PN-AAV-263 45745

PURDUE UNIVERSITY
International Education and Research
International Programs in Agriculture

IE&R

IPIA

AN ECONOMIC EVALUATION OF SELECTED AGRICULTURAL TECHNOLOGIES WITH IMPLICATIONS FOR DEVELOPMENT STRATEGIES IN BURKINA—FASO

Presented by:
Farming Systems Research Symposium
Kansas State University, Manhattan, Kansas

by:
Michael Roth and John Sanders

October 1984

An Economic Evaluation of Selected Agricultural Technologies With Implications for Development Strategies in Burkina-Faso*

Michael Roth

John H. Sanders

Revised
January 1985

*Burkina-Faso was formerly Upper Volta. This paper was prepared for the Farming Systems Research Symposium, Kansas State University, Manhattan, Kansas, October, 1984.

**Graduate Student and Associate Professors, Department of Agricultural Economics, Purdue University, West Lafayette, Indiana 47907. The authors are indebted to Phil Abbott and Bill Morris for modeling assistance and critical comments. Any errors are the sole responsibility of the authors.

The USDA reported in 1981 that Sub-Saharan Africa is the only region in the world where per capita food production has declined over the past two decades. The drought of the early Seventies in the Sahel has resulted in very large increases in food aid and in developmental assistance to countries in this region (Eicher, pp. 12-15). Imports of food staples into Sub-Saharan Africa have been increasing by 7% annually (Delgado and Mellor, 1984, p. 1). Farming Systems Research (FSR) has been emphasized as one of the panaceas for quickly making technology more relevant to the needs of small farmers. However, the process of developing and evaluating technology is a long term, gradual, institutional evolution. It requires the development of capacity to work with experiment station scientists to put together the component parts of new technology, the agronomic expertise to set up farm trials, and collaboration between agronomists and economists to evaluate the results of the farm level testing.

Here the results of farm level trials in Burkina-Faso on tied ridges and fertilization are combined with baseline survey data to compare alternative agricultural development strategies. The tied ridges and fertilization are land substituting strategies, which increase yields and labor utilization. Chemical fertilizer requires increased cash expenditures hence higher risks. Tied ridges enable improved water conservation thus reducing the risk from fertilization. Animal traction allows a substitution for labor[1] but requires a large initial investment plus the availability of pasture and or another low cost feed source.

---

[1] In some cases animal traction can have a yield effect. Two well-known cases are through better water retention with improved land preparation or more timely weeding. See footnote 13 on page 11 for some experiment station results on the yield effects of mechanization.

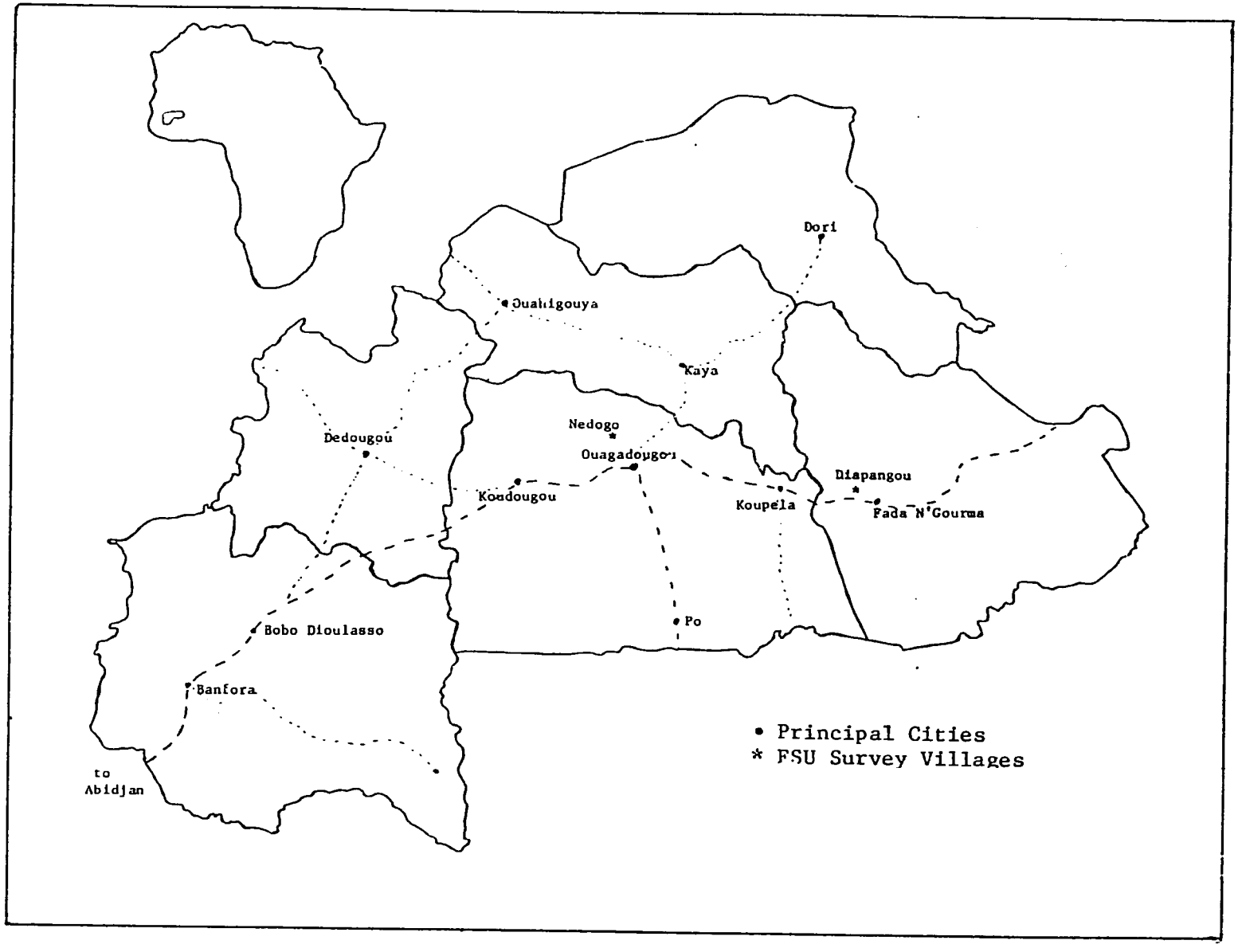


Figure 1: Map of Burkina Faso

Areas with higher population pressure would be expected to have a higher return to the land substituting technologies. In spite of large scale out-migration to other countries and to the more fertile, higher rainfall areas to the east, south and west, the highest population concentrations are still on the Central (Mossi) Plateau. The traditional system of long fallow periods and shifting of household sites has been breaking down with the higher population pressures. Hence, the implicit value of land has been rising. With the breakdown of the fallow system has been a decrease in organic material in the soil and more surface crusting. This has decreased the soils water absorbtion capacity and lowered soil fertility. Yields of all crops and particularly the basic cereals, sorghum and millet, are low and are apparently declining due to deteriorating soil quality and lower rainfall in recent years (Ruthenberg, 1976; and W. Morris, personal conversation). In the east, there is less population pressure and soil fertility is higher. Crop yields are superior to those on the Central Plateau and there is greater potential for area expansion.

In this paper the evaluation technique is whole farm modeling with mathematical programming. The first section will briefly describe the farming systems in the two regions. The second section will explain the methodology employed. The third through fifth sections will report the results for animal traction, fertilization, and then the combination of animal traction, fertilization, and tied ridges. The final section compares results from the different development strategies in the two regions and draws implications for future research.

Description of Farming Systems on the Central Plateau and in the Eastern Region of Burkina-Faso[2]

Approximately 60 percent of the population of Burkina-Faso is concentrated on the Mossi Plateau.[3] The high population pressure has led to a breakdown of the traditional fallow system and to declining soil fertility and cereal yields. Some organic fertilizer is used principally in the compound areas near the household for corn production but to only a limited extent on principal cereal fields (Bonkian, 1980). Moreover, use of chemical fertilizer to maintain soil fertility is rare and when applied is less than 50 kg/ha (ICRISAT, 1980; Lassiter, 1981; and Singh, et al., 1983). Use of organic matter and fertilizers in the Eastern region is also limited but lower population densities have permitted more land fallowing and thus better maintenance of soil fertility. The practice of fallowing combined with better soils inherent to the region produce higher crop yields than on the Central Plateau. Total rainfall in both regions averages 600-900 mm per year and is concentrated in a 3-4 mo . rainy season (June to September).

Under the traditional agricultural practices followed in Burkina-Faso, land and labor are the primary inputs into the production process. Hand labor represents the principal power source for tillage operations, though use of animal traction is gaining more widespread acceptance.[4] Most labor

---

[2] For a more elaborate description of crop enterprises as they pertain to risk management by farmers on the Central Plateau see Lang and Roth, 1984.

