n	9		15	15	5	3	6	1
Dissankuy	-	28.9	-	6.3	.5	58.7	5.6	-
n		16		9	1	5	4	
Diapangou	2.0	32.1	12.0	13.6	6.3	24.9	9.2	-
n	2	14	1	10	5	1	3	

[1]Includes loans outstanding at the beginning of the study.

[2]Extended family.

[3]Includes all those not previously mentioned in village except traders.

[4]Includes all those outside village except traders.

[5]Percentages do not sum to 100 due to rounding.

[6]Excludes two loans for a total value of 3,300,000 CFA.

In Dissankuy and Diapangou, traders outside the village were an important source of loan funds, providing respectively 59 percent and 25 percent of the total value of loans received. In Dissankuy, one large loan received from a trader outside the village represented 53 percent of the total borrowed in that village.

In Poedogo, traders in the village provided 11 percent of the informal loan funds received, while traders outside of the village were responsible for providing seven percent of the borrowed funds. The proportion of borrowed funds provided by traders in Poedogo was less than at Dissankuy and Diapangou. It should be noted that one farm operator in Poedogo received a total of 3,300,000 CFA from a Ouagadougou trader for the purchase of a tractor and associated implements. This credit was not included in table values and descriptive statistics because of it's unusual size and use. The borrower was a very large, wealthy and influential farm operator. Borrowing of this magnitude underscores the importance of traders in the wealthier villages, and gives an indication of potential funds available for agriculture in the informal system.

The Poedogo data also points to the importance of labor employed outside of Burkina on the village economy. Workers employed in Abidjan, but related to the borrower, accounted for 30 percent of the total value of loans received. This proportion is comparable to that provided by "other persons" in Poedogo.

In the informal credit system, traders were more important as sources of borrowed funds than as beneficiaries of farmer lending. This is not surprising given traders' greater access to cash generating activities. Traders were active as lenders only in the grain surplus villages. Except in Poedogo, credit received from traders were larger on average than those provided by other sources (Table 20).

Traders often hire individuals to act as agents for them in the purchase of cereals. Farmers may not consider those agents as traders *per se*. In situations where these agents practice advance sales (with reimbursement of cereal grain at harvest), the influence of traders in providing credit could have been under-estimated. No information was available from the sample concerning the extent of credit provided by buying

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Table 20. Mean value of informal borrowing by source of borrowed funds.

	Source	
Village	Traders	Non-Traders
	CFA	
Nedogo	-	3,650
n		24
Bangasse	-	3,916
n		18
Poedogo[1]	6,859	5,465
n	8	45
Dissankuy	36,917	5,262***[2]
n	6	29
Diapangou	26,083	11,492**[2]
n	6	30

[1]One observation missing.

[2]** and *** indicate a level of significance of .10 and .05 respectively.

agents. Their role could have been important in Poedogo which is near Manga, an active grain market.

Use of Borrowed Funds.

One of the primary objectives of the FSU credit study was to determine the degree to which informal credit was being used for agricultural investments. Tapsoba (1981) found that for the Eastern ORD the major function of the informal credit system was to provide loans for social obligations, household food consumption and trade. Sawadogo (1979) observed that informal sources were sometimes used for credit sales of agricultural inputs in the Kaya region. The FSU credit study addressed the issue of informal credit use over a wider geographical area, as well as over a greater number of agroclimatic zones.

Table 21 presents the uses to which informal borrowing was put by farmers in the FSU study villages. Only in Poedogo did agricultural uses represent a significant share of total borrowed funds, accounting for 21 percent of the total value of loans received. The provision of draft animals accounted for 14 percent of the loan funds borrowed in Poedogo. In Dissankuy, 15 percent of borrowed funds were used for investment in draft animals. Three percent of borrowed funds were used for animal traction equipment both in Poedogo and Diapangou. Informal agricultural credit was also used in Poedogo for seeds, tools and expenses related to communal farm labor. In Nedogo credit was used to obtain seeds.

It should be pointed out that services provided on credit are not included in the data because of the difficulty in estimating the value of the service had it been purchased in cash. Cash borrowing for purchases of services is included. In Dissankuy, there were eight instances of agricultural services provided on credit. These borrowings were most often in the form of rental fees paid on credit for the use of cotton insecticide sprayers. At Dissankuy, this type of loan showed up in farmer lending as well, as did lending for ridging services. Credit rental of agricultural services was minor in the other villages (one credit rental in Poedogo and one credit rental in Diapangou).

Use of borrowed funds for household food consumption was greatest in Bangasse, the village which showed the highest net cereal purchases per capita (Fig. 8). Nine of the 11 borrowing households cited food consump-

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Table 21. Use of informal farmer borrowing by village, April 1984 to January 1985.[1]

Village	Agricultural				Non Agricultural				
	Draft Animals	Animal Traction Equipment	Livestock	Other	Household Food Consumption	Commerce	Bride Price	Family Obligations	Other
	Percent of Total Value[2]								
Nedogo	-	-	-	2.2	24.8	3.4	16.3	18.8	34.5
n				1	6	2	3	3	9
Bangasse	-	-	-	-	65.2	-	14.2	17.7	2.8
n					14		1	2	1
Poedogo	14.4	3.3	-	3.5[3]	9.4	40.3	6.3	16.2	6.7
n	2	1		5	17	11	1	12	5
Dissankuy	14.7	-	-	-	17.5	-	.5	53.5	13.8
n	2				16		1	1	15
Diapangou	-	3.0	1.7	-	31.3	34.6	7.5	2.9	19.0
n		1	1		4	9	1	3	17

[1]Includes loans outstanding at the beginning of the study.

[2]Percentages do not sum to 100 due to rounding.

[3]Two loans were recorded for a total of 3,300,000 CFA for the purchase of a tractor and implements. These loans have been excluded.

tion as the reason for at least one credit. Food consumption represented an important use of borrowed funds in Diapangou (31 percent of total loans received), but only four of the 21 households who borrowed did so for food needs. The presence of one food consumption loan for 125, 000 CFA greatly inflates the proportion of borrowed funds used for food consumption. When this loan is removed from the sample, use of borrowed funds for household food consumption drops to only six percent of the total borrowed in Diapangou.

In Nedogo, 25 percent of the total borrowing was cited as being for food consumption purposes. It should be pointed out, however, that of the two households who identified household food consumption as their principle reason for borrowing, credits to one accounted for 95 percent of the total value of the food consumption borrowing, and roughly half of this was from pre-1984 loans. Borrowing for food consumption purposes was therefore not as important in Nedogo as the data might initially indicate.

Commerce was an important use to which borrowed funds were put; in Diapangou and Poedogo, 35 percent and 40 percent of the total value of farmer borrowing was used for this purpose. In Poedogo, eight of 11 loans received for commerce were contracted for in September as in-kind loans for millet and rice. This is the time when cereal prices are the highest (Sherman, 1984) and when the largest number of net sales per capita were registered in Poedogo (Fig. 10). These in-kind credits represented 25 percent of the total utilized for trade.

In kind loans for commerce of non-cereal commodities (tobacco and cola nuts are not included in the data presented because of the inability to determine the value of the commodity had it been purchased in cash. Borrowing of this type was only observed in Poedogo (four observations). One household held three loans and reimbursed a total of 285,500 CFA for tobacco purchased on credit. The other household had one borrowing for cola nuts and reimbursed 2,000 CFA.

In Nedogo, Bangasse and Poedogo, family obligations accounted for more than 15 percent of borrowed funds. In Dissankuy, one large loan for family obligations accounted for 54 percent of the total amount borrowed. In Nedogo, the category "other" was important. Cash borrowing for the

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purchase of such things as cola nuts, tobacco and a tire for a cart were included here.

Purchases on credit of consumption goods were not widespread. In Poedogo, three minor transactions for sales on credit of batteries (200 CFA reimbursed), a sewing machine (2,000 CFA reimbursed) and thread were observed. In Dissankuy, bicycle repairs were providedon credit in one case (1,000 CFA reimbursed) and dolo was purchased once on credit.

In summary, the results of the study support the conclusion that informal credit is mainly used for non-agricultural purposes in all villages studied. Food needs, family obligations and commerce all are important uses to which borrowed funds are put. When informal credit was used for agricultural purposes, it was most likely to be used for animal traction.

Farmers' Perceptions.

One of the objectives of this study was to assess farmers' perceptions of the availability of informal loan funds for agricultural uses. For three levels of agricultural borrowing, farmers were asked to indicate whether the amount in question would be available to them from an informal credit source. The results are presented in Table 22.

Except in Bangasse, large majorities in each village felt that they would be able to borrow 5,000 CFA for use in their farm enterprise. As would be expected, when the amount increases from 5,000 to 50,000 CFA, fewer farmers felt they would be able to procure funds in the informal credit system. With the exception of Diapangou, when borrowing levels reached 100,000 CFA, less then 15 percent of farmers interviewed felt they would be able to secure loans of this magnitude outside of formal lending institutions.

Those farmers who felt that a given amount was available were asked to indicate the source from which they would be able to borrow the sum in question. At the 5,000 CFA level, family members represented a major perceived source of informal loan funds for all villages except Poedogo. Farmers in Poedogo cited "other persons in the village" most often. This category was also important in Nedogo. Traders, especially those outside the village, were cited relatively more frequently as the loan amount increased. In general, at all levels of borrowing, relatives constituted

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Table 22. Farmers' perceptions of availability of informal loan funds for agricultural uses, percent of sample considering amount available.

