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# EVALUATION OF NEW TECHNOLOGIES IN BURKINA FASO USING WHOLE FARM MODELLING

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# Evaluation of New Technologies in Burkina Faso Using Whole-Farm Modelling

Whole farm modelling (Linear Programming) is used to model the production unit of the farming systems on the Central Plateau of Burkina Faso. The model is used to indicate the degree of adoption, impact on income, and the production constraints preventing further adoption of soil fertility and water retention technological interventions.

# EVALUATION OF NEW TECHNOLOGIES IN BURKINA FASO USING WHOLE-FARM MODELLING

A variety of research has been conducted in Burkina Faso to increase food production through technological interventions.[1] This paper presents some results related to water conservation (tied ridges) and soil fertility (fertilization). The paper starts with a description of the most important constraints in the farming system, followed by a discussion of the new technologies and economic results of field trials. Finally, linear programming is used to evaluate the new technologies in a whole-farm context.

## INTRODUCTION

Burkina Faso is located in the semi-arid tropics of West Africa. On the Central Plateau of Burkina, the long term average annual rainfall is around 800 mm, although it has averaged 100 to 150 mm below average since the mid-sixties. Rainfall is highly variable and unpredictable. Soils are predominately sandy-clay with weak aggregates, and after a rain the soil surface dries and forms a crust which restricts water infiltration and aeriation and increases rainfall runoff (Kowal and Kassam, 1978). This leads to problems with water retention and soil erosion. The population of the Central Plateau is increasing at a rate of 2.7 percent per year, or a net increase of 1.7 percent per year considering out-migration. The increased man-land ratio has caused a change in the traditional farming system. Traditionally farmers plant land for five to seven years and then it is fallowed for up to 20 years to restore the fertility. With limited access to new land, however, fields are cultivated continuously. In Nedogo, one village studied on the Central Plateau, many of the fields have been planted without fallowing as long as the farmer can remember (FSU, 1983). The shorter fallow period in combination with the present farm management

[1] Burkina Faso was formerly Upper Volta.

practice of burning or removing all plant meterial for household use and animal feed exhausts the soil. The end result is that as more pressure is put on the land for food production, soil deterioration will increase, resulting in lower yields and food production. The main crops in this area are millet and sorghum, and yields are already low. Another important constraint is labor shortage at the critical periods of planting and first weeding. Most of the agricultural labor is provided by family members during the agricultural season. Little labor is available for hire during peak periods because a labor pool does not exist and farmers cannot be hired away from their own farm work at the average going wage of 50 CFA/hr. Animal traction is currently used on only 10% of farms. Animal traction is used extensively permitting households to increase their cultivated area but with little or no increase in yield per area (Jaeger and Sanders, 1985).

The primary constraints are low soil fertility, limited and unpredictable rainfall and labor shortages. Part of the solution to overcome these problems lies in changing the present farming system of the Central Plateau through technological intervention. This paper presents an evaluation of soil and water management technological interventions that have been tested in Burkina Faso.

## NEW TECHNOLOGIES

The research focused partly on the water management technique of tied ridging. Tied ridges are small depressions made between the crop rows either by hand tillage or with a combination of animal traction and hand tillage.[2] Given the continuing deterioration of the soil, the limited supply of local

[2] If done by hand, depressions 32 cm long x 24 cm wide x 16 cm deep are made between the rows and spaced 1 1/2 meters apart. If done with animal traction, the cultivator is equipped with a middle sweep to create a furrow which is then followed by hand tillage to make a 16 cm high ridge perpendicular to the furrow every one to two meters. Ridging with animal traction is a traditional practice, however, the tying of the ridges is not.