[3] In spite of large scale emigration out of the country, the World Bank estimates man-land ratios of 30 people/km^2 in the Central Plateau compared with 8 people/km^2 in the Eastern region and 12 people/km^2 for the country as a whole. An estimated 0.7 million Burkinabe presently live outside the country, constituting roughly 25% of the labor force.

[4] Donkey traction is more common on the Central Plateau and the East while oxen traction is more prevalent in the West and Southwest areas of Burkina Faso. Roughly 21,000 oxen teams, 3,000 horse teams, and 24,000 donkey teams were being used in Burkina Faso in 1978 (Ministry of Rural Development, various O.R.D. Annual Reports).

used on the farm is provided directly by family members. Very little hired or exchange labor is used in farm operations (generally less than 10% of total labor requirements). Farms in general are small, around 4-8 hectares in size, but differences in area cultivated exist between the two regions. Family size and total area cultivated tend to be larger on the Central Plateau but land/labor ratios tend to be smaller.[5]

The principal crops cultivated are red and white sorghum and millet.[6] These crops are grown on the household's main cereal fields and are frequently intercropped with cowpeas (Singh, et al., 1983). Small areas of corn are planted on the highly manured plots immediately surrounding the household compound. Some rice, peanuts, bambara nuts, cotton, and fonio are also cultivated. The red sorghum is primarily grown for beer production, though it is used for animal feed and human consumption as well.[7] Peanuts are grown as a cash crop to help pay taxes and meet household expenses. The corn is harvested early to meet family consumption needs during the hungry season (i.e., "soudure"). This period corresponds to the month prior to harvest of the main sorghum and/or millet fields when grain stocks can be depleted. Most of the millet and white sorghum (80-95%) are stored at harvest for consumption during the year. White sorghum is usually preferred in this regard because of its superior storing quality (2 to 3 times as long as millet according to farmers).

---

[5] The ratio of area cultivated per worker has been estimated to be 0.94 for hand tillage farms in the village of Nedogo on the Central Plateau (Jaeger, 1984) and 1.21 for the aggregate of 13 villages in the Eastern region (Barrett, et al., 1982).

[6] Over 90% of crop area on both the Central Plateau and in the Eastern region are in sorghum and millet.

[7] Red sorghum is not generally cultivated in the Eastern region.

Land quality and availability of labor are the major determinants of cropping patterns. Sorghum and millet are cultivated on village and bush fields, but distinct differences in soil quality exist. Farmers explain that they plant sorghum on the better quality soils because it is more responsive to higher soil fertility than millet. Millet is planted on the poorest soils where its greater drought and low fertility resistance give it a comparative advantage. Under traditional "hoe" practices then, the area devoted to sorghum is determined by the quantity of good land the farmer has available. The area of millet is primarily determined by the amount of labor available at the critical bottleneck periods.[8] (See SAFGRAD-FSU, 1983.) The better soils in the East thus permit more sorghum in the crop mix than what is grown in the Central region.

Absolute yield levels for the basic cereals are low and declining on the Central Plateau. Millet yields are 300 to 500 kg/ha., sorghum 400 to 700 kg./ha., and corn yields 900 to 1200 kg/ha. on the more fertile compound soils. To meet the minimum consumption needs of Burkina-Faso's growing population, higher yields especially of sorghum and millet will be required.

High yielding cereal varieties have been available on the experiment station in Burkina-Faso for some time. ICRISAT's E-35-1 sorghum has yielded 3.5 to 4 t/ha. under experimental conditions while IRAT's corn varieties have given yields of 3 t/ha. Cowpeas yielding 1.5 to 2 t/ha. have been obtained by IITA under experimental monoculture conditions (Singh, et al., 1983, pp. 9, 12, 13; and World Bank, 1982, Appendix).

---

[8] The area devoted to millet is usually expanded until labor bottlenecks at planting and/or weeding are faced.

Unfortunately, these new varieties have had little impact at the farm level (Stoop, et al., 1982, p. 522). The farming systems project of SAFGRAD-FSU has taken new varieties and other improved technologies and put them into trials on farmers' fields. In these agronomist managed trials, yields of 1-1.5 t/ha. of sorghum and 1.5-2.5 t/ha. of corn have been achieved (Kaylen, 1982, p. 5; SAFGRAD-FSU, 1983; SAFGRAD-FSU, 1984). Due to less varietal improvement of millet combined with the poorer land quality upon which it is normally grown, millet yields above 1 t/ha. have not yet been attained.

Improving soil fertility is critical to increasing cereal yields. Higher yields can be achieved through increased utilization of inorganic fertilizers but this requires better water retention in order to reduce the riskiness of the higher cash expenditure on inputs. This is especially important on the Central Plateau where water retention is poor and rainfall highly irregular. The breakdown of the fallow rotation,[9] the failure to return organic material to the soil, and overgrazing all contribute to soil degradation. This often leads to crusting hence increased run-off (Saunders, 1980, p. 15). Under these conditions improved water retention through land preparation or ridging can reduce the erosive effects and lead to higher soil productivity.

When better water retention is obtained, the potential response to inorganic fertilizer is increased. Combining these two new technologies may be an economic alternative to increase cereal yields. Another proposal to

---

[9] The soils on the Central Plateau are generally sandy and shallow. On these fragile soils, with their tendency for the topsoil to erode away and to form a crust, an adequate fallow could require 10 to 15 years (Hammond, 1966, p. 28).

increase farmer incomes, especially in the Eastern Region, is through land area expansion with the introduction of animal power (donkeys and oxen) and improved traction equipment.

The role of economic analysis is to take these agronomic results and evaluate their benefits and costs in a whole farm context. This paper uses economic modeling tools to evaluate the potential impact of these new technologies on farming systems in an older settled region (Central Plateau) and a frontier region (East) of Burkina-Faso.

Methodology

Simple budgeting of costs and returns of alternative technologies are generally employed to evaluate the results of field trials. On both the Central Plateau and in the East, significant yield increases and higher returns to various new technologies have been shown. However, the partial budgeting techniques employed in these evaluations are limited in two ways. First, the explicit values of land and labor in Burkina-Faso are unknown and are generally included in an ad hoc manner.[10] Secondly, the budgeting analyses are partial, hence they ignore the substitutability of inputs on the farm and how they are allocated to alternative crop activities based on fixed endowments and implied prices of resources.

New technology needs to be considered in a whole farm context to account for the effects of constraints on availabilities of land, seasonal labor, credit for purchase of modern inputs, and other interactions. The

[10]In the context of farming practices in Burkina-Faso, major problems arise in valuing traditional inputs. Land is primarily allocated by tribal custom whereas labor is almost entirely provided by family members. In either case, little exchange takes place in markets where an explicit price is determined.

availability of higher quality land is severely limited and possesses higher implied prices than the poorer quality bush soils. Of particular importance are the constraints on the flow of labor. Critical labor bottlenecks arise at planting and first weeding. In these peak labor periods all farmers are working to capacity on their own farms and hired labor is difficult to obtain. The implied price of labor at these times is much higher than the average wage rates observed at other times of the agricultural season.[11] These implicit prices are an important factor in farmers decisions concerning the timing of operations, cropping mix, and choice of production technologies.

One advantage of whole-farm modeling is that an implicit value (shadow price) is derived for all on-farm and off-farm resources available in restricted supply. An estimate of the marginal returns associated with labor is especially important since certain new technologies are labor intensive. Tied ridging, for example, requires a very large investment of labor resources to perform the ridging operations unless the operation is mechanized.

Representative farm models were constructed for each region, using mathematical programming, to assess the impact of prospective new technologies. Linear programming techniques were used to simulate producer behavior based on the profit maximization paradigm and a constraint on minimum maize production. Details on the construction of these models, their assumptions and data utilized are available in Roth, et al. (forthcoming).

---

[11]Shadow prices of labor at peak times can be upwards of five times higher than wage rates observed at other times of the agricultural season. When there is no agricultural work, as during the off-season, the shadow price of labor nears zero.

Briefly, the farm models developed for each region have the option of performing farm tillage operations under one of three types of tillage practices. Within each model, farmers possess four types of resources: land of various qualities, family labor, animal traction, and modern inputs. Land is disaggregated into four types, including high quality fields encircling the family compound, village fields, and higher and lower quality bush fields. Bush fields on the Central Plateau are permanently cultivated whereas land fallow is practiced on these soils in the Eastern region. Each farmer has a fixed quantity of each of the first three land types but has an unlimited quantity of bush land at his disposal. Stocks and flows of labor are disaggregated into weekly time periods to capture the critical labor constraints at planting and first weeding. A constraint on the minimum area of maize is included to ensure the family has sufficient grain for the hungry season.

Crop activities included in each representative farm were selected from cropping patterns observed in each region. A summary of crop activities, land types, and yield levels under traditional management practices are given in Appendix 1. The remaining sections analyze the response of the representative farms to new technologies.