Village	Amount in CFA 5,000	50,000	100,000
	Percent		
Nedogo n[1] = 30	83.3	46.7	10.0
Bangasse n = 27	60.0	23.3	3.3
Poedogo n = 30	93.3	36.7	13.3
Dissankuy n = 30	100.0	37.0	14.8
Diapangou n = 30	96.7	70.0	40.0

[1]Number of households.

an important perceived source of agricultural loan funds.

Farmers' perceptions of available sources of loan funds are generally in agreement with observed borrowing behavior; Table 19 shows that family members and traders were important sources of funds for outstanding loans. Poedogo, was an exception. Compared to the levels of agricultural borrowing observed in the sample, farmers seem overly optimistic concerning the availability of loan funds for this purpose. Their perception that larger loans are most likely to be obtained from traders, seems justified based on the mean value of loans received from this source (Table 20).

Cost of Capital.

The cost of capital is an important variable to be considered in the evaluation of the credit options available to farmers. In the informal system, interest payments can take several forms. They may be explicit, where the value of the reimbursement made exceeds the value of the principle, or implicit. In the latter case the exchange of a good or service at some time during the term of the loan may represent the interest payment. In the rural economy, the mutual exchange of goods and services is an every day occurrence. It is difficult to determine if the exchange is wholly or partly dependent on the credit relationship which exists between the two parties. Even when the exchange of a good or service can be determined to have occurred, quantifying the value of the exchange is almost impossible, given the small degree to which village markets are monetized. It is clear that the provision of credit cannot be separated from the mutually beneficial social relationships and obligations, including status and prestige, which exist in the village setting.

During the study period, data from the 150 households was collected on 514 credit transactions. This figure includes cash and in-kind loans both received and extended. It takes into account all credits outstanding at the beginning of the study in April 1984 as well as those extended during the 1984-85 agricultural season. Credit transactions for services and credit sales of other than cereal grains were excluded.

As part of the monthly stocks and transactions questionnaire, each farmer was asked to provide information on his cash and in-kind reimbursements. During the nine month period of the study, 145 loans extended and 90 loans received had been reimbursed. These constitute the data set to be used in analyzing the cost of capital in the informal sector.

Calculating interest rates for informal credit is complicated. In the case of in-kind credits and/or reimbursements, values must be calculated for the loans and repayments. In all cases, prevailing market prices were used to determine credit amounts and repayment values. In 17 cases the quantity of cereal grain reimbursed equaled the amount lent or borrowed. In these cases, interest rates could only be determined where the prevailing market price of the commodity was higher at the time of repayment. This method does not allow estimation of interest rates in cases where lenders store grain and sell later when prices are higher.

In many instances, loans reimbursed did not carry explicit interest rates. Of the 145 loans extended and reimbursed, 58 were interest bearing (40 percent). Of the 90 loans received and reimbursed, 17 required interest payments (19 percent). This finding is consistent with Tapsoba's (1981) observation that most informal credit is for mutual assistance. He divided the informal credit system into two parts, the noncommercial segment, in which no-interest credit transactions are the norm, and the commercial segment.

Table 23 presents mean annual interest rates for short term informal lending and borrowing across villages. Short term was defined as credits whose terms were 12 months or less. Interest was calculated using the straight line formula. The mean annual interest rate on farmer extended loans was 245 percent. Farmers paid on average 230 percent per year for loans that they received. Mean interest rates on farmer lending and borrowing were not significantly different at the 0.20 probability level.

Although these interest rates are high, there was considerable variation in the observations. Annual interest on lending ranged from 0.6 percent to a maximum of 660 percent. The annual interest rate paid on farmer borrowing varied from a low of 33 percent to a high of 720 percent.

Interest rates must be interpreted in light of several factors. The opportunity cost of capital and delinquency rate must be taken into account. Lenders who are active in the commercial sector may also be lending in the noncommercial sector with no interest (i.e. negative real interest rates).

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Table 23. Mean annual interest rates for short term informal credit, villages combined.

Credit Type	Annual Interest Rate
	Percent
Lending	
Mean	245.3
SD	237.3
n	40
Borrowing	
Mean	229.9 NS
SD	191.2
n	16

The two traders in the Diapangou sample, provide an example. Of the 20 loans extended (and reimbursed) 14 bore interest. The principle value of the interest bearing loans represented 49 percent of the value of the total principle lent. Tapsoba (1981) found similar examples.

Less data was available on medium term (one to five years) credit. Four- and five-year loans were included in the medium term data in order to increase the sample size. Only one medium term credit was recorded in the data on informal borrowing. The analysis includes only those medium term credits observed on the lending side, a total of 17 (one observation was eliminated because the term was twice as long as that of the longest loan).

The mean annual interest rate for medium term lending was 11 percent. The observed interest rates ranged from a minimum of 0.60 percent to a maximum of 60 percent. Tapsoba (1981) considered loans not repaid after 6 months to be delinquent. The medium term borrowing observed may therefore represent payments on delinquent short term credit.

Formal Credit.

On the national level, most formal agricultural credit is administered by the regional ORD. Financing is provided by the Caisse Nationale de Crédit Agricole (CNCA) and outside sources. In the cotton producing areas, SOFITEX is important in the credit market. In irrigated areas, various institutions provide funding for agricultural production. Non-governmental organizations also administer credit programs.

Funds are lent to farmers through the mechanism of village groups. Responsibility for loans is therefore collective. In order to obtain a loan, a farmer must be a member of this local village group, and must have his application approved by this body.

Membership in an ORD-sponsored village group requires the purchase of a membership card and participation in group activities. In some cases, payment of periodic dues may be required. Membership fees vary according to the activities of each group. In the villages studied they ranged from 500 to 2,500 CFA. These fees constitute a pool of capital which can be made available through informal loans. Group members may also engage in activities such as farming a common field or making bricks.

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Donation of grain to a common granary may also be required. This grain may then be available for lending. The degree to which economic and social factors constitute barriers to entry into village groups is not known.

The majority of ORD/CNCA credit is provided for draft animals and animal traction equipment. Credits typically involve a combination of cash payments and in-kind loans. In areas where cotton is an important crop, production inputs are available on credit. The financing is provided by SOFITEX through the local ORD. In some areas, a credit program exists as part of irrigation projects.

In April 1984, each farmer in the sample was asked to provide a five year history of his formal borrowing. This history included formal borrowing from 1979 to 1983. It excluded short term credit for the 1984-85 agricultural season.

The proportion of farmers who benefited from formal credit during the five year period varied widely from village to village. In Nedogo and Bangasse, 33 percent and 36 percent of the farmers interviewed had received a formal loan in the last five years. All of the farmers interviewed in Poedogo had received formal loans. In Dissankuy and Diapangou, 90 percent and 73 percent of the sample farmers respectively had received formal credit during the 1979-83 period.

The distribution of formal credit among the villages was also variable. Nedogo and Bangasse, each received less than seven percent of the total lent in all villages during the five year period. Poedogo received 20 percent of total funds disbursed, while Dissankuy and Diapangou received 37 percent and 34 percent, respectively (Table 24).

Table 24 underscores the importance of animal traction credit within the formal system. In Nedogo, Poedogo and Diapangou, virtually all loans granted during the five year period were used for animal traction (defined as draft animals and animal powered equipment, including carts). In contrast, 62 percent of the formal credit granted from 1979-83 to farmers in Dissankuy was used for the purchase of production inputs. These included fertilizer, agricultural chemicals, seeds, sprayers, and other agricultural inputs. This short term credit was disbursed on a regular basis;

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Table 24. Distribution and use of formal credit by village, 1979 to 1983.

Village	Total in All Villages	Use: Animal Traction[1]	Use: Production Inputs[2]
		(Percent)[3]	
Nedogo	6.30	100.00	-
n		11	
Bangasse	2.58	-	100.00
n			26
Poedogo	19.85	100.00	-
n		35	
Dissankuy	37.25	38.10	61.90
n		8	112
Diapangou	34.03	99.96	.04
n		26	1

[1]Draft animals and associated equipment (carts, ploughs, seeders, etc.)

[2]Fertilizers, agricultural chemicals, seeds etc.

[3]Percentages do not sum to 100 due to rounding.

73 percent of the farmers received these production loans in four of the five years. The regular nature of these loans accounts for the high proportion of total loan funds disbursed in Dissankuy.

In Bangasse, where few farmers utilize animal traction, all of the formal credit was for production inputs. This credit was utilized, in almost all cases, for the production of irrigated rice and green beans. These loans, however, were not of substantial size. Bangasse accounted for only 3 percent of the total value of formal borrowing in the villages over the five year period.

In summary, within the informal credit system, farmers act as both lenders and borrowers. Beneficiaries of farmer lending are likely to be located in or near the same village. Village sources are also important in the provision of borrowed funds.

Traders both in the village and outside were seen as an important source of credit in the three grain surplus villages. In two villages, traders provided larger loans on average than non-traders. Traders were not an important source of loan funds for agricultural uses.