organic matter, and the farmers present low level of commercialization, low levels of commercial fertilizers were incorporated into the field trials. On-farm farmer managed trials of sorghum were conducted in four villages, one of which was Nedogo on the Central Plateau, in 1983 and 1984 (Lang et al., 1984 and Ohm et al., 1985a). The trials were designed to test low levels of fertilization (100 kg/ha 14-23-15 NPK fertilizer and 50 kg/ha urea), tied ridges made 6-8 weeks after planting (taking into considerations that labor is most constraining at planting and first weeding), and a combination of fertilization and tied ridges. Economic budget analysis is presented for Nedogo in Table 1. Similar results were obtained in the other three village sites. The conclusions to be drawn from Table 1 are that tied ridging alone or fertilization alone can be profitable; however, fertilization alone carries a high risk of losing the cash outlay. Only when in combination do the two technolgies provide a subtantial net return and a return/hr of additional labor at a level of risk of losing the cash outlay that may be acceptable to farmers.

Farmer interviews and labor data analysis throughout the years of field trials clearly indicated that if the labor requirement for tied ridging could be decreased, more hectarage would be devoted to the technology. (Tied ridges using manual tillage take farmers an average of 100 hours/ha additional time, while tied ridges using animal traction take 75 hours/ha). This was communicated to other researchers, and a Peace Corps Volunteer with IITA in Burkina designed a prototype mechanical device to tie the ridges.[3]

[3]The device is essentially a paddle wheel (45 cm in diameter) with four paddles, one scraping the ground building up earth until it is tripped by the operator every 1 1/2 to 2 meters to create the tie in the ridge. When oxen are used, the ridging and tying with the mechanical ridge tier (MRT) can be done in one operation. Donkeys can do both operations at one time but only if they are managed well, healthy and in good condition and the soil is loose or moist. Preliminary cost estimate of the mechanical ridge tier is 15,000 CFA (as compared to a cultivator at a cost of 20,000 to 25,000 CFA).

The mechanical device is attached to an animal drawn cultivator with one large middle sweep and either ties the ridges as they are made or ties the ridges after the field has been ridged by making a second pass with the mechanical ridge tier attached to the cultivator.

The mechanical ridge tier (MRT) was tested in Burkina Faso in 1985 (Nagy et al., 1986). A trial with a similar protocol to the farmer-managed sorghum with tied ridges and fertilization experiment (Table 1) was conducted, although all treatments were fertilized. In Table 2, the net revenue/ha figures of all three tied ridging treatments are above the net revenue/ha figure of the control and the difference is expressed as the net revenue gain/ha. The net revenue gain/ha of the three tied ridging treatments represent the net revenue gained solely because of the increased yield from the use of tied ridging. The net revenue gain/ha of using the MRT are below the net revenue gain/ha of tying the ridges by hand. The cost of the MRT and the lower yields observed in treatments MRT-1 and MRT-2 contributed to the lower net revenue gain/ha relative to the TR-Manual treatment.

The important fact however is that there is a labor constraint which precludes the tying of ridges manually on a significantly large hectarage per household. A survey conducted to obtain the labor demands required by the use of the MRT indicated that the MRT substantially reduces the labor time required for tying the ridges. In Nedogo, when ridging and constructing tied ridges simultaneously with the MRT in one pass, farmers with donkey traction took on average one actual hr/ha more time than when the traditional ridging operation was performed alone. Thus if two men performed the one pass MRT operation with donkey traction, it would require two manhours to construct tied ridges on one hectare in contrast to the estimated 75 hours to tie the ridges by hand. When the two pass method was use--ridging first, then tying the ridges with the MRT attached to the cultivator--the second pass to tie

the ridges with the MRT required on average 14 actual hrs/ha which still represents a substantial labor saving over that of tying the ridges by hand.