Animal Traction Technology

Animal traction has been promoted, in development schemes across West Africa, as a technology appropriate for small "hoe" farms. Under the traditional hand tillage practices followed throughout most of West Africa, serious labor bottlenecks arise at times of planting and first weeding of major cereals. Use of animal traction with appropriate equipment can reduce the severity of these bottlenecks by increasing the productivity of human labor

(decreasing the amount of labor time spent on an operation per unit of area).[12] Besides the area extensification effects this can promote, animal traction also offers the potential to intensify production per unit of area. With deeper preplant plowing and incorporation of crop residue better soil aeration and water absorption can be achieved.[13] Manure from draft animals can improve soil structure and fertility while the technology's labor-saving effects can permit more timely operations.

In the context of draft power use in the two regions studied here, benefits realized in practice have fallen short of the technology's potential. On the Central Plateau, animal traction is primarily used during weeding operations. Plowing is limited because donkeys, the principal traction animal, are not strong enough for the task while oxen are often left in a weakened state following the long dry season. Farmers also say plowing conflicts with time spent on planting.[14] In the Eastern region, animal

---

[12]On station trials in Mali by the Institut de Recherches d'Agronomie (in Sargent, et al., 1981), for example, have shown animal traction to decrease total labor requirements by 43%. The higher labor productivity that ensues oftentimes encourages expansion of cultivated area.

[13]Charreau and Nicou (1977) found that deep plowing increased yields by 19% for groundnuts, 20-30% for cereals, 27% for cotton, and more than 50% for rice on experiment station trials conducted by IRAT in Senegal. Kline, et al. (1969) found yield increases from plowing of more than 40% on millet and peanuts, from on-station research in the Gambia.

[14]Farmers start planting immediately with the onset of rains to take full advantage of seasonal rainfall. Fields can be planted for only 2-3 days after rains. Hence plowing of fields and then planting slows considerably the rate of planting. Several common soil preparation activities that are performed are line tracing, used to delineate rows, and soil scarification. These operations loosen the surface crust and facilitate line planting and subsequent weeding with animal traction equipment (ICRISAT, 1980). The area planted to maize and peanuts is frequently plowed. Land preparation for these crops is begun following completion of planting the major cereal fields of sorghum and millet. The soil is softer and plowing combats the weed problems arising on these fields at this time.

traction is used primarily for land preparation.[15] Most farmers are equipped with plows and/or ridgers but weeding equipment is less common. Since farmers customarily perform weeding by hoe, the area increase from animal traction is less than on the Central Plateau.[16]

On farm studies of the performance of animal traction are limited. The few farm management surveys which have been performed show labor savings of 10-35 percent on weeding of cereals and 10-60 percent on land preparation of maize and peanuts (ICRISAT, 1980; McIntire, 1981; Swanson, 1982; Lassiter, 1981; and Singh, 1983). Area extensification effects (increase in area per worker) range from 2-20 percent. Large yield increases from animal mechanization have been reported in the literature (Jaeger, 1984), but these appear to be due to other complementary factors. Animal traction adopters are often better managers with better resource endowments, who employ higher levels of other inputs in the production process.

To incorporate the effect of animal traction into the farm models, four adjustments were made: a) labor reductions of 11-43 percent for different crops and operations were used to represent the technology's labor saving effects (Table 1); b) yields are increased moderately on areas cultivated with animal traction (Table 2); c) manure from draft animals is used to

---

[15]Barrett, et al. (1982) report in their Eastern region study that only 14% of cultivated area of oxen farmers and 10% of area of donkey farmers were weeded with animal traction equipment. This contrasts markedly with the 59% and 85% of cultivated area plowed by donkeys and oxen in the East.

[16]Indeed, Jaeger (1984) shows area cultivated/worker to increase from 0.94 ha. for hand tillage households to 1.23 ha. for donkey traction households in Nedogo compared with an increase of only 1.21 ha. to 1.26 hectares for animal traction households, respectively, for the Eastern Region (Barrett, et al., 1982).

TABLE 1: Estimated Reduction in Labor Times in the Shift From Hand to Animal Power [a] (Percentages)

		Sorghum/ Millet	Maize	Peanuts	Rice
Central Plateau	Land Preparation	+16(+13)	-40(-47)	-40(-47)	-26(-36)
	First Weeding	-30(-43)	-20(-27)	-11(-15)	
	Second Weeding	-30(-43)			
Eastern Region	Land Preparation		-43(-50)	-43(-50)	-26(-36)
	First Weeding	-23(-30)	-38(-43)	-11(-18)	
	Second Weeding	-15(-22)	-25(-35)		

NOTE: The coefficients represent the percentage reduction in human labor time by crop and type of operation due to use of donkey traction. Figures in parenthesis are percentage reduction for oxen traction.

[a] These figures represent average rates of reduction. In reality, the percentage labor savings were varied according to different land types employed. Labor savings were synthesized from studies performed in both regions of Burkina Faso.

TABLE 2: Percentage Yield Increases Estimated for Animal Traction Adoption [a]

	Sorghum/ Millet	Maize	Peanuts	Rice
Swamp Land				9(18)
Highly Manured Compound Soils	6(12)	9(18)		
Village Soils	5(10)	7(14)		
Higher Quality Bush Soils	5(10)	7(14)	-9(-9)	
Lower Quality Bush Soils	3(6)		-9(-9)	

NOTE: Coefficients in the Table represent the percentage yield increases from employing donkey traction technology. Figures in parenthesis refer to yield gains for oxen traction. Yield increases were synthesized from studies performed in both regions of Burkina Faso.

[a] The same estimated percentage increases in yields from animal traction were utilized for both the Central Plateau and Eastern Region.

expand the area of high quality land available;[18] and d) the number of active workers per household is increased to reflect the observed larger family size of households possessing animal traction.

One of the most difficult aspects of the modelling effort was the comparison of different types of traction households. The cross sectional analyses, which are commonly used to evaluate animal traction, are weak in describing the dynamic processes involved in the shift to adoption of the technology. Also, by comparing households possessing animal traction with those that do not, the problems of varying resource levels and management skills between groups are introduced. Here, it was only possible to make inferences about the adjustment processes from the limited cross-sectional observations which were available. A more complete analysis of animal traction adoption would include the longitudinal adjustment of households over time to introduction of the improved traction systems.

The effect of animal traction on demographic characteristics of the household, area cultivated and cropping patterns are shown in Tables 3 and 4. Animal traction is shown to be associated with larger farm size and a larger number of workers per household in both regions. Donkey and oxen households cultivate areas approximately 55 and 70 percent larger respectively than hand tillage households. The main determinant of this area expansion, however, is a larger number of workers. On the Central Plateau

---

[18]A donkey producing a recoverable 0.75 mt of manure is estimated to increase the quantity of high quality sorghum land by approximately 0.1 hectares. Ownership of an ox roughly doubles the area enlarged. Manure increases the quantity of compound land or high quality sorghum land depending on where economic returns are the highest. Information on recoverable manure and field application rates was taken from Bonkian, 1980; Nourrissat, 1965; Martin and Leonard, 1967, p. 139; and Delgado, 1978.

TABLE 3: Demographic Characteristics, Area Cultivated, Land Use Patterns and Land-Labor Ratios Under Alternative Traction Scenarios, Central Mossi Plateau (Per Farm Results)

Variable	Representative Farm [a] Central Mossi Plateau			Jaeger-Nedogo [b] (1983)	
	Hand Tillage	Donkey Tillage	Oxen Tillage	Hand Tillage	Donkey Tillage
Demographic Characteristics					
Residents	10.0	14.0	15.0	--	--
Active Workers	5.0	6.5	7.0	4.71	6.64
Total Area Cultivated (Ha)	4.8	7.3	8.13	4.41	8.18
Cropping Proportions (%)					
Millet	65.6	68.9	68.1	62.0	63.0
White Sorghum	16.6	11.0	9.8	15.4	18.5
Red Sorghum	12.5	4.8	1.7	12.7	8.6
Maize	3.1	6.2	8.5	2.0	2.4
Peanuts	1.7	8.8	11.6	5.4	5.5
Bambara Nuts	--	--	--	1.8	1.2
Rice	0.5	0.3	0.3	0.5	0.1
Land - Labor Ratios:					
Area Cultivated/Worker	0.96	1.12	1.16	0.94	1.23
Area Cultivated/Resident	0.48	0.52	0.54		

[a] Representative farm refers to a farming system which has been developed from farm data collected by ICRISAT, IRAT, Purdue SAFGRAD/FSU, etc. The information was incorporated in a mathematical farm model which produced the results shown here.

[b] Nedogo is a Purdue SAFGRAD survey village located about 30 kms from Ouagadougou on the Central Mossi plateau. Results for the Central Plateau are compared with Jaeger's (1984) study of hand tillage and donkey traction households compared in the village of Nedogo to help validate the representative farm forecasts.