Much informal borrowing is non-commercial in nature and involves mutual assistance among villagers. Forty percent of the total number of loans extended and reimbursed had explicit interest charges. Only 19 percent of reimbursed farmer borrowing required explicit interest payments. The mutual exchange of goods and services between borrower and lender undoubtedly occurs. In the commercial sector of the informal system the cost of capital varies widely and may be high. Mean annual interest rates of 230 percent and 245 percent were observed for farmer borrowing and lending respectively (Table 23). Most interest-bearing loans were short term.

Although formal credit is available in all the study sites, it is concentrated in the grain surplus villages (Table 24) and is used mainly for the provision of animal traction equipment. Very little informal borrowing occurred for agricultural purposes in the sample villages (Table 20). The low level of informal agricultural borrowing is consistent with results from the Eastern ORD (Tapsoba, 1980; Tapsoba, 1981).

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When informal credit was used for agriculture, it was most likely to be used for animal traction. This may indicate the relative attractiveness of animal traction technologies over more input-intensive techniques. If farmers' demand for intensification technologies increases, informal credit sources could provide funds for investment. Once effective demand for intensification techniques has been established, formal credit is one policy tool available to influence the investment climate within which farmers operate.

B. Land Tenure.

The objective of the land tenure survey was to undertake a preliminary analysis of land tenure arrangements and the possible implications that the existing arrangements may have for technology adoption. The survey was done in two phases. The first phase constituted a questionnaire given to the farmers in the socio-economic group in each village. Farmers were asked to specify how they obtained the right to farm their present land holdings and specify if the tenure arrangements were of a borrowed or non-borrowed nature. When land was borrowed, farmers were asked about the contractual arrangements. They were asked about the duration that the land was borrowed for and the rental costs. Farmers who lent land were asked if they had taken back any rented land and the reasons for their action. Information was taken on each of the farmers fields and the area of each field was measured. A brief history of the village settlement patterns was also obtained.

The second phase of the analysis involved asking farmers specific questions about the relationship between tenure arrangements and technology adoption (Goold, 1985). The questionnaire was carried out by Elizabeth Goold, a student in the School of Development Studies, University of East Anglia. The questionnaire was conducted in Nedogo and Diapangou. The two villages were chosen because of their differences in ethnicorigin and land availability. Nedogo is primarily Mossi and is a land deficit village while Diapangou is Gourmantché and is a land surplus village.

Access to land in terms of the security of tenure may be important when farmers are deciding to adopt intensive agricultural technologies and farm management practices. Tied ridges, fertilizer and mulch increase the quality of land and make the land more productive. The services provided by these technologies are not fully depreciated at the end of each year and there is a carryover effect in the years to come. Thus farmers may not invest in these technologies if they do not know whether they will be farming the same land in the next agricultural season. They will not be able to capture the full return on their investment. This argument also holds for investments in fruit trees, wind breaks and live fences.

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From the data gathered from the first phase of the survey, it is not possible to show that security of tenure is directly related to the level of technology adoption and farm management practices of farmers. However, what can be shown is the proportion of land under various levels of security of tenure. Thus if a large proportion of land in the village has security of tenure meaning that the farmer knows the land is his to farm in his life-time, land tenure then would not constitute a major constraint to technology adoption.

Four tenure categories delineated by their security of tenure were formed from the survey data (Table 25). Category I land includes all non-borrowed land of the household that has been passed down from parents, immediate family, members of the menage, extended family and friends. These lands are inherited along with the rights to control the land. Category II includes all land that is borrowed from parents, the immediate family and members of the menage. Although classified as borrowed, the land tenure arrangement is looked upon as a definite gift. The land had no acquisition cost, no specified future date for its return and the borrower does not have to pay a rental fee at the end of the year. Category III includes all land that has been borrowed from, friends and relatives other than parents or direct family members. Category IV includes all land obtained from the chief de terre or chief de village. A rental fee due at the end of the agricultural season is usually associated with the land in categories III and IV.

The non-borrowed land in category I and the borrowed land from parents and the immediate family in category II comprise the highest security of land tenure. The land in these two categories reflect future long term usage by the farmers who presently farm the land. The security of land tenure in categories III and IV is less than that of categories I and II. The possibility exists that the land can be taken away from farmers who farm category III and IV land.

The percentage of land area in categories I and II (Table 25) for Nedogo, Bangasse, Poedogo and Diapangou is 79.4, 69.8, 90.9 and 88.7 respectively. This indicates that a large portion of the land in each of the four villages has a high security of tenure. The Bangasse figure of 69.8 is lower than the other three villages. However, about one-half of

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Table 25. Percentage of Cultivated Land Area by Tenure Category, 1984.

Tenure Category[1]	Nedogo	Bangasse	Poedogo	Dissankuy	Diapangou
	Percentage of land area				
I	54.0	62.8	64.8	19.3	81.8
II	25.4	7.0	26.1	0.0	6.9
III	17.6	15.7	2.6	35.0	11.3
IV	3.0	14.5	6.5	45.7	0.0
	100.0	100.0	100.0	100.0	100.0

1. Category I includes non-borrowed land that has been passed down from parents, immediate family, members of the menage, extended family and friends. Category II includes land that has been borrowed from parents or immediate family. Category III includes land that has been borrowed from members of the menage, friends and relations other than parents or direct family members. Category IV includes land obtained through the chief de terre or chief de village.

the borrowed land (categories III and IV) is not subject to a rental fee and is borrowed for an indefinite time period. The security of tenure for this land is thus closer to that in categories I and II. In Dissankuy, 80.7 percent of the land is in the less secure tenure categories III and IV. However, the insecurity of land tenure is not as great in Dissankuy as is indicated by the 80.7 percent figure. In Dissankuy 100 percent of the farmers who cultivate borrowed land grow cotton and 100 percent of these farmers use fertilizer on all their cotton fields. Thus farmers who borrow land are willing to invest in fertilization.

Part of the work of the second phase of the analysis was a questionaire on farmers' responses to several suggested agricultural improvements (Goold, 1985). The household heads were asked whether they would authorize various improvements on land that had been borrowed from him by a farmer who was not of the household head's clan (immediate and extended family).

The responses are given in Table 26 for Nedogo and Diapangou for seven agricultural improvements. The first four improvements relate to the planting of trees. In Nedogo, there was a close to even split by the 15 respondents. In Diapangou, the majority answered 'No' to the authorization of growing fruit trees and trees for firewood and 'Yes' to the authorization of growing windbreaks and living fences. The growing of trees, especially fruit trees and trees for firewood represents a symbol of ownership to many farmers. Thus a farmer who grows trees on borrowed land may lose the right to cultivate it because the owner may view it as a bid to take over the full property rights. The majority of household heads in both Nedogo and Diapangou responded that they would authorize animal enclosures, anti-errosion ditches and volta phosphate use.

The questionnaire was conducted from the viewpoint of the lender of the land. The answers may have been different if the questionnaire was conducted from the viewpoint of the borrower. The seven improvements enhance the qualities of the land and may increase the probability of the lender taking it back. The responses of the lenders as given in Table 23 do, however, provide some information about tenure relationships.

While tenure arrangements for borrowed land vary among villages, there are similarities. Most of the land in the borrowed categories do

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Table 26. Land lenders who would allow a non-Kinsman land borrower to carry out land improvements.[1]

Land Improvements	Nedogo		Diapangou	
	Yes	No	Yes	No
Fruit trees	7	8	5	10
Trees for firewood	7	8	4	11
Windbreaks	8	7	9	6
Living fences	8	7	12	3
Animal enclosures	14	1	14	1
Anti-errosion ditches [2]	14	1	14	1
Volta phosphate	15	-	15	-

[1]From Goold, 1985.

[2]Includes diguettes and tied ridges.

not have a specified date at which they must be returned. For the borrowed land of indeterminate loan period that is subject to a rental charge, the rental fee is usually one tine (18-20 kgs) of sorghum or millet once a year. In Dissankuy where the land is more productive, the rental fee is usually two tines and in some cases three. Crops like peanuts and maize are at times also used. Goats and poultry are also used as are labor services but these are not common.

There are a few fields that are borrowed seasonally. One 0.72 hectare field in Nedogo used to grow peanuts is borrowed a year at a time. Two fields comprising 0.14 hectares in total were borrowed seasonally in Bangasse at a rental fee of 2750 CFA each. The fields were used for rice and green bean production in irrigation projects near Bangasse. Four fields in Diapangou for a total of 0.654 hectares were borrowed seasonally. Three fields were used to grow peanuts and one field was used to grow millet.

Another indicator of the security of tenure is the degree to which borrowed land is taken back and the circumstances under which it is taken back. Farmers were asked if any borrowed land had been taken back by the owner within the last five years. In Nedogo only two fields were taken back. The reason given by one farmer was that he needed the land for his son. The other field was taken away because the borrower increased the size of the original cultivated area of the field without the lender's permisson. This was viewed by the lender as a move on the part of the borrower to claim the land. In Bangasse, four fields were taken back from the borrowers. Three fields were taken back because the lenders needed them for themselves and their family. The other field was taken back because the lender thought the borrower was trying to claim the land. In Poedogo, eight fields were taken back, seven because the owner needed it for his own production and one because the borrower was cutting down the trees. In Dissankuy, one field was taken back because the lender needed it and two were taken back because the borrower did not pay the rental fee at the end of the year. Diapangou did not register any land that had been taken back in the last five years.