## TECHNOLOGY EVALUATION USING LINEAR PROGRAMMING

While simple budgeting analysis indicates that the new technologies of tied ridging and fertilization are profitable on a per hectare basis, it does not address the issue of how the technologies "fit" within the farming system with respect to the resources of the farm, i.e., what are the land, labor or capital constraints. The methodology used for this evaluation is linear programming (LP) which is a whole-farm modelling technique. Simple budgeting of costs and returns is limited in two ways (Roth and Sanders, 1984). First the explicit values of land and labor in Burkina are unknown and when used are generally included in an ad hoc manner. Secondly, the budgeting analyses are partial, hence they ignore the substitutibility of inputs on the farm and how they are allocated based on the fixed endowments and implied prices of resources and do not indicate which resources are constraining. The research questions for the farm model are as follows (Sanders and Roth, 1985): (1) whether the new technologies would be adopted (given the assumptions of the model farm), (2) what would be their income effect, and (3) what are the most pressing production constraints preventing adoption.

Briefly, the linear programming farm model has the option of performing tillage operations under one of three types of tillage practices: manual, donkey and oxen. A farmer possesses four types of resources: land of various quality, family labor, animal traction, and modern inputs. Land is divided into four types: high fertility compound land, two types of sorghum land with one having better fertility and water retention capability and the fourth, the lower quality millet land. Stocks and flows of labor are dissaggregated into weekly time periods to capture the critical labor

constraints at planting and first weeding. Information on the technical aspects of the tied ridging and fertilization technologies from the on-farm trials and socio-economic survey were incorporated into the model. Tied ridging was given as an option on maize compound land and tied ridging and fertilization in combination were options on the two types of sorghum land and on the millet land. On-farm researcher-managed trials indicated a significant maize yield response from tied ridges alone but little additional response when fertilizer was added in combination with tied ridges on compound land (Lang et al., 1984). Thus only the tied ridging option is available for maize on compound land. The alternative of modelling fertilizer alone was not considered because of the high risk of losing the cash outlay as observed from the on-farm farmer-managed trials.

Table 3, column 1 presents the results of the donkey traction LP model under traditional management practices (no fertilizer and no tied ridges) and column 2 presents the results with the technology interventions of tied ridging (ridged with donkeys but tied by hand) and fertilization.[4] The results indicate that tied ridges are constructed on maize on compound land and tied ridges and fertilization are used on all the red sorghum land (high quality sorghum land) and a small portion of the white sorghum land (lower quality sorghum land). The new technologies do not completely displace the total hectarage under traditional management practices because of the labor constraint. The shadow price of labor during the period when ridges must be tied is 343 CFA/hr or approximately five times the average wage of 50 CFA/hr,

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

indicating a critical labor constraint during this period. Total per capita cereal production increases from 150 kgs to 186 kgs and net farm income per worker increases from 30,800 CFA to 36,200 CFA. The conclusions to be drawn from the LP model are that the two technologies can fit into the production system of animal traction farmers but that a labor constraint still prevents the technologies from being adopted on all the hectarage.

The model was also run with the option of using the MRT. Labor requirements consisted of the following: 2 additional manhours/ha to ridge and tie with the MRT at the same time (one pass), or 20 additional manhours if the donkey must make a second pass with the tier (two passes). The LP model results using the MRT at second weeding are presented in Table 3. Column 3 presents the results when two passes are required (ridging first followed by tying with the MRT). All the red sorghum and white sorghum land are ridged and tied including a small proportion of millet land. Column 4 presents the results when only one pass is used to ridge and tie and results in a greater proportion of millet land devoted to the technologies. The use of the MRT therefore increases the number of hectares that can be profitably tied ridged given the labor resources of the farm. The labor constraint continues to be binding during the period of tying the ridges. The shadow price of labor is 171 CFA/hr when the two pass system is used, and 241 CFA/hr with one pass.

The model was run with several tied ridging labor times to examine the sensitivity of the results and take into consideration that labor times vary from farmer to farmer. Scenarios were also run with the yields increased by 10%. The results for tied ridges by hand are presented in Figure 1 and tied ridges by machine in Figure 2. The results indicated that farmers who are able to construct tied ridges by hand with the least amount of labor

obtain a significantly higher net return. Net farm income is again increased by using the MRT, especially if the donkey is able to do the operation in one pass or if the hours/ha it takes to do two passes can be decreased to 10 hours. When one pass is used, total per capita cereal production increases 60% from 150 kgs with traditional management to 240 kgs. Net revenue per worker increases a total of 37% over traditional management practices.