Table 4: Demographic Characteristics, Area Cultivated, Land Use Patterns and Land-Labor Ratios Under Alternative Traction Scenarios, Eastern Region

(Per Farm Results)

	Representative Farm[a/] Eastern Region			Michigan State University-BEAP Study[b/]	
Variable	Hand Tillage	Donkey Tillage	Oxen Tillage	Hand Tillage	Animal Traction
Demographic Characteristics					
Residents	7.3	11.7	14.3	7.34	11.72
Active Workers	3.5	5.0	6.0	3.47	5.07
Total Area Cultivated (Ha)	4.1	6.39	7.1	4.21	6.40
Cropping Proportions (%)					
Sorghum	18.8	17.3	19.6	31.7	25.7
Sorghum/Millet (75:25)	18.8	12.1	10.8		
Millet	18.5	16.4	18.7	19.4	27.7
Millet/Sorghum (75.25)	33.2	43.2	41.5	32.2	21.7
Maize	3.9	2.5	2.5	4.2	3.4
Rice	1.2	0.8	0.7	1.3	3.3
Peanuts	5.6	7.4	5.9	6.4	9.0
Bambara Nuts	-	-	-	0.8	0.5
Soybeans	-	-	-	0.4	4.1
Cotton	-	-	-	0.7	1.6
Other	-	-	-	2.9	2.8
Land - Labor Ratios:					
Area Cultivated/Worker	1.17	1.28	1.18	1.21	1.26
Area Cultivated/Resident	.56	.55	.50	.57	.55

a/ Representative farm refers to a farming system which has been developed from farm data collected by Michigan State University, in the Eastern O.R.D. (Organismes Regionaux de Developpement de L'Est), Purdue/SAFGRAD Farming Systems Project and others. The information was incorporated into a mathematical farm model which produced the results shown here.

b/ This was a farm study conducted by the Bureau of Economic Analysis and Planning of the Eastern O.R.D. and Michigan State University. The study encompassed 25 villages in 12 agro-climatic zones. The figures are overall results across all villages and act as a benchmark for validating the Representative farm model.

the number of active workers increases from 5 to 7 in moving from manual to oxen traction households.[19] In the East the increase is from 3.5 to 6 active workers. Once the number of workers is adjusted for, the area extensification effect is greatly reduced. Area cultivated per worker on the Central Plateau is shown to increase from .96 ha. for hand tillage households to 1.12 ha. for donkey households to 1.16 ha. for oxen households, representing area increases of 17 to 21 percent. These gains are much smaller but consistent with Jaeger's results for Nedogo and with other studies (Sargent, et al., 1981, pp. 26, 64, 65). No area increase was observed for the Eastern region reflecting the lack of weeding equipment mentioned earlier.

A summary of the impact of animal traction on cereal production and net farm income is shown in Table 5 (also see Appendix 2). The higher productivity of the Eastern region is apparent. Compared with the minimum consumption standard of 180 kg/capita/yr. used by the government of Burkina Faso, a large surplus is produced. Animal traction substantially increases total household production and farm income. However, the gains are less dramatic when computed on a per worker or per resident basis (Table 5). On the Central Plateau, donkey traction increases farm revenue/worker by 4% and oxen traction by 14%.

Several implications can be drawn from the analysis. First, returns to animal traction which appear to be large, are greatly diminished when computed on a per-capita level. In cases where large returns are reported in

---

[19]There is debate over whether only larger families adopt animal traction or whether animal traction by increasing capital investment per worker and alleviating seasonal labor constraints thereby encourages larger family size. This is an empirical problem requiring more field research.

TABLE 5: Returns to Animal Traction Per Household, Per Worker and per Resident

	Hand Tillage	Donkey Tillage	Oxen Tillage
Central Plateau			
Cereal Production/worker	397	426	444
Cereal Production/resident	199	198	207
Income Per Household ('000 FCFA)	131.8	178.4	211.4
Net Farm Income/worker ('000 FCFA).	26.4	27.5	30.2
Eastern Region			
Cereal Production/worker	560	585	567
Cereal Production/resident	269	250	238
Income Per Household ('000 FCFA)	103.9	135.8	152.9
Net Farm Income/worker ('000 FCFA)	30.0	27.4	25.8

NOTE: The number of workers and residents per household in each region were reported in Tables 3 and 4.

Household characteristics utilized in the representative farm modeling were obtained from the literature review. The yields and prices utilized to determine production and income can be found in appendices 1 and 2.

the literature, questions arise as to whether the effects of management ability, resource endowment, or higher input use of farmers have been appropriately accounted for. Second area extensification pushes cultivation onto poorer soils where with disappearing land fallow and lack of soil improving inputs, declining soil fertility occurs. With low and declining levels of soil fertility, the economic evaluation of land substituting inputs becomes especially important. In the next two sections the representative farm models are used to evaluate the impact of fertilization and tied ridging.

Chemical Fertilizers

Over 90% of the fertilizer sold in the country is a general purpose cotton fertilizer (14-25-15). In 1982, the FAO Upper Volta fertilizer project estimated the real farm gate costs of cotton complex fertilizer at 127 CFA/kg., compared with 65 CFA/kg. charged to farmers by the regional extension agencies (ORDs). This represents a fertilizer subsidy of 49 percent. Recently, Burkina-Faso has been asked to phase out the subsidy and bring fertilizer prices more in line with world prices.

The yield response of various crops to chemical fertilizer were estimated from on-farm trials conducted in the two regions (Table 6). The physical response is lowest on poor quality bush soils and highest on lower slope soils and areas close to the compound. Response rates in the Eastern Region are estimated to be higher than on the Central Plateau, especially on the outlying soils which receive the benefits of the fallow rotation.

The results of evaluating the impact of the fertilizer technology on various measures of productivity are shown in Tables 7 and 8. The fertilizer technology is evaluated at both subsidized and unsubsidized fertilizer prices. In both regions, fertilizer increases cereal production and net

TABLE 6: Yield Response of Various Crops by Type of Land for the Central Plateau and Eastern Region [a] (kg/ha)

Region		Sorghums/ Millets	Maize	Peanuts
Central Plateau [b]	Highly Manured Compound Soils		450(45)	
	Village Soils	450(70)	500(80)	
	High Quality Bush Soils	240(55)		
	Lower Quality Bush Soils	110(34)		275(57)
Eastern Region [b]	Highly Manured Compound Soils		475(40)	
	Village Soils	500(70)	550(69)	
	High Quality Bush Soils	360(62)		
	Lower Quality Bush Soils	180(44)		175(58)

NOTE: Figures in parentheses are the percentage increases over yields achieved under traditional management practices.

a) These responses represent a summary of yield increases obtained from farm level experiments. The response figures given here are for applications of 50 kg of urea and 100 kg of cotton fertilizer (14-25-15) per hectare. Different yield responses were used for millet and sorghum. For example, yield responses of millet an sorghum on low quality soils on the Central Plateau were estimated at 95 an 125 kg/ha, respectively.

b) These soils on the Central Plateau are permanently cultivated. In the Eastern Region a fallow rotation system is practiced.

SOURCES: This information was synthesized from farmer managed trials conducted by ICRISAT (1980, 1981, and 1982) and SAFGRAD/ FSU (1983, 1984).

Table 7: Productivity Measures for Alternative Fertilizer Prices and Power Sources, Central Plateau

			Subsidized Fertilizer Prices	Unsubsidized Fertilizer Prices
	Price Urea Price Compound Fertilizer	No Modern Inputs	62 65	120 125
Hand Tillage Household	% Total Area Fertilized	0	34	7
	Cereals Production: (kgs)			
	Per Household	1,987	2,505	2,301
	Per Resident	199	251	230
	Oilseeds Production (kgs)			
	Per Household	219	282	279
	Net Farm Income ('000FCFA)			
	Per Household	131.8	152.4	140.3
	Per Worker	26.4	30.5 (15.5)	28.1 (6.4)
Donkey Traction Household	% Total Area Fertilized	0	36	25
	Cereals Production: (kgs)			
	Per Household	2,766	3,126	2,946
	Per Resident	198	223	210
	Oilseeds Production (kgs)			
	Per Household	465	886	874
	Net Farm Income ('000FCFA)			
	Per Household	178.4	212.8	192.7
	Per Worker	27.5 (4.2)	32.7 (23.9)	29.6 (12.1)
Oxen Traction Household	% Total Area Fertilized	0	25	15
	Cereals Production: (kgs)			
	Per Household	3,106	3,285	3,106
	Per Resident	207	219	207
	Oilseeds Production (kgs)			
	Per Household	594	1,311	1,299
	Net Farm Income ('000FCFA)			
	Per Household	211.4	254.4	288.1
	Per Worker	30.2 (14.4)	36.3 (37.5)	32.6 (23.5)

Figures in parenthesis are the increase over net farm income per worker, hand tillage households.