The amount of borrowed land taken back over the last five years represents a small percentage of the total borrowed land. However, it is

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evident that borrowed land can be taken back when the lender has a need for it or feels his claim is threatened or when the rental fee is not paid.

In summary, in four of the villages, the majority of the land has a high security of tenure at this point in time. Thus in villages like these, the present land tenure system should not prevent the adoption of intensive technologies on a wide basis because of the insecurity of tenure. There may however be problems with the adoption of some types of technology on the less secure borrowed land.

Although a small amount of land has been taken back by the lenders in each village over the last five years, it is evident that borrowed land can be taken back. The responses of lenders to several suggested agricultural improvements indicated that borrowed land would be taken back if the borrower planted fruit trees or trees for firewood. Planting trees for wind breaks and live fences would be tolerated more. Lenders saw no problem in authorizing animal enclosures, anti-errosion ditches or volta phosphate. The Dissankuy experience also indicated that farmers use fertilizer on borrowed land.

In Burkina Faso, the increasing man-land ratio is causing a change in the traditional farming system. Land use changes such as shorter fallow periods, increasing use of marginal land and the cultivation of fields further away from the compound is taking place (ICRISAT, 1984). Left to itself, the land tenure system will be influenced by the changes in land use. This is summed up by Vierich (ICRISAT, 1984, P.6).
"These changes in land use patterns are being accompanied by systematic changes in land tenure, in particular by decreasing importance of usufruct and increasing permanent household control of land. These trends are complementary to greater willingness to invest in land improvements."

It remains to be seen whether farmers, who cultivate less secure borrowed land will lose their land use rights or change to a more secure tenure status. As the land tenure system changes, it merits monitoring. Income distribution problems may arise if a disproportionate number of farmers who borrow land are hesitant to invest in intensive technologies and management practices. It is incumbent upon policy makers to avoid creation of institutional constraints in the land tenure system which limit incentives for the use of more productive agricultural technologies.

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C. Stocks and Transactions.

Since May 1983, stocks and transactions data have been collected for both cereals and animals. These data help provide a better understanding of the decision making environment within which farm families operate, and have also been valuable as variables to explain farmer behavior. Farmers reacted positively to the stocks and transactions interviews. They expressed the feeling that the interviews helped them to think about their inventories and to plan for future needs. In addition, the stocks and transactions interviews proved valuable for the collection of data on informal credit.

In the 1983 FSU/SAFGRAD annual report, analyses of factors affecting grain consumption, net sales and gifts of grain, cash cropping and risk acceptance were undertaken using stocks and transactions data. Beginning in December 1983, monthly bulletins have been published showing aggregate grain flows and per capita animal stocks in each of the five FSU study villages. These bulletins have been well received and distributed widely throughout the research community. They furnish information on purchases, sales, gifts and consumption of cereal grains.

Annual Cereal Consumption. Cereal consumption data were recorded for 30 sample households in each of the five study villages. These data were taken monthly except during March, when the enumerators were participating in a training program. Data collection resumed in April, and covered the period from February to March. Cereal consumption was reported in local units and conversion was made to kg. In addition, the number of people residing in the household was recorded.

To estimate the consumption per consumer unit (CU), the proportions of males and females in various age categories were calculated from census data taken in April. These fixed proportions were used to determine the number of consumers in each category from the reported monthly sample population. Consumer units were then calculated using estimates of consumer equivalents (Table 27) determined by Matlon (1977). Adjusting the empirical consumption figures to take into account the relative consumption needs of different age categories resulted in a more accurate estimation of cereal

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Table 27. Consumer equivalents used to determine consumer units.

Age	Male	Female
Years		
0 - 4	.20	.20
5 - 9	.50	.50
10 - 15	.75	.70
16 +	1.00	.75

Source: Matlon, Peter J. 1977. "The size distribution, structure, and determinants of personal income among farmers in the north of Nigeria". Ph. D. dissertation, Cornell University.

consumption.

Per capita consumption showed considerable variation among villages, ranging from a high of 255 kg/year in Dissankuy to a low of 135 kg/year in Poedogo (Table 28). Per capita cereal consumption was highest in those villages not located on the Central Plateau. A consumption of 135 kg/year per capita in Poedogo seems to be quite low, considering that this is generally a region of surplus production. The consumption of grain directly from plants in-field made estimation of consumption during September and October difficult. The consumption data only take into account grain consumption. Consumption of cereals in other forms, as well as a high proportion of non-cereal grain consumption, could explain the low figure. The former is undoubtedly important in Poedogo, a region where red sorghum is grown for dolo production.

Definitive minimum cereal requirements have not been determined for Burkina Faso. The FAO and USAID utilize a 180 and 192 kg per capita minimum requirement, respectively (Haggblade, 1984; USAID, 1983). Although no documentation is available, indications are that GOBF is using 190 kg as a minimum per capita requirement. Except for Dissankuy and Diapangou, the observed annual per capita consumption figures were below these minima (Table 28). This may reflect reduced stocks as a result of a poor 1983-84 harvest. It may also be that cereals account for a proportion of caloric intake in the study villages different from the proportion used to calculate the minima.

Estimation of cereal consumption on a consumer unit basis indicated annual consumption of cereal grains greater than the FAO, GOBF and USAID minimum requirements in all villages (Table 28). The nutrition status in the study villages may therefore not have been as poor as the per capita statistics might indicate.

Net Cereal Purchases. One interesting research issue in grain marketing studies is the question of forced sales. The assumption has been that farmers are obliged to sell grain at harvest, when the price is the least attractive, in order to generate cash income for loan repayment or other uses (Sherman, 1984). Later in the year, as stocks decrease, they are forced to purchase grain.

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Table 28. Observed annual cereal consumption (kg) for five villages December 1983 through November 1984.

Village	Per Capita	Per Consumer Unit.
	kg	
Nedogo	163	237
Bangasse	150	224
Poedogo	135	202
Dissankuy	255	380
Diapangou	194	300
Mean	179	269

To assess the purchase behavior of farmers in FSU villages, net purchases were calculated on a monthly basis from December 1983 to November 1984. As for consumption data, February and March were combined into one period. These data represent the aggregate performance of the households in each village and the degree to which purchases outweigh sales or vice versa. To minimize the effect of variations in household size, the data has been converted to a per capita basis (Figs. 8-10).

In Nedogo, net purchases rose steadily after January (Fig. 8). Purchases were greater than sales in May, and net purchases reached their peak in August, just prior to the maïze harvest. The data in Nedogo indicated that for the village as a whole, net purchases are highest just prior to harvest, when prices are expected to be highest (and stocks lowest). In 1984, net purchases declined after August.

Farmers in Bangasse (Fig. 8) were selling more grain per capita than they were purchasing in the two months following the 1984 harvest. In December 1983, however, net purchases were positive and rose to a peak in June 1984. The 1983 purchase activity may be the result of an unusually poor 1983 harvest; of the five villages studied, Bangasse showed the highest per capita net purchases. These peaked in June, reaching 10 kg per capita. Normally the highest net purchases could be expected to take place in July and August, just prior to the maïze harvest. In 1984, however, the highest amount of food aid was received during the months of May, June and July. This undoubtedly influenced net purchases just prior to harvest.

The data for Diapangou include only households which were not regularly engaged in cereal grain trading. Net purchases (Fig. 9) reached a peak in June, and declined thereafter, except for a slight increase in August. Net purchases were declining during the period when prices could be expected to be highest. Sales in September, October and November 1984 coincide with periods of peak reimbursements on informal borrowing (FSU credit survey). Sales in January 1983 may have been influenced by the need to make payments on animal traction loans; 73% of the sample farmers held loans of this type.

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In Dissankuy (Fig. 9), net sales were highest in September, just prior to the 1984 harvest, and declined as the harvest approached. In October, and November, purchases outweighed sales. These data suggest that sales behavior corresponds to periods of relatively favorable prices. In Dissankuy, grain purchases also seemed to be taking place at a period when prices were most favorable.

The Poedogo data (Fig. 10) show that net purchases increased from December to February/March and declined thereafter. September was the only month where sales were greater than purchases. In 1979 and 1980, Sherman (1984) showed that prices were highest in September for the Manga region. During the 1984 post harvest period, purchases were again greater than sales.

In summary, it appears that in Nedogo, Bangasse and Diapangou sales were greater than purchases for the sample as a whole following harvest. In Dissankuy and Poedogo there is evidence that grain purchases are occurring immediately after harvest. In Poedogo, net purchases reached 9 kg per capita.

The data presented here represent aggregations over all sample households, and are useful as an indicator of general village behavior. Analysis on a household to household basis, to further study the determinates of individual marketing strategies, is a logical next step.