## SUMMARY AND CONCLUSIONS

The water retention and fertility research results indicate that the combination of tied ridging and fertilizer is both technically and economically superior to traditional management practices. When only one of the technologies is used, yields are constrained by the absence of the other and in the case of fertilizer alone, the risk of losing the cash outlay is very high. When the two technologies are used in combination, the next constraint is labor availability. The results indicate that the mechanical ridge tier can decrease the labor constraint to the point where most of the staple crop land is under tied ridges.

The LP results indicate that tied ridging and fertilization technologies would have a better chance of being adopted if yields can be improved through plant breeding. For example, the shift in the yields by 10% in Figures 1 and 2 demonstrate a significant increase in net returns. The use of intermediate inputs such as tied ridging and low levels of fertilizer creates an environment in which new varieties are much more likely to be successful than under the current low fertility, moisture stress conditions.

The MRT also has the potential of increasing the adoption of animal traction by making it more profitable. The MRT allows animal traction to be used intensively (in combination with fertilization) to increase yields per area in land scarce areas rather than being used extensively as it is now.

The LP results demonstrate the advantages of whole-farm modelling in the evaluation of new technologies. Simple budgeting can show profitability on a per hectare basis. But LP analysis goes further, indicating the number of hectares on which the technology will be adopted given the constraints. It also increases the understanding of which constraints are critical, and in what time periods. Finally, the modelling produces a measure of total farm benefit in terms of net farm revenue or cereal production.

Table 1. Economic analysis of farmer managed trials of sorghum with fertilizer and tied ridges, Nedogo, 1983 and 1984.

| | Treatments[1] | | | |
|---|---|---|---|---|
| | C | TR | F | TR,F |
| | 1984, Manual Traction | | | |
| Grain Yield, kg/ha[2] | 157 | 416 | 431 | 652 |
| Yield Gain Above Control, kg/ha | - | 259 | 274 | 495 |
| Gain in Net Revenue, CFA/ha[3] | - | 23,828 | 13,275 | 33,607 |
| Return/hr of Additional Labor, CFA[4] | - | 238 | 140 | 172 |
| % Farmers Who Would Have Lost Cash | - | 0 | 27 | 9 |
| | 1984, Donkey Traction | | | |
| Grain Yield, kg/ha | 173 | 425 | 355 | 773 |
| Yield Gain Above Control, kg/ha | - | 252 | 182 | 600 |
| Gain in Net Revenue, CFA/ha | - | 23,184 | 4,811 | 43,267 |
| Return/hr of Additional Labor, CFA | - | 309 | 51 | 255 |
| % Farmers Who Would Have Lost Cash | - | 0 | 50 | 0 |
| | 1983, Manual Traction | | | |
| Grain Yield, kg/ha | 430 | 484 | 547 | 851 |
| Yield Gain Above Control, kg/ha | - | 54 | 117 | 421 |
| Gain in Net Revenue, CFA/ha | - | 4,968 | -1,169 | 26,799 |
| Return/hr of Additional Labor, CFA | - | 50 | - | 137 |
| % Farmers Who Would Have Lost Cash | - | 0 | 56 | 0 |
| | 1983, Donkey Traction | | | |
| Grain Yield, kg/ha | 444 | 624 | 604 | 962 |
| Yield Gain Above Control, kg/ha | - | 180 | 160 | 518 |
| Gain in Net Revenue, CFA/ha | - | 16,560 | 2,787 | 35,723 |
| Return/hr of Additional Labor, CFA | - | 221 | 29 | 210 |
| % Farmers Who Would Have Lost Cash | - | 0 | 58 | 42 |

Source: Ohm et al., 1985b.

[1]C = Control (no tied ridges or fertilizer); TR = tied ridges constructed at second weeding ; F = 100 kg/ha 14-23-15 applied in band 10-15 cm from row at first weeding plus 50 kg/ha urea applied in pockets 10-15 cm from seed pockets at second weeding.