Table 8: Productivity Measures for Alternative Fertilizer Prices and Power Sources, Eastern Region

			Subsidized Fertilizer Prices	Unsubsidized Fertilizer Prices
	Price Urea Price Compound Fertilizer	No Modern Inputs	62 65	120 125
Hand Tillage Household	% Total Area Fertilized	0	70	50
	Cereal Production (kgs):			
	Per Household	1,962	2,616	2,326
	Per Resident	269	358	319
	Oilseeds Production (kgs)			
	Per Household	269	379	308
	Net Farm Income ('000FCFA)			
	Per Household	102.3	120.4	108.2
	Per Worker	29.3	34.4 (17.4)	30.9 (5.5)
Donkey Traction Household	% Total Area Fertilized:	0	32	21
	Cereals Production (kgs):			
	Per Household	2,924	3,515	3,496
	Per Resident	250	300	299
	Oilseeds Production (kgs)			
	Per Household	456	593	508
	Net Farm Income ('000FCFA)			
	Per Household	134.9	153.6	140.1
	Per Worker	27.0 (7.8)	30.7 (4.8)	28.0 (-4.4)
Oxen Traction Household	% Total Area Fertilized:	0	44	22
	Cereals Production (kgs):			
	Per Household	3,400	4,182	4,080
	Per Resident	238	292	285
	Oilseeds Production (kgs):			
	Per Household	500	652	566
	Net Farm Income ('000FCFA)			
	Per Household	152.1	174.8	159.2
	Per Worker	25.3 (-13.7)	29.1 (-0.6)	26.5 (-9.6)

Figures in parenthesis are the increase over Net Farm income per worker, hand tillage households.

farm income. However, the elimination of the fertilizer subsidy substantially reduces returns. The model results indicate that as subsidies are reduced, the area fertilized is cut back starting with the poorer soils where fertilizer response rates are lowest. Even at unsubsidized prices, however, some of the better soils continue to be fertilized.

When viewed in the whole-farm context, the potential impacts of fertilizer technology lead to fairly pessimistic results. At unsubsidized fertilizer prices, farm income per capita increases only 5 to 9 percent depending upon the type of tillage used. These returns to fertilization are very low even without considering other constraints such as cash requirements, risk, and the necessary marketing infrastructure.[20]

Even though physical gains to fertilizer are larger in the Eastern region, returns per worker are not greatly different than on the Central Plateau. The reason for this is that while fertilizer prices are constant across both regions, commodity prices are much lower in the East, thus contributing to a higher real cost of fertilizer in the region.[21]

Chemical fertilization is a risky input in a semi-arid area because a successful response requires the availability of adequate water at the critical stages of plant development. The most critical input in a semi-arid area appears to be a technology to provide or to conserve a more assured

---

[20]The potential profitability of chemical fertilizer will depend upon the availability of cash or credit to the farmer and an input delivery system. The process of agricultural development implies the need for the private and public sector to facilitate these changes. The objective here is only to measure the potential farm level profitability once this process occurs. Since yields are declining in the Central Plateau, the provision of inorganic fertilizer will become increasingly necessary over time.

[21]The price of sorghum in the East was 46 FCFA/kg. compared to 58 FCFA/kg. on the Central Plateau.

water supply. With improved availability of water the probability of a profitable response to fertilization is increased. In the next section an economic evaluation is made of the water conservation technique of tied ridges combined with chemical fertilization and animal traction.

Tied Ridging

One of the promising agricultural technologies in Burkina-Faso is tied ridging. This technology consists of constructing mounds of dirt between ridges in the field, at distances of approximately one meter, to facilitate entrapment of rainfall and promote water infiltration.[22] This technology reduces soil erosion and increases available soil moisture. The yield response of cereals to a more ample supply of water has been shown to be significant (see Table 9 where a 40% increase in yields is reported), but usually constrained by low levels of soil fertility especially on the Central Plateau. When tied ridging is combined with improvements in soil fertility, dramatic increases in cereal yields are possible. The results of on-farm trials in Table 9 show a doubling of yields for the combination of tied ridges and moderate fertilization.

Tied ridging can be performed at various periods of the agricultural season. The maximum yield effect would be expected at planting, but farmers have said this conflicts with their planting strategies (i.e., getting their principal millet and sorghum fields planted as early as possible). Tied ridging performed later at first weeding confronts the high implicit price

---

[22]The construction of tied ridges can vary considerably from that of small depressions dug in the ground, which require little labor, to tall ridges formed in a "lattice" type manner which can require considerable labor to construct.

TABLE 9a: Results of Tied Ridging Experiments on Sorghum Fields, Nedogo, Upper Volta, 1983

Donkey Traction Technology

	I	II	III	IV
Mean Yields (Kg/Ha.)	444	624	604	962
Revenue (CFA/Ha.) [a]	25,752	36,192	35,032	55,796
Cash Inputs:				
100 Kg. Cotton Fertilizer			6,200	6,200
50 Kg. Urea			3,000	3,000
Labor Input (hrs.):				
Base	390	390	390	390
Fertilizer			20	20
Tied Ridges		120		120
Animal and Equipment Depreciation, Maint., & Feed (CFA/Ha.)	3,000	4,000	3,000	4,000
Net Revenue/Ha.	22,752	32,192	22,832	48,596
Revenue/Hr.	58.3	63.1	55.7	80.4

Source: Adapted from 1983 Purdue SAFGRAD/FSU Field Trial Results, Upper Volta.

I = Traditional
II = Tied Ridges Made 30 Days After Seeding
III = 100 Kg./Ha. Cotton Fertilizer + 50 Kg/Ha. Urea
IV = Tied Ridges + 100 Kg/Ha. Cotton Fertilizer + 50 Kg/Ha. Urea

[a] Yield Times Crop Price of 58 CFA/Kg.

TABLE 9b: Results of Tied Ridging Experiments on Sorghum Fields, Diapangou, Burkina Faso

Oxen Traction Technology

	I	II	III	IV
Mean Yields (kg/ha)	526	578	857	991
Revenue (CFA/ha) [a]	24,196	26,588	39,422	45,586
Cash Inputs:				
100 Kg. Cotton Fertilizer			6,200	6,200
50 Kg. Urea			3,000	3,000
Labor Input (hrs.):				
Base	425	425	425	425
Fertilizer			20	20
Tied Ridges		120		120
Animal and Equipment Depreciation, Maintenance and Feed (CFA/ha)	3,000	4,000	3,000	4,000
Net Revenue/ha	21,196	22,588	27,222	32,386
Revenue/Hr.	49.9	41.4	61.2	57.3

Source: Adapted from 1983 Purdue SAFGRAD/FSU Field Trial Results, Burkina Faso

I = Traditional
II = Tied Ridges Made 30 days after seeding
III = 100 kg/ha Cotton Fertilizer + 50 kg/ha Urea
IV = Tied Ridges + 100 kg/ha Cotton Fertilizer + 50 kg/ha Urea

[a] Yield Times Crop Price of 46 CFA/kg.

of labor from labor bottlenecks existing at this time. The tied ridging practiced by farmers in the field and followed in this paper is to construct the ridges using animal traction at first weeding, but performing the labor intensive tying of ridges by hand in slack periods immediately following.

The tied ridging technologies used here (see Table 10) are for maize and sorghum and based upon experimental results reported by ICRISAT (1982), IRAT (1983), and SAFGRAD-FSU (1983 and 1984). The fertilizer rates of 100 kg. of cotton fertilizer (14-25-15 NPK) and 50 kg. of Urea are moderate levels and are costed at unsubsidized prices.

Tables 11 and 12 show the impact of the tied ridging plus fertilization plus animal traction technology in contrast with hand tillage farming systems in the two regions. On the Central Plateau, donkey traction farmers are estimated to cultivate 0.75 hectares and oxen farmers 1.0 hectares using the new technology. Tied ridging is implemented on the better soils, starting first on compound soils then onto further outlying soils. Returns to the technology are substantial. On the Central Plateau income per worker increased by 11 percent (donkey) and 24 percent (oxen), respectively. Results for the Eastern Region are less dramatic. Areas planted using the new technology are smaller and the impact less pronounced. This reflects both the poor efficiency of animal traction and higher fertilizer to output prices relative to the Central Plateau. Both of these effects offset the slightly higher yield in the Eastern region.

The potential benefits of the new technology appear to be considerable. Tied ridges on both the Central Plateau and Eastern region are implemented on only 10% of total crop area yet a significant increase in household income is achieved. The technology, however, appears to be economically viable on only the better quality soils. On the poorer bush soils

TABLE 10: Yield Response to Tied Ridging Plus Fertilizer Technology Used in the Whole Farm Analysis

Region	Land Type	Maize [a]	Sorghums
Central Plateau	Highly Manured Compound Soils	650 (60)	
	High Quality Village Soils	600 (90)	550 (80)
	High Quality Permanently Cultivated Bush Soils		425 (90)
	Low Quality Permanently Cultivated Bush Soils		325 (100)
Eastern Region	Highly Manured Compound Soils	700 (55)	
	High Quality Village Soils	650 (75)	610 (80)
	Higher Quality-Fallowed Bush Soils		520 (90)
	Lower Quality-Fallowed Bush Soils		420 (100)

[a] Figures are yields achieved under donkey traction technology; yields for oxen were estimated to be 10 percent higher. Figures in parenthesis are the percentage increase over yields estimated for donkey traction alone (i.e. without tied ridging or fertiliztion treatments).