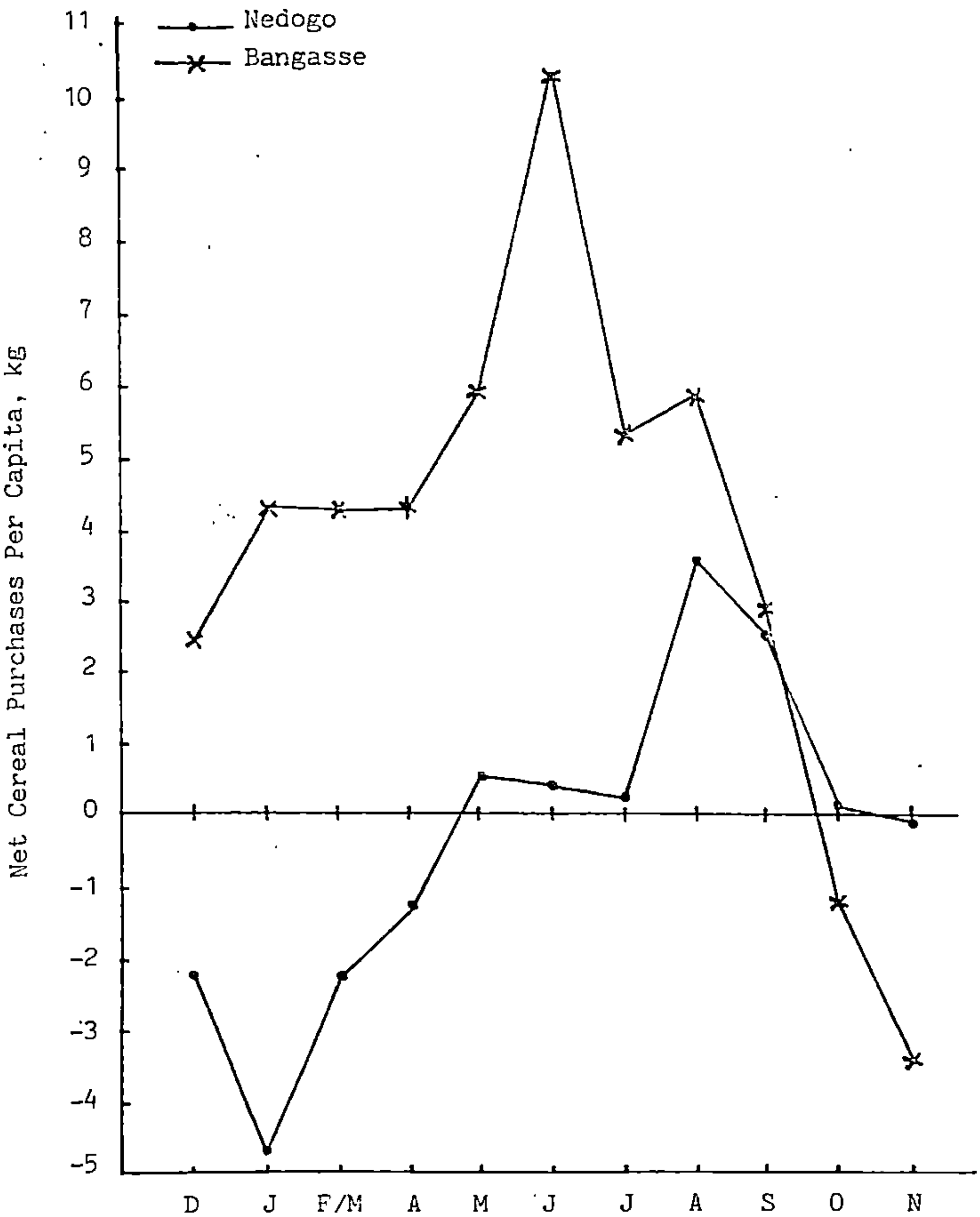

Fig. 8. Net cereal purchases per capita, December 1983 through November 1984 at Nedogo and Bangasse.

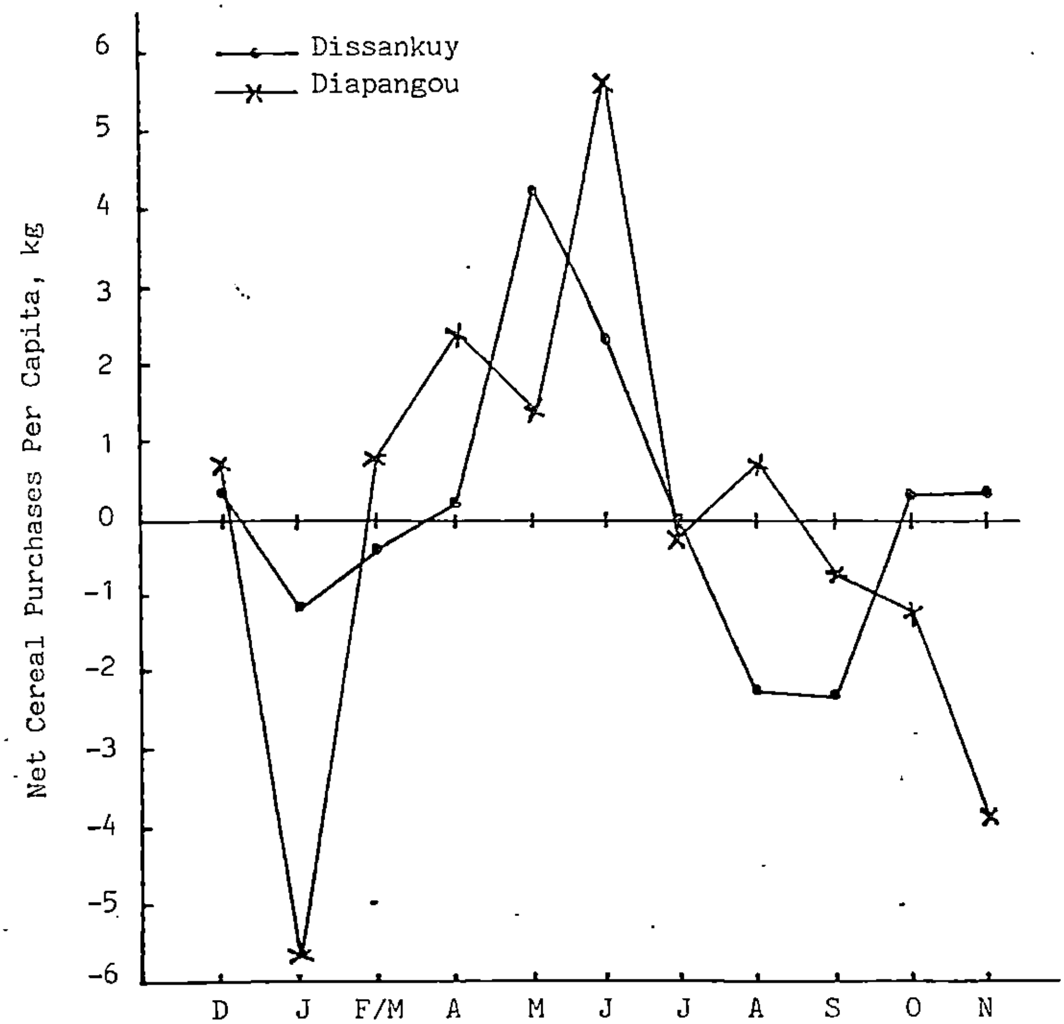

Fig. 9. Net cereal purchases per capita, December 1983 through November 1984 at Dissankuy and Diapangou.