[2]The TR, F treatments are significantly different from the control in all cases. The TR treatments and the F treatments are significantly different from the control in 1984 but not in 1983.

[3]Net Revenue = Yield gain x 1984 grain price (92 CFA/kg) minus 1984 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%. 1 US Dollar = 436 CFA (1984).

[4]Net Revenue/additional labor of tied ridging and fertilizer application. Manual and Donkey traction require 100 and 75 hours of additional labor/ha for tied ridging respectively. Fertilizer application requires 95 additional hours/ha.

Table 2. Economic analysis of the mechanical ridge tier (MRT), 1985

| | Treatments[1] | | | |
|---|---|---|---|---|
| | Control | TR-Manual | MRT-1 | MRT-2 |
| Grain Yield, kg/ha[2] | 740 | 954 | 875 | 927 |
| Yield Gain Above Control, kg/ha | - | 214 | 135 | 187 |
| Gross Revenue, CFA/ha[3] | 37,000 | 47,700 | 43,750 | 46,350 |
| Net Revenue, CFA/ha[4] | 23,132 | 33,832 | 28,415 | 31,015 |
| Net Revenue Gain Above Control, CFA/ha | - | 10,700 | 5,283 | 7,883 |

Source: Nagy et al., 1986.

[1]Control = traditional flat animal traction cultivation; TR-Manual - tying of animal traction made ridges manually at second weeding; MRT-1 = tying the ridges with the MRT at second weeding; MRT-2 = tying the ridges with the MRT at both first and second weeding. All treatments received 100 kg/ha of 14-23-15 applied at first weeding in a band 10-15 cm from crop rows and 50 kg/ha urea applied similarly at second weeding.

[2]The three tied ridging treatments are significantly different from the Control.

[3]Post harvest sorghum farm price of 50 CFA/kg x yield. 1 US $ = 426 CFA (1985).

[4]Gross revenue minus fertilizer cost (90 CFA/kg for 14-23-15 and 78 CFA/kg for urea including 6 months interest charge of 15%) and minus yearly MRT cost 1,467 CFA/ha for treatments MRT-1 and MRT-2 (15,000 CFA total cost annualized over 5 years at 15% interest rate assuming the MRT is used on 3 ha/year).

Table 3. Effect of Tied Ridging Technologies with Donkey Traction on Area Cultivated, Production and Net Farm Income Estimates, Central Plateau.

| Variable | Traditional Management (donkey) | Tied-Ridging Technology a/ | | |
|---|---|---|---|---|
| | | Tied by Hand | Tied With Machine | |
| | | | Two Passes | One Pass |
| Total Area Cultivated (ha) | 5.5 | 5.6 | 5.7 | 5.6 |
| Maize | | | | |
| Traditional | .20 | | | |
| With Tied Ridges | | .20 | .15 | .15 |
| Red Sorghum | | | | |
| Traditional | .60 | | | |
| With Tied Ridges | | .60 | .68 | .60 |
| White Sorghum | | | | |
| Traditional | .80 | .70 | | |
| With Tied Ridges | | .10 | .80 | .95 |
| Millet | | | | |
| Traditional | 3.18 | 3.15 | 3.18 | 1.88 |
| With Tied Ridges | | | .05 | 1.27 |
| Peanuts | .76 | .86 | .79 | .71 |
| Fertilizer (kgs/farm) | | | | |
| Urea | | 45 | 84 | 149 |
| 14-23-15 Fertilizer | | 90 | 168 | 298 |
| Total Cereals Production (kgs) | | | | |
| Per Household | 2103 | 2604 | 2970 | 3354 |
| Per Resident b/ | 150 | 186 | 212 | 240 |
| Net Farm Income (000FCFA) c/ | | | | |
| Per Household | 215.3 | 253.2 | 273.2 | 296.4 |
| Per Worker d/ | 30.8 | 36.2 | 39.0 | 42.3 |