TABLE 11: Effect of Tied Ridging Technology Plus Animal Traction on Area Culitivated, Production and Net Farm Income Estimates, Central Plateau

		Traditional Management	Tied-Ridging Technology [a]	
Variable:		Hand Tillage Only	With Donkey Traction	With Oxen Traction
Total Area Cultivated (hectares):		4.8	6.96	7.67
Maize:	Traditional	.15		
	with Tied Ridges		.20	.20
Red Sorghum:	Traditional	.60	.07	
	with Tied Ridges		.53	.60
White Sorghum:	Traditional	.80	.80	.65
	with Tied Ridges			.15
Millet		3.15	4.39	4.61
Rice		.03	.03	.03
Peanuts		.07	.94	1.43
Fertilizer Used: (kg./farm)	Urea		37	49
	Cotton Fertilizer		73	98
Total Cereals Production (kgs):				
	Per Household	1987	2975	3381
	Per Resident	199	213	225
Total Oilseeds Production (kgs)		219	618	835
Net Farm Income ('000 FCFA)				
	Per Household	131.8	189.8	229.3
	Per Worker	26.4	29.2	32.8
No. of Workers Per Household		5.0	6.5	7.0

[a] Based on 50 kg Urea and 100 kg/ha Cotton Fertilizer; labor time of 100 hours per hectare and yield estimates given in Table 10.

TABLE 12: Effect of Tied Ridging Technology Plus Animal Traction on Area Cultivated, Production and Net Farm Income Estimates, Eastern Region

Variable:		Traditional Management	Tied-Ridging Technology[a]	
		Hand Tillage Only	With Donkey Traction	With Oxen Traction
Total Area Cultivated (hectares):		4.10	6.14	6.78
Maize:	Traditional	.15	.16	.02
	with Tied Ridges			.14
Sorghum:	Traditional	.77	.66	.83
	with Tied Ridges		.43	.54
Sorghum/Millet:	(75:25)	.77	.77	.77
Millet		.77	.61	.77
Millet/Sorghum	(75:25)	1.36	3.16	3.46
Rice		.05	.05	.05
Peanuts		.23	.29	.20
Fertilizer Used:	Urea		21.7	28.2
	Cotton Fertilizer		43.3	56.5
Total Cereals Production (kgs):				
Per Household		1961	3153	3733
Per Resident		269	269	261
Total Oilseeds Production: (kgs)		269	422	456
Net Farm Income ('000 FCFA)				
Per Household		103.9	136.4	155.4
Per Worker		29.7	27.3	26.0
No. of Workers per Household		3.5	5.0	6.0

[a] Based on applications of 50 kg Urea and 100 kg cotton fertilizer per hectare, labor time of 100 hours and yield estimates given in Table 10.

customarily planted in millet, an economic response to tied ridges and fertilization has not yet been found. Once the physical and economic factors responsible for this lack of response in millet can be identified and resolved,[23] the potential impact of tied ridges will be greater.

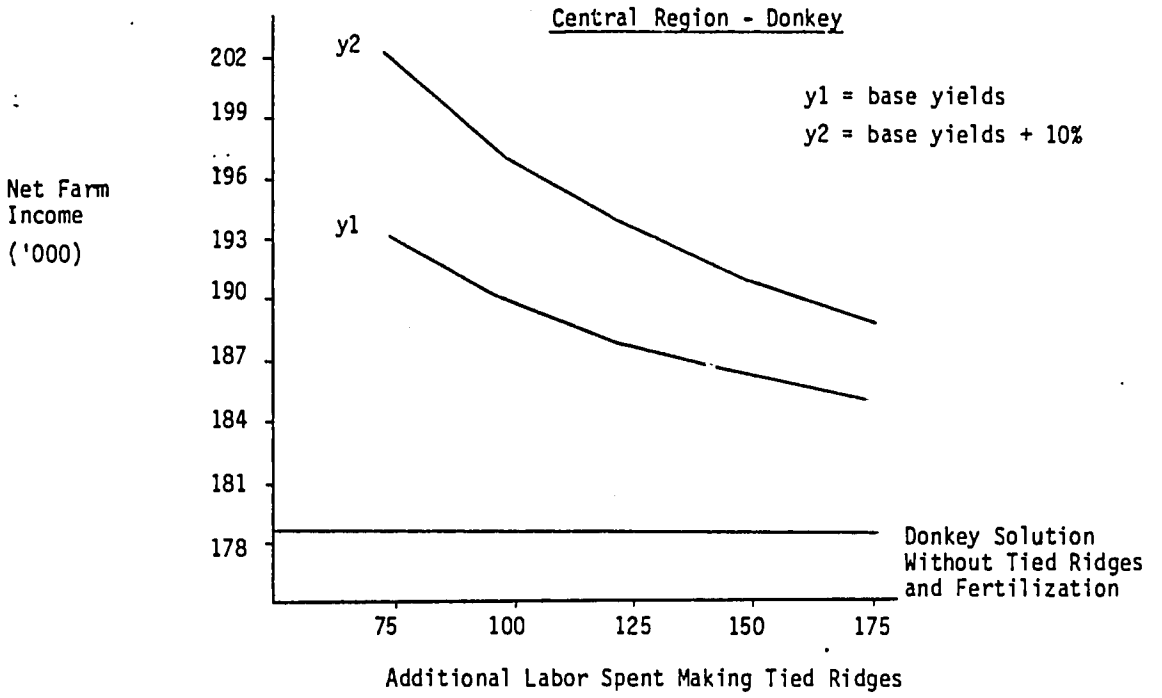
Figure 2 illustrates the sensitivity of the tied ridging results to yields and labor requirements for their construction.[24] The level of net income/household is shown to be very sensitive to yields obtained under the technology and to the amount of additional hand labor required per hectare for the tying of ridges. The research focus now is to further refine the technology to achieve higher yields and reduce labor requirements.

Both improved varieties and more cost effective fertilization would shift upward the curves in Figure 2. In the new environment created by the improved water retention capacity of the soil due to the tied ridges and the increased nutrient availability from the chemical fertilizers, a large payoff to the introduction of new varieties should exist (see Lang, et al., 1984). The SAFGRAD-FSU farm trials of 1984 have incorporated two new Framida parent sorghum varieties combined with the tied ridges and fertilization. Preliminary observations show them to have superior yield response with less lodging than the traditional varieties.

---

[23]Due to lower fertility, poorer water retention capacity, lack of organic materials and lack of crop residues being returned to these poorer soils in Burkinabe farming systems, improving millet yields is not a trivial problem. ICRISAT has substantially increased the number of scientists working on millet in its Niger operations.

[24]Yield level Y_1 corresponds to the response rates given in Table 10. Yield level Y_2 represents a 25% increase in the yield response rates, increasing total yields by about 10%. The figures 75-175 represent the range of labor rates observed in the literature for time requirements to do the tied ridging. The large variance in labor times is attributable to the newness of the operation, variation in farmer adaptation of the technique and measurement error.



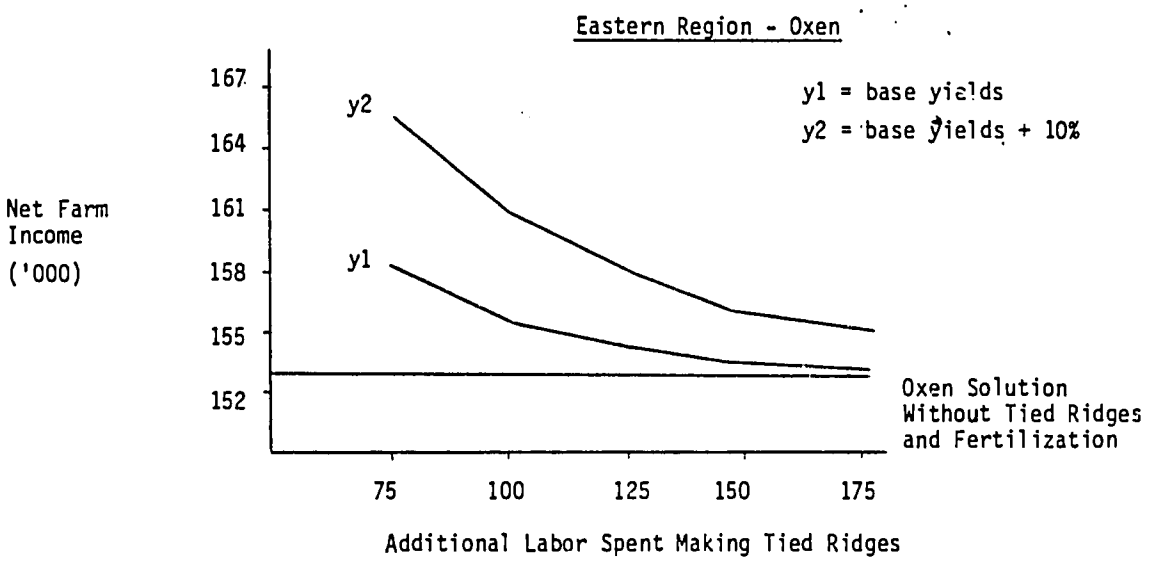


Figure 2: Effect of Various Yields and Labor Spent Tied Ridging On Total Net Revenue of the Farm.