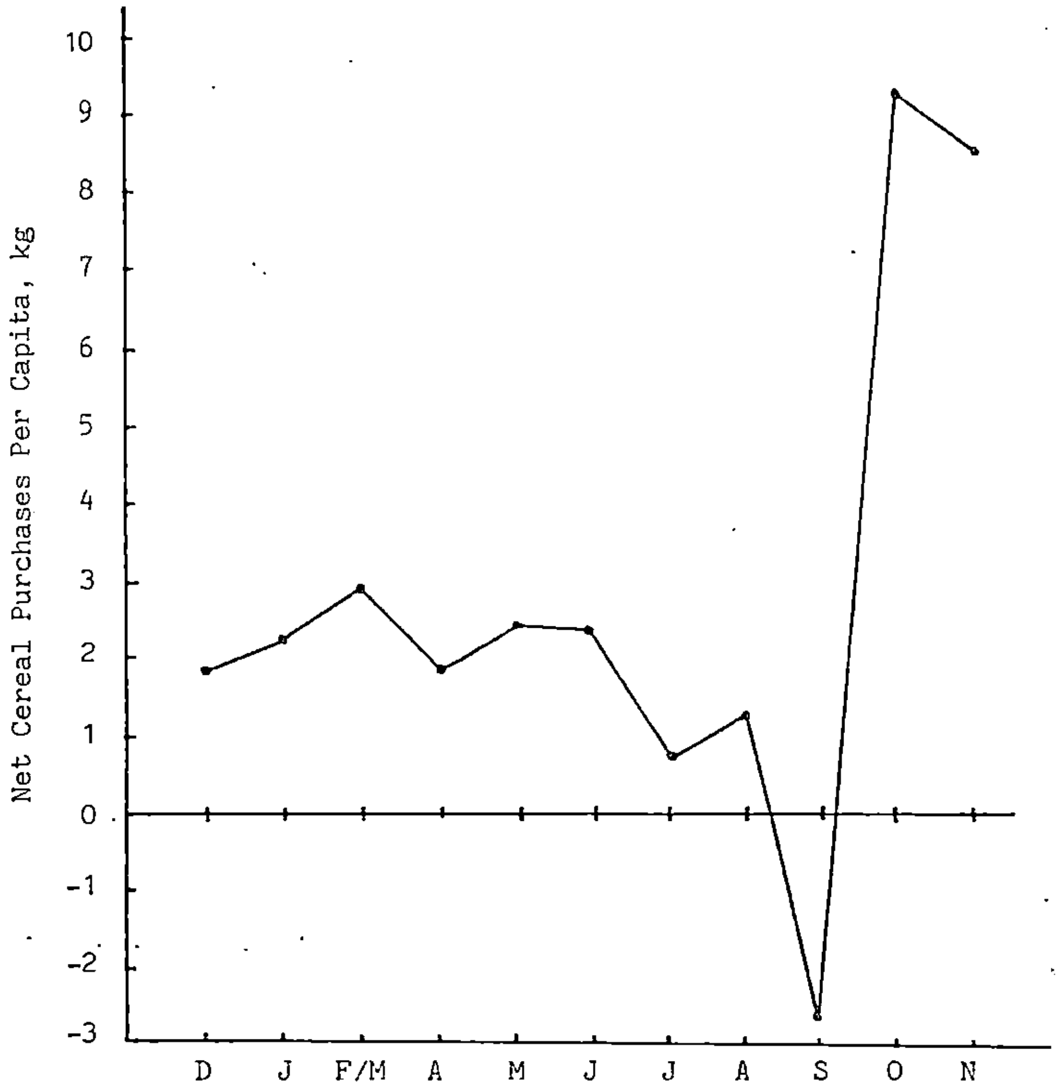

Fig. 10. Net cereal purchases per capita, December 1983 through November 1984 at Poedogo.

D. Adoption of Technologies in FSU Villages

A survey of technology adoption by FSU cooperator farmers was conducted in November and December of 1984 in the five FSU villages. The objectives of the survey were to determine the extent to which FSU cooperator farmers adopted the technologies of tied ridges, new varieties and fertilizer that FSU works with in the villages, and to identify some of the key variables that distinguish adoptors of the technologies from non-adoptors.

It must be made clear that the FSU program is research oriented and not specifically designed for an extension role. Although FSU research involves direct interaction and feedback from the farmer cooperators, any adoption by farmers of the technologies that FSU works with is not solicited by FSU but is a welcome externality of the program. The FSU farmer-managed and researcher-managed trials however do provide a demonstration effect and add to the programs provided by the local extension services. When asked who introduced them to tied ridges, 95 percent of the farmers said FSU. Across all villages with the exception of Dissankuy, a similar question on fertilizer brought the response that 50 percent of the farmers were introduced to fertilizer by FSU and 50 percent by the local ORD.

The survey was conducted by interviewing the FSU farmer cooperators of the farmer-managed trials and the researcher-managed trials. The farmers within the farmer-managed trial group also comprise the farmers that FSU collects socio-economic data from. The socio-economic data made it possible to analyse some of the key variables that may distinguish adoptors from non-adoptors.

The percentage of farmers adopting each of the three technologies on the whole is small (Table 29). Table 29 does indicate a demonstration effect for tied ridges in that the number of farmers adopting tied ridging increased with the number of years FSU has had a program in the village. The demonstration effect is less pronounced for new varieties and fertilizer technologies although a slight pattern emerges when Poedogo and Dissankuy are removed. The number of farmers (Table 29) adopting new varieties and fertilizer and the land area devoted to these technologies (Table 30) in Poedogo and Dissankuy are influenced by the commercial market.

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Table 29. Number of farmers adopting tied ridges, fertilizer and new varieties by village, 1984

Village	No. of Years FSU in Village 1/	No. of Farmer Cooperators		No. of Farmers Adopting Technology					
				Tied Ridges		New Variety		Fertilizer	
		Socio -Econ Group	Research Managed Group	Socio -Econ Group	Research Managed Group	Socio -Econ Group	Research Managed Group	Socio -Econ Group	Research Managed Group
Nedogo	5	29	40	10 (34%)	7 (18%)	5 (17%)	2 (5%)	2 (7%)	5 (13%)
Bangasse	3	23	30	6 (26%)	6 (20%)	0	0	2 (9%)	1 (3%)
Poedogo	2	27	-	1 (4%)	-	11 (41%)	-	9 (33%)	-
Dissankuv	2	30	30	1 (3%)	0	0	0	2/ 28 (93%)	2/ 30 (100%)
Diapangou	3	27	34	6 (22%)	9 (38%)	3 (11%)	2 (6%)	3 (8%)	0

1/ At Poedogo and Dissankuy , it was the first year for the farmer managed trials.
2/ The figures relate only to land sown to cotton. Small amounts of fertilizer are used on cereals.

Table 30. Average hectares of technology adopted by village, 1984.

Technology	Nedogo Socio-Econ Group	Nedogo Research Managed Group	Bangasse Socio-Econ Group	Bangasse Research Managed Group	Poedogo Socio-Econ Group	Poedogo Research Managed Group	Dissankuy Socio-Econ Group	Dissankuy Research Managed Group	Diapangou Socio-Econ Group	Diapangou Research Managed Group
					hectares					
Tied Ridges	.31	.32	.04	.02	.11	-	.05	0	.38	.03
New Variety	.78	.01	0	0	.12	-	0	0	.05	.03
Fertilizer	1.1	0	0	0	3	-	5.9	0	.77	0

The farmers at Poedogo and Dissankuy are more commercialized than the other three villages. At Poedogo, red sorghum is partially used as a cash crop and a commercial outlet is available for its sale for brewing purposes. The usage of fertilizer on cotton crops in Dissankuy is a direct result of the influence of SOFITEX and its commercial marketings of cotton production and its program of making available commercial inputs. The Poedogo and Dissankuy experience indicates that farmers will respond and adopt technologies given security in the input and product markets.

It must be emphasized that the data shown in Tables 29 and 30 reflect the poor agricultural seasons in 1983 and 1984. The near drought conditions and untimely rains affected farmers' financial positions as well as their planned work patterns. For example, discussions with farmers and field staff suggest that more farmers who cultivate manually may have constructed tied ridging had it been a more normal year. When rainfall is infrequent, the soil becomes hard and the construction of tied ridges manually becomes very difficult. Also the late planting dates along with having to reseed more often than in a normal year affected planned work patterns. The low level of tied ridge construction in Poedogo may also be a reflection of the number of years FSU has been working in the village. The 1984 agricultural season was the first year that farmer-managed trials were done. As a result of seeing the increased yields from tied ridges in the FSU farmer-managed trials, most Poedogo farmers said they would construct tied ridges in 1985. The poor harvest in 1983 affected farmers' grain inventories and cash flows. This may have had the effect of decreasing the amounts of purchased inputs farmers bought. Purchases of inputs like fertilizer were decreased especially in Poedogo where in previous years more fertilizer was used.

Farmers were asked what they saw as the advantages and disadvantages of the technologies and why they either did not use them or use them more extensively. The responses were consistent across villages and in most cases were as expected. Answers given for the advantages of tied ridges were better water conservation, increased plant size and yield over flat cultivation and increased soil fertility by reducing soil errosion and

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trapping organic matter. In Nedogo the farmers said that plants on tied ridges did not lodge from high winds as much as the plants on the flat. Since tied ridging is done one month after planting, the ridging adds soil around the plants and provides support. The responses by the farmers of the disadvantages of tied ridging relate more to the constraints involved in constructing tied ridges then to their disadvantages per se. The problem of labor availability is cited as the main reason for either not constructing tied ridges or for not constructing more. Farmers without animal traction cited the reason that they do not have animal traction equipment and without rain in the proper time period, the ground is too hard. Farmers did say that the construction of tied ridges in the basfonds (low areas) could result in lower yields.

Farmers saw that fertilizer increased yields and said that they would like to use more fertilizer but gave insufficient financial resources as the reason for not doing so. At Dissankuy, farmers indicated that they did not use more fertilizer on crops other than cotton because the land is fertile. Dissankuy does have more fertile soils than the other villages. The advantages and disadvantages of using new varieties were not well spelled out. At Nedogo in a specific case relating to KN1, a new variety of cowpea, farmers said they would grow more but lacked the inputs and equipment to treat the seed before planting. Farmers responded in the questionnaire that they were hesitant to try new varieties until they saw and appraised the varieties' performance.

The questionnaire also asked farmers if they used mulch and animal manure. In Nedogo, 42 of the farmers used mulch, 9 in Poedogo and 35 in Diapangou. The area that mulch is used on is very small. The average at Nedogo is 0.009 hectares, 0.025 at Poedogo and 0.208 at Diapangou. The Diapangou average however falls to 0.009 hectares when three farmers who use mulch extensively are dropped from the average. Mulch is primarily used around old termite mounds. The soil in the termite mound is made richer by the termites but the soil is less porous and mulch is added to increase moisture absorption. The use of mulch is one way of adding organic matter to the soil to improve water absorption. However, the plant material used for mulch is also used for livestock feed and for the household. Thus mulch is in short supply.

Farmers use animal manure close to the huts on the compound fields on which they usually grow maize. Farmers seldom use manure on other fields. They would use more manure but there is a finite supply which is not enough to cover all their fields.