Source: Nagy et al., 1985.

a/ Based on 50 kg/ha urea and 100 kg/ha 14-23-15 fertilizer, labor times of 75 hrs/ha for Tying the Ridges by Hand, 20 hrs/ha for Machine--Two Passes, and 2 hrs/ha for Machine--One Pass. Yield estimates are given in text.

b/ Based on 14 residents/household.

c/ Annualized cost of 4,400 FCFA for Tied-Ridging Machine subtracted in columns 3 and 4. 1 US $ = 426 FCFA ( 1985 est.).

d/ Based on 7 active workers/household.

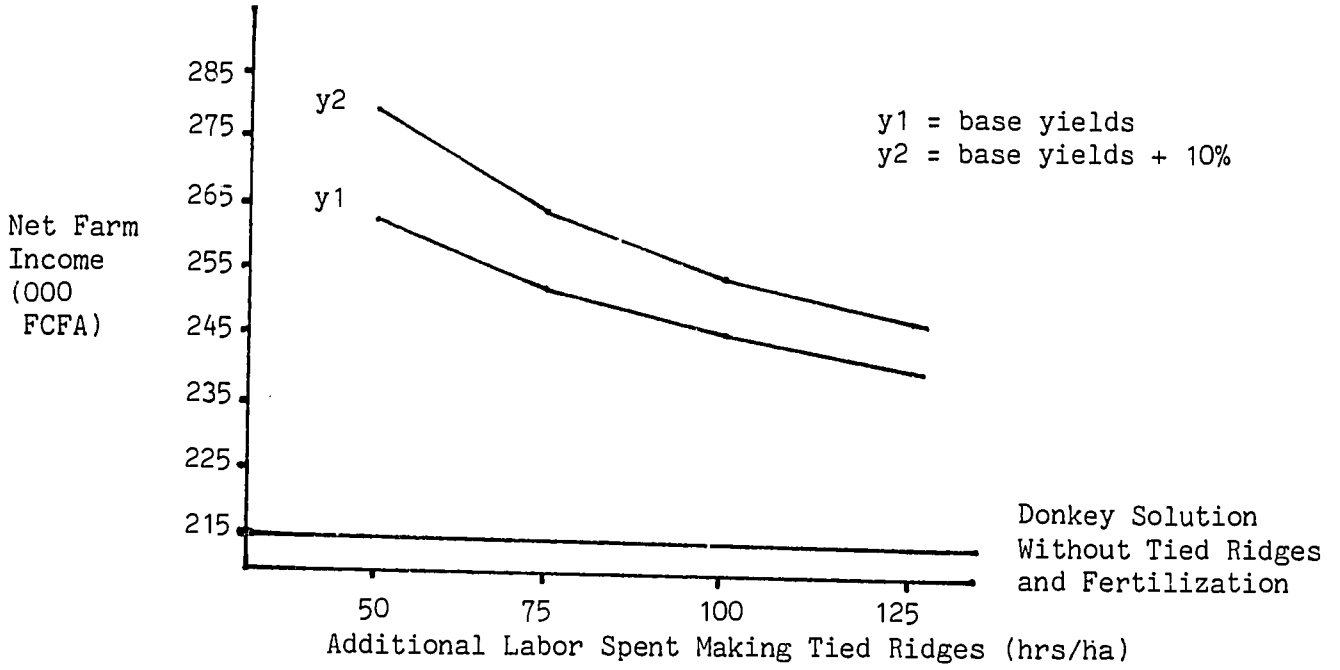


Figure 1. Effect of various yields and labor spent on tied ridging by hand on net revenue of the farm on the Central Plateau.