With the development of animal traction equipment it should be possible to decrease the labor requirements for constructing the tied ridges. A prototype implement fitting an animal traction plough with a ridger is currently being tested in the field and appears to be producing good results. If labor times can be reduced through improved animal traction equipment, economic returns to the new technology will be further improved.

By putting all the component technology pieces together dramatic increases in household income are possible. The combined effects of water retention, inorganic fertilizer, and animal traction are all necessary. Introducing these agronomic innovations creates an improved environment, which promotes a high return to improved varieties.

Intensive vs. Extensive Technological Change

In previous sections, three different types of technological change were considered. These results are summarized in Tables 13 and 14 to enable a simpler comparison. Animal traction households are shown to have substantially higher incomes than hand tillage households reflecting principally the impact of a larger number of workers. When measured on a per worker basis, the increase in area cultivated per worker and in total labor productivity (income/worker) are smaller especially on the Central Plateau. Land productivity (income/hectare) is shown to decline slightly with the expansion of total area cultivated. In the East, the income increase per household from animal traction is not as large as on the Central Plateau. There is less area expansion and less increase in area cultivated per worker. This is apparently due to the failure to introduce appropriate cultivation equipment.

TABLE 13: Summary of Various Productivity Measures Estimated from Sole and Combined Impacts of Animal Traction, Fertilization and Tied Ridging Technologies, Central Plateau

Alternative Power Sources	Traditional Technologies	Land Substituting Technologies	
		Fertilization[a]	Tied Ridges[a] Plus Fertilization
Hand Tillage:			
Total Area Cultivated (hectares)	4.82	4.82	b
Active Workers/Household	5.0	5.0	
Area Cultivated/Worker	0.96	0.96	
Income per Household ('000 FCFA)	131.8	140.3	
Income Per Hectare	27.5	29.1	
Income Per Worker	26.4	28.1	
Donkey Households:			
Total Area Cultivated	7.29	7.29	6.96
Active Workers/Household	6.5	6.5	6.5
Area Cultivated/Worker	1.12	1.12	1.07
Income Per Household	178.4	192.7	189.8
Income Per Hectare	24.4	26.4	27.3
Income Per Worker	27.5	29.6	29.2
Oxen Households:			
Total Area Cultivated	8.13	8.13	7.67
Active Workers/Household	7	7	7
Area Cultivated/Worker	1.16	1.16	1.10
Income Per Household	211.3	228.1	229.3
Income Per Hectare	26.0	28.1	29.9
Income Per Worker	30.2	32.6	32.8

[a] The unsubsidized price of fertilizer was utilized: 122 CFA/kg Urea and 125 CFA/kg cotton fertilizer.

[b] Since the tied ridging is a very labor intensive operation, it was assumed that animal traction would be necessary to assist in the contruction of the ridges.

TABLE 14: Summary of Various Productivity Measures Estimated From Sole and Combined Impacts of Animal Traction, Fertilization and Tied Ridging Technologies, Eastern Region

Alternative Power Sources	Traditional Technologies Alternative	Land Substituting Technologies	
		Fertilization[a]	Tied Ridges Plus Fertilization
Hand Tillage:			
Total Area Cultivated (hectares)	4.10	4.10	b
Active Workers/Household	3.5	3.5	
Area Cultivated/Worker	1.17	1.17	
Income Per Household ('000 FCFA)	103.9	108.2	
Income Per Hectare	25.3	26.4	
Income Per Worker	29.7	30.9	
Donkey Households:			
Total Area Cultivated (hectares)	6.39	6.39	6.14
Active Workers/Household	5.0	5.0	5.0
Area Cultivatee/Worker	1.28	1.28	1.23
Income Per Household ('000 FCFA)	135.8	140.1	136.4
Income Per Hectare	21.3	21.9	22.2
Income Per Worker	27.2	28.0	27.3
Oxen Households:			
Total Area Cultivated (hectares)	7.10	7.10	6.78
Active Workers/Household	6.0	6.0	6.0
Area Cultivated/Worker	1.18	1.18	1.13
Income Per Household ('000 FCFA)	152.9	159.2	155.4
Income Per Hectare	21.5	22.4	22.9
Income Per Worker	25.5	26.5	26.0

[a] The unsubsidized price of fertilizer was utilized: 122 CFA/kg Urea and 125 CFA/kg Cotton Fertilizer

[b] Since the tied ridging is a very labor intensive operation, it was assumed that animal traction would be necessary to assist in the construction of the ridges

Moving across the tables to the more intensive, land substituting technologies of fertilization and tied ridges, the effect on household income and on land and labor productivity is larger on the Central Plateau than in the Eastern region. Since soil fertility is lower and declining more rapidly there, it is not surprising that land substituting inputs should have a high payoff. Another important factor is that areas closer to the nation's capital receive a higher product price. The close proximity of the major market of Ouagadougou to the Central Plateau appears to offset the higher physical yield response of the frontier region.

An important result is that while tied ridges and/or fertilization have a significant impact on household incomes and on land and labor productivities the technologies remain viable on only the better quality soils. As yet the technology has not been produced to extend these intensive practices onto the poorer quality soils where millet is normally cultivated. This will be a major challenge first for agronomists and later for plant breeders.

In the East the promotion of appropriate animal traction equipment and improvement of roads and market information, to obtain higher product prices, may have higher short run returns than the introduction of land substituting inputs. This is discouraging because the on-farm trials of tied ridging, fertilization, and new sorghum and maize varieties have shown good physical results in the East (SAFGRAD-FSU, forthcoming). Investments in marketing infrastructure may be a necessary component to make new agricultural technologies economically viable.

In summary, significant returns are possible from the introduction of animal traction with appropriate cultivation equipment in both regions of the country. However, in the future as soil fertility continues to decline

on the Central Plateau, the focus of research efforts there should be more directed to the land substituting technologies -- i.e., fertilization and tied ridges. These investments would include the development of an animal ridger, experimentation on different levels and types of inorganic fertilizer, and the continued development of improved varieties of sorghum and maize.

References

Barrett, V., G. Lassiter, D. Wilcock, D. Baker, and E. Crawford, 1982. "Animal Traction in Eastern Upper Volta: A Technical, Economic, and Institutional Analysis," MSU International Development Paper No. 4, Michigan State University, East Lansing, Michigan.

Bonkian, A., 1980. "Manure Use in Two Villages of Central Upper Volta." ICRISAT, Ouagadougou, Upper Volta.

Charreau, C. and R. Nicou, 1971. "L'amélioration du profil culturel dans des sols sableaus et sablo-agrileux de la zone tropicale sèche ouest-Africaine et ses incidences agronomiques (d'après des travaux des chercheurs de l'I.R.A.T. en Afrique de l'Ouest)". Agronomie Tropicale, XXVI (Septembre):903-978.

Delgado, C.L., 1978. "The Southern Fulani Farming System in Upper Volta: A New Old Model for the Integration of Crop and Livestock Production in the West Africa Savannah," CRED, University of Michigan, September.

Delgado, C.L., 1984. "The Economic Context of Mixed Farming in Upper Volta: A Conceptual Framework," International Food Policy Research Institute, Washington, D.C., mimeo, 20 pages.

Delgado, C.L. and J.W. Mellor, 1984. "A Structural View of Policy Issues in African Agricultural Development," Invited Paper for the Annual Meeting of the American Agricultural Economics Association, Cornell University, Ithaca, New York.

Eicher, C.K., 1983. "West Africa's Agrarian Crisis", presented at 5th Bi-Annual Conference of West African Association of Agricultural Economists, Abidjan, Ivory Coast, December.

Hammond, P.B., 1966. Yatenga: Technology in the Culture of a West African Kingdom, New York, The Free Press.

ICRISAT, 1980. "1980 Annual Report," Ouagadougou, Upper Volta.

ICRISAT, 1981. "1981 Annual Report," Ouagadougou, Upper Volta.

ICRISAT, 1982. "1982 Annual Report," Ouagadougou, Upper Volta.

IRAT, 1983. "Rapport de Synthese, 1982," Ouagadougou, Upper Volta.

Jaeger, W.K., 1984. "Animal Traction and Resource Productivity: Evidence From Upper Volta," Animals in the Farming System, Proceedings of Kansas State University's 1983 Farming Systems Research Symposium, Manhattan, Kansas, May, pp. 441-460.

Kaylen, A.M., August, 1982. "Current Farming Conditions in Nedogo and Digre, Upper Volta," unpublished M.S. Thesis, Purdue University, West Lafayette, Indiana.