The data from the evaluation of technology survey for the farmer-managed group was combined with previously collected socio-economic data for an analysis of some of the key variables that may distinguish adoptors from non-adoptors. Numerous farm specific characteristics and human capital variables can play a part. Farm specific characteristics include farm size, commercialization, labor, credit and other input availability, marketing opportunities, agro-climatic and soil type considerations and land tenure arrangements. Human capital variables include education, experience, health and private and public information. Other factors that can play a part are the farmers' risk aversion characteristics, risk perceptions, social customs and motivational priorities i.e., survival motivations versus profit achievement or profit motivations (Collinson, 1983).

From the available data, six variables were analysed and are presented in Table 31. These are age, farm size, cash crops, labor availability, management and formal credit. For each of the six variables, the analysis compared the difference between the two means of adoptors and non-adoptors. The small number of adoptors in many technology categories precluded an analysis of all three technologies in all villages. Six specific cases were chosen and are presented in Table 31. An analysis of fertilizer users at Dissankuy was not undertaken because close to 100 percent use fertilizer on cotton and the amount used on cereal crops could not be separated from that used on cotton.

The six variables analysed in Table 31 do not encompass all the farm specific and human capital variables listed above. Most of the human capital variables like education, experience and public information are difficult to quantify and at present are at very low levels in Burkina. Information on the education of the household heads was gathered but as expected the number of farmers having some formal education other than

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Table 31. Characteristics associated with technology adoption and non- adoption.

Village/ Technology	Age 1/		Farm Size		Cash Crops		Labor/ha.		Management		Formal Credit	
	A	N-A	A	N-A	A	N-A	A	N-A	A	N-A	A	N-A
	Years		Hectares		Hectares		Man Hr. Equiv.				000's CFA	
Nedogo; Tied Ridges			**** 2/		****		***		****		***	
Mean	52.6	53.5	9.3	5.4	1.13	.5	.64	.85	1.5	2.3	31.8	10
S.D.	12.6	14.5	3.2	3	.54	.45	.2	.35	.85	.65	29.6	18.9
n	17	51	10	19	10	19	10	19	10	19	10	19
Nedogo; New Variety			****		****		***		***		****	
Mean	51.3	53.1	11	6	1.43	.57	.45	.83	1.4	2.1	42.7	8.9
S.D.	18.6	13.8	1.6	3.3	.47	.46	.11	.33	.89	.71	29.6	18.6
n	6	63	5	24	5	24	5	24	5	24	5	24
Bangasse; Tied Ridges			****		****		***		***		*	
Mean	48.9	49.8	3.6	1.9	.72	.27	1.46	2.18	1.5	2.4	15	7.6
S.D.	15.4	16.4	1.3	.62	.36	.16	.61	.74	1	.6	21.2	10.3
n	12	46	4	19	4	19	4	19	4	19	4	19
Poedogo; New Variety	***		**		*				*			
Mean	47.5	56.5	4.7	3.3	.38	.23	1.5	1.65	1.7	2.1	55.5	53.2
S.D.	10.4	13.2	3.4	1.4	.39	.23	.6	.78	.9	.9	19.6	33.5
n	11	16	11	16	11	16	11	16	11	16	11	16
Poedogo: Fertilizer	****		*						*			
Mean	43.6	57.4	4.4	3.6	.32	.27	1.65	1.54	1.78	2.11	54.3	54.7
S.D.	9.2	11.9	3.3	2.1	.28	.32	.76	.71	.67	.96	24.3	29.1
n	9	18	9	18	9	18	9	18	9	18	9	18
Diapangou; Tied Ridges			***				***					
Mean	47.9	45.6	9.9	5.9	.77	.61	.75	1.49	1.7	1.8	82.9	72.6
S.D.	7.2	11.8	4.9	2.8	.67	.4	.28	.89	.82	.8	66.7	60.3
n	15	46	6	21	6	20	6	21	14	41	6	21

1/ A = Adoption by farmers , N-A = non-adoption by farmers.
2/ **** , *** , ** , * = significant at the 1 , 5 , 10 , and 20 percent levels respectively.

Koranic schooling was very low. Lack of available data precluded an analysis of more of the farm specific variables.

Turning to the analysis, the age of the decision maker can either reflect experience or tradition bound attitudes that may result in resisting change. The heads of households were taken to be the decision makers. It was hypothesized that young farmers would be more open to the adoption of new technology than older farmers. This relationship held only at Poedogo for both new variety and fertilizer adoption. In the other four cases, the mean age was not different between adoptors and non-adoptors. Two difficulties arise with the age variable. First, precise ages are not really known, especially for the older farmers and secondly, in the larger menages with elderly household heads, the decision making may be done by a younger person.

In all cases with the possible exception of fertilizer at Poedogo, the farm size variable corresponds to the hypothesis that larger farm size is associated with technology adoption. The hypothesis is based on the premise that the economies of size in transactions cost, risk from additional investment and lower input costs may favor the larger sized farm (Perrin and Winkelmann, 1976).

The number of hectares of cash crops is used as a proxy for the level of farm commercialization. Cash crops are defined as those crops which are sold to generate cash income as opposed to staple crops which are grown primarily for consumption. The cash crops include ground nuts, bambara nuts and cotton. The hypothesis is that there is a positive relationship between the level of commercialization and the level of adoption. The more commercialized a farm is the more cash there is to spend on inputs.

A positive relationship between commercialization and adoption is expressed for both tied ridges and new varieties at Nedogo and for tied ridges at Bangasse. The relationship was not evident for fertilization at Poedogo nor was it evident for tied ridges at Diapangou. In Poedogo however, red sorghum is used in the dual role of a staple and cash crop and the relationships may have shown up had the data been available to split out red sorghum hectarage into the two components.

Labor availability is hypothesized to have a positive relationship

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with the adoption of tied ridges and fertilizer use because additional labor is required in both cases. New variety adoption may require more labor if seeds of new varieties require treatment or additional labor is required at harvest. Adoption of new varieties may also be an answer to increasing production without increasing labor use at critical labor shortage periods. The amount of available labor for each farm was obtained on a man-hour equivalent basis by weighting the number of active workers by the production weights given in the Introduction with the addition of weighting active workers older than 60 by 0.6.

In the three tied ridge cases, the relationship between labor availability per hectare and tied ridge adoption is negative rather than positive. This is however explained by the fact that as noted previously, farmers who construct tied ridges have larger farm sizes. Thus when dividing the man-hour equivalent figure by area, the man-hour equivalent/ha figure for tied ridge farmers is smaller than for non-tied ridge farmers. Thus this variable restates that the size of land holding is positively related to tied ridge adoption. The fertilizer and new variety cases at Poedogo show no relationship while the Nedogo new variety case exhibits a similar response to that of tied ridges.

It was hypothesized that the better farm managers would be the adoptors of the technologies. The field staff, who work with the farmers during the cropping season, were asked to rate the farmers as to their management characteristics which included timeliness, quality of work and work efficiency. The farmers were also rated on their comprehension of the reasons for doing the FSU trials. The field staff were asked to rate the farmers on a scale of one to three, one being the best. Each farmer was given a composite rating from the above four characteristics. In 95 percent of the cases, an individual farmer received the same ranking for all four characteristics.

The means of the composite ratings of the management variable for adoptors and non-adoptors are given in Table 30. In all cases with the exception of Diapangou, adoptors had a lower mean rating than non-adoptors indicating that the characteristic of being a better manager is associated with technology adoption.

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The credit variable is the total value of formal credit of each household over a five year credit history beginning in 1979. The formal credit data is from the FSU credit survey. It is hypothesized that those farmers who are able to obtain a higher level of credit will adopt technologies because they have the means to purchase new technology inputs. The FSU credit survey indicates that at Nedogo, Poedogo and Diapangou, almost 100% of the formal credit loans are for animal traction equipment. At Bangasse 100% of the formal credit loans are for agricultural inputs (see Table 24 in section on credit) although the average amount is low.

Because the adoptors of tied ridges in Nedogo and Diapangou are primarily farmers with animal traction, it would be expected that there would be a positive relationship between tied ridge adoption and the level of credit. This was the case in Nedogo but not in Diapangou. In Bangasse where all tied ridge adoptors are manual farmers, a weak positive relationship exists. The lack of a relationship in Poedogo for fertilizer and new varieties is expected. An exception is the Nedogo new variety case. In all cases, the standard deviations are very large. This is due to the fact that in both the adoptor and non-adoptor groups the amount of some farmer borrowings were from very low levels to zero.

In summary, although FSU is primarily a research entity, a demonstration effect was evident in that some farmers adopted the tied ridge, fertilizer and new variety technologies in the FSU villages. A positive relationship between adoption and the number of years FSU worked in the villages was evident especially for tied ridges. The adoption rates may however have been hampered by the poor 1983 and 1984 agricultural seasons.

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 was the primary reason for not utilizing more fertilizer. Farmers were generally hesitant about trying new varieties until they could give them a good appraisal.

In summarizing the characteristics of adoptors and non-adoptors, the main characteristic of tied ridge adoptors is that they have larger than

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average size land holdings. Other characteristics are a larger than average cash crop area and a higher management level. All three characteristics showed up most noticeably in Nedogo and Bangasse. The main characteristic of new variety adoptors was farm size and the other characteristics were cash crop area and management level all exhibiting a positive relationship. The Poedogo fertilizer case indicated that younger farmers used fertilizer. Other characteristics included farm size and management level.