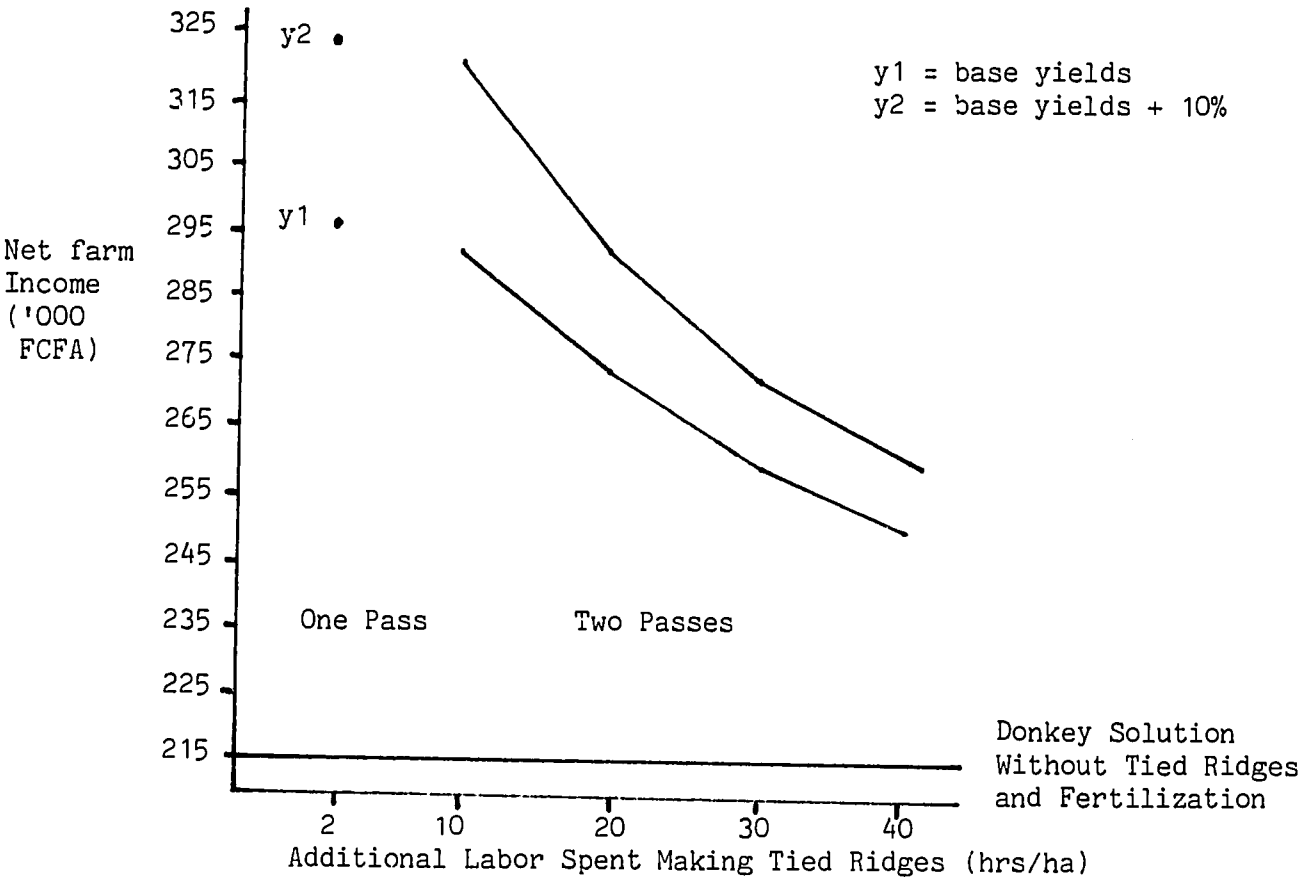


Figure 2. Effect of various yields and labor spent on tied ridging with machine on net revenue of the farm on the Central Plateau.

## REFERENCES


FSU/SAFGRAD. 1983. FSU/SAFGRAD 1982 Annual Report. International Programs in Agriculture, Purdue University, West Lafayette, Indiana.

Jaeger, W.K. and J.H. Sanders. 1985. Profitability of animal traction: field study in Burkina Faso