Kline, C.K., D.A.G. Green, R.L. Donahue, and B.A. Stout, 1969. "Agricultural Mechanization in Equatorial Africa." Research Report No. 6, Institute of International Agriculture, Michigan State University, East Lansing, Michigan.

Lang, M. and M. Roth, 1984. "Risk Perceptions and Risk Management by Farmers in Burkina-Faso," Purdue, West Lafayette, Indiana, mimeo, 25 pages.

Lang, M., R. Cantrell, J.H. Sanders, 1984. "Identifying Farm Level Constraints and Evaluating New Technology in the Purdue Farming Systems Project in Upper Volta," in C.B. Flora (ed.), Animals in the Farming System, Proceedings of Kansas State University's 1983 Farming Systems Research Symposium, Manhattan, Kansas, May, pp. 184-206.

Lassiter, G., 1981. "Cropping Enterprises in Eastern Upper Volta," Michigan State University, East Lansing, Michigan, mimeo, February.

Martin, J.H. and W.H. Leonard, 1967. Principles of Field Crop Production, New York, The MacMillan Company.

McIntire, J., 1981. "Crop Production Budgets in Two Villages of Central Upper Volta," ICRISAT, Ouagadougou, Upper Volta, July.

Nourrissat, P., 1965. "La Traction Bovine au Senegal, Experiences du C.R.A. de Bambey," L'Agronomie Tropicale, No. 9:825, September.

Ruthenberg, H., [1956] 1980. Farming Systems in the Tropics, 3rd ed, Cambridge: Oxford University Press.

Roth, et al., Forthcoming. "New Technology Evaluations for Farms on the Central Plateau and Eastern Regions of Burkina-Faso".

SAFGRAD-FSU, 1983. Farming Systems Research in Upper Volta, 1982 Annual Report, Ouagadougou, Upper Volta.

SAFGRAD-FSU, 1984. Farming Systems Research in Upper Volta, 1983 Annual Report, Ouagadougou, Upper Volta.

SAFGRAD-FSU, Forthcoming. Farming Systems Research in Burkina-Faso, 1984 Annual Report, Ouagadougou, Burkina-Faso.

Sargent, M.W., J.A. Lichte, P.J. Matlon, and R. Bloom, 1981. "An Assessment of Animal Traction in Francophone West Africa," African Rural Economy Program Working Paper No. 34, Michigan State University, East Lansing, Michigan.

Saunders, M.O., April 1980. "The Mossi Farming System of Upper Volta," Farming System Research Unit Working Paper No. 3, Purdue University, West Lafayette, Indiana, mimeo, 31 pages.

Singh, R.D., E.W. Kehrberg, and W.H.M. Morris, 1983. Small Farm Production Systems in Upper Volta, Descriptive and Production Function Analysis, Department of Agricultural Economics, Agricultural Experiment Station Bulletin No. 442, Purdue University, West Lafayette, Indiana, December.

Stoop, W.A., M. Pattanayak, P.J. Matlon, and W.R. Root, October 1982. "A Strategy to Raise the Productivity of Subsistence Farming Systems in the West African Semi-Arid Tropics," Sorghum in the Eighties, Proceedings of the International Symposium on Sorghum, Vol. 2, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra Pradesh, India, pp. 519-526.

Swanson, R.A., May 1982. "A Farming Systems Research in Upper Volta," FSU/SAFGRAD, Document No. 15, Ouagadougou, Upper Volta.

U.S. Department of Agriculture, ERS, 1981. Food Problems and Prospects in Sub-Saharan Africa: The Decade of the 1980's, Washington, D.C., August.

World Bank, 1982. Upper Volta, Agricultural Issues Study, Washington, D.C., October.

Appendix 1A: Yield Levels for Sole Crops and Crop Mixtures by Type of Land and Traction Technology Assumed for the Central Plateau Representative Farm

Type of Land	Crop Mixture	Hand Tillage
Swamp Land	Rice	850
Compound Land	R. Sorghum	850
	W. Sorghum	770
	R. Sorghum/W. Sorghum	638/185
	Maize	1000
Red Sorghum Land	R. Sorghum	640
	R. Sorghum/Cowpeas	640/55
	W. Sorghum	590
	W. Sorghum/Cowpeas	590/55
	Maize	625
White Sorghum Land	R. Sorghum	430
	R. Sorghum/Cowpeas	430/45
	W. Sorghum	450
	W. Sorghum/Cowpeas	450/45
	Millet	420
	Millet/Cowpeas	420/45
	W. Sorghum/R. Sorghum	340/105
	Millet/W. Sorghum	315/115
	Maize	350
	Peanuts	520
Millet Land	W. Sorghum	310
	W. Sorghum/Cowpeas	310/35
	Millet	340
	Millet/Cowpeas	340/35
	Millet/W. Sorghum	255/78
	Peanuts	480

Appendix 1B: Yield Levels of Sole Crops and Crop Mixtures by Type of Land and Traction Technology Assumed for the Eastern Region Representative Farm

Type of Land	Crop Activity	Hand Tillage
Swampy Land	Rice	820
Compound Land	Maize	1200
	Sorghum	900
	Maize/Sorghum	840/270
Permanently Cultivated Village Fields	Sorghum	710
	Sorghum/Cowpeas	710/85
	Sorghum/Millet	500/185
	Sorghum/Millet/Cowpeas	500/185/85
	Millet/Sorghum/Cowpeas	305/355/85
	Maize	800
Higher Quality Bush Field Soils (NL-New Land)	NL - Sorghum/Cowpeas	620/65
	NL - Groundnuts	425
	Sorghum/Millet	395/155
	Sorghum/Millet/Cowpeas	395/155/65
	Millet/Sorghum/Cowpeas	255/280/65
	Sorghum/Maize	395/150
	Soybeans	375
	Groundnuts	350
Lower Quality Bush Field Soils (NL-New Land)	NL - Sorghum/Cowpeas	450/55
	NL - Groundnuts	325
	Millet/Cowpeas	410/45
	Millet/Sorghum	287/114
	Millet/Sorghum/Cowpeas	287/114/45
	Sorghum/Millet/Cowpeas	190/205/45
	Groundnuts	285
	Soybeans	300
	Cotton	250
Continuously Cultivated (Exhausted) Bush Fields	Millet/Cowpeas	320/35
	Groundnuts	195
	Cotton	175

a/ Comparisons of income figures across regions should be avoided. Because of different supply and demand conditions within each region and high marketing costs between regions output prices on the Central Mossi Plateau are higher than in the eastern region. For example prices used for the Central Plateau (Eastern Region) are 59 (46) FCFA for white sorghum 55 FCFA for red sorghum, 58 (46) FCFA for millet, 60 (40) FCFA for maize, 92 (69) FCFA for peanuts, 117 (73) FCFA for rawpeas and 80 (90) FCFA for rice.

b/ Income is total value of all crops produced, valued at market prices, minus cost of seed, hand tools, repairs and depreciation and costs of animal traction. Hired labor was not included due to its relative unimportance in total labor budgets in these two regions. Use of modern inputs was excluded from these as well, because of low use by farmers.

c/ Jaeger reports total revenue/worker as FCFA 24,422 for hand tillage households, FCFA 28,418 for donkey households and FCFA 31,862 for donkey and oxen households.

d/ The total farm income figures reported here are higher than the income figures reported in the Michigan State U-BEAP study (i.e. net revenue from crop production was reported to be between 75-79,000 FCFA for hoe households, FCFA 71,099 for donkey households and FCFA 146,220 for oxen households). The difference is the higher yield levels used for peanuts and cowpeas assumed for the representative farm.

APPENDIX 2: Measures of Production and Income Per Household, Resident and Active Worker Under Three Alternative Traction Scenarios, Plateau and Eastern Region Representative Farms

	Representative Farm Central Mossi Plateau			Representative Farm Eastern Region		
	Hand Tillage	Donkey Tillage	Oxen Tillage	Hand Tillage	Donkey Tillage	Oxen Tillage
Production:						
Production per Farm (Kg)						
Sorghum				908	1,291	1,537
White Sorghum	360	378	396			
Red Sorghum	387	238	99			
Millet	1,072	1,750	1,983	821	1,379	1,575
Maize	147	377	603	192	209	240
Rice	21	23	25	41	45	48
Peanuts	40	281	409	70	145	134
Cowpeas	179	184	185	199	311	366
Total Cereals Production	1,987	2,766	3.106	1,962	2,924	3,400
Total Oilseeds Production	219	465	594	269	456	500
Cereal Production/worker	397	426	444	560	585	567
Cereal Production/resident	199	198	207	269	250	238
Percent change in Cereal Prod/worker		7.3	11.8		4.5	1.3
Farm Income: ('000 FCFA)						
Total Farm Income[a/] [b/]	131.8	178.4	211.4	103.9 [d/]	135.8 [d/]	152.9 [d/]
Income per worker[a/] [b/]	36.4 [c/]	27.5 [c/]	30.2 [c/]	29.7	27.2	25.5