The characteristic that consistantly showed the strongest relationship to adoption in all cases was farm size. Farmers controlling larger land areas are associated with adopting the technologies. Perrin and Winklelman (1976) found similar results with respect to farm size for new varieties in countries where variety introductions were recent. Underlying the size effect are the factors of economies of size in the transaction costs of evaluating and acquiring new technologies, differences in prices for inputs and products and difference in land productivity (Perrin and Winklelmann 1976). Given that farmers with large sized farms may be the first adoptors of technology as is suggested by this preliminary analysis, questions concerning future income distribution should be pursued.

The widespread use of new technologies in Burkina have not yet taken place. This gives researchers and policy makers time to consider studying the underlying factors of farm size and other variables that play a role in the adoption of new technologies. The Perrin and Winklelmann study on new variety adoption indicated that initially, small farmers lagged behind larger farmers but that adoption levels were similar after a period of time. Whether this relationship will hold in Burkina for the adoption of new varieties and other technologies is yet to be determined. In the future, as adoption of technology increases, adoption patterns need to be monitored. Appropriate policies must be put into place to decrease the constraints on technology adoption and ensure that income distribution problems do not arise.

IV. CONCLUSIONS AND IMPLICATIONS

Tied ridges can result in significant increases of cereal crop grain yields throughout the Central Plateau even on areas with very gentle slopes, 2 to 5%. This is because the water infiltration rates are low for most of the soils, partially due to low organic matter, and with flat cultivation much of the limited rainfall is lost due to surface runoff. Although tied ridges constructed prior to planting can result in greater yields than tied ridges constructed later in the season, it is usually impractical to construct them prior to first or second weeding. Because seeding is done manually, availability of labor is a serious constraint and because seeding must be effected as soon as possible after rains which may be infrequent during May and June, there is no time or available labor to construct tied ridges or till the soil prior to seeding.

An alternative is to construct tied ridges as soon as possible after plant emergence. For most farmers this is during second weeding when plants are tall enough and when labor is slightly more available than earlier in the season. With current available equipment, daba or weeding equipment including the butteur and houe-manga, construction of tied ridges even when weeding with animal traction involves substantial manual labor. Because of the large amount of labor required, tied ridges may not be generally accepted although several of the FSU/SAFGRAD cooperator-farmers do practice tied ridging on areas other than those of FSU farmer-managed trials.

A promising alternative is the use of a mechanical tied ridger which attaches to a butteur to construct tied ridges during weeding and which would require no additional manual labor. A low-cost, easy-to-operate mechanical tied ridger has been developed and on-farm research must now be conducted to determine its effectiveness and farmer reactions.

There is a need for research on soil tillage prior to planting because of the potential increase in rainfall infiltration. However, soil tillage prior to planting may not be a viable alternative until farmers are able to afford mechanization so that they can effect the tillage and planting operations quickly after a rain.

A technology with more immediate potential may be the development of a low-cost, easy-to-operate no-till planter for animal traction. This would enable farmers to alleviate labor constraints at planting and to plant their cereal crops more quickly after a rain.

Fertilization with minimal amounts of cotton fertilizer (100 kg/ha) plus 50 kg/ha urea can result in significant yield increases. However, sorghum yield response to fertilization is variable and involves the risk of losing the cash cost of the fertilizer. In addition, the problems of fertilizer purchases and availability of fertilizers must be dealt with. Experimentation to benefit from possible accumulation of nutrients in successive years of fertilization with minimal amounts of fertilizers should be continued. In a very dry season it is probable that not all of the applied nutrients even at minimal rates of application, will be removed by crop growth. The inconsistent responses to fertilization with VP1, UV5 and urea compared to the more consistent responses from cotton fertilizer suggests that more research is needed to characterize soils for concentrations of a broad range of nutrient elements essential for crop growth.

Continued research is needed on intercropping of cereals and legumes in conjunction with fertilization and tied ridging. The possible benefits of fixed nitrogen for crops in subsequent years should be determined. There is a need for improved indeterminate cowpeas as well as determinate cowpeas.

Because of the short rainy season and because frequency of rainfall is more unpredictable late in the season, September and October, than in July and August there is much interest in culture of early-flowering varieties of cereals. However, the unpredictability of rainfall patterns underscores the need for farmers to grow varieties which represent a range in number of days from planting to flowering so that not all of their cereal production is severely damaged by a potential stress period during flowering.

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It is more likely that new varieties can perform better than local varieties when grown with improved, more intensive management than under low-fertility and moisture stress.

New varieties must be tested on-farm in researcher-managed and then farmer-managed trials and with improved management practices. It is more likely that improved varieties will provide satisfactory performance if the farmer is willing or is able to adopt water conservation and fertilization technologies along with the new varieties.

Individual technologies can be exploited more fully when adopted in certain packages than when adopted separately. For example, crop response to tied ridges and fertilization is greater when the two technologies are combined compared to crop response to each technology separately.

To date partial budgeting analysis has been utilized for the economic evaluation of FSU technologies. This approach is useful and is the first step in the economic analysis of technologies especially when the data base and information is limited. Through its work over the past several years, FSU has increased its data base and information on the farming systems of Burkina Faso. Given the present data base and information, it is now possible to extend the economic analysis of new technologies by using a whole-farm modeling approach. Whole-farm modeling treats the farm operation as a system and looks at the interrelationships among resource endowments, production opportunities and farmers' motivations (Ghodake and Hardaker, 1981). One of the most widely used whole-farm modeling methods is linear programming. This method explicitly models the farmers' optimization problem subject to the farmers' resource endowments. Since labor and land are the major determinants of cropping patterns, the model takes these inputs into account. Multiperiod labor requirements and availability are explicitly taken into account by the model. Land quality as well as quantity can also be modeled explicitly.

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The linear programming approach provides a means for appraising the effect of new technology introduction on the farm enterprise. Various new technology packages can be incorporated into the model. The data requirements for the incorporation of new technologies into the model are the costs of the technologies, the associated yield effects, and the labor requirements by period.

The solution of the base model (without the technologies) is then compared to the solution of the model with the technologies. The resultant crop areas, labor and land usages, and the financial positions are compared. Useful information such as the shadow prices on the constrained resources (such as labor) can pinpoint areas in which future research is required to decrease the effect of the constraint and where research could have the highest payoff. The linear programming model can also be modified to incorporate farmers' risk behavior and is an area that merits more study. The model can also be used to disaggregate farmers by type in light of the heterogeneity in resource endowments and agro-climatic regions. Intra-household effects of technology adoption on the division of labor of household members can also be studied.

Two avenues exist for the use of whole farm modeling methods such as linear programming in Farming Systems work. First, the model can be used in an analytical sense to evaluate technologies and policies after all the field data has been gathered and reliable coeficients calculated. The second use is as a research planning device to assess potential avenues of research before specific data collection begins.

In the analytical mode, comparisons between the base model and the models with a technology package can be conducted as previously outlined (for examples, see Roth and Sanders, 1984; Roth et al. 1984 and Jaeger, 1984). The model can also be used to assess the impact of various policy measures that directly affect the farmer but over which the farmer has no control. For example, the effect of different fertilizer prices on the overall farm operation can be assessed (Roth et al, 1984). Other possibilities for policy analysis that draw directly from past FSU research are in the area of credit. Information from the credit

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survey could be explicitly incorporated into the model. The costs of capital and credit terms could be used to establish under what conditions credit becomes a constraint once the farmer has decided to adopt a new technology.

The second use of whole farm modeling is as an Ex Ante research planning device. The models can be used in studying the possibilities for use of new technologies for which little on-farm experimental data is available (Goodwin et al, 1980). Model coeficients can be synthesized from available sources of information including researchers' perceptions and incorporated into the model. Sensitivity analysis can be carried out to obtain model solutions under various ranges of the synthetic coeficients. The information can be used in a preliminary evaluation of the new technologies and give an indication as to which technologies may give the highest payback when considering both the benefit to the farmers and the return on the research investment. For those technologies that show promise, an agenda can then be established for field data collection. Thus the specific data requirements are known and this may cut down on data collection time and costs.

A possible case that can be analysed in such a manner is the use of herbicides. Small amounts of herbicides are being used in the Dissankuy area. A preliminary analysis can be undertaken with the aid of the model and then a decision can be made whether or not to collect field data and research the technology further. The model can also be used as an aid to assess researcher managed trial results before the research is conducted on the farmer-managed level.

Both the analytical and research planning modes permit researchers to define problems and clarify issues. The whole farm modeling approach provides a focus for agronomic and socio-economic data collection and integrates the two areas. The structure provided by the modeling process enables identification of research needs and reveals where data limitations exist. When used to compliment the experience of researchers and information obtained from farmers, whole farm modeling can be a valuable tool for farming systems research.

Although outside of the farming systems mandate, the micro farm

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models can provide valuable information to those studying the implications of technology adoption at the macro level. As technology adoption increases, micro level effects such as changes in cereal prices, changes in input prices and changes in trade flows of agricultural goods will take place. Collaboration between micro analysts and macro sector modeling analysts can be mutually beneficial (Roth, 1983). Since the setting of research priorities can determine future technology availability, it is important that farming systems research take into account intermediate and longer term trends in input and product prices, as well as market opportunities.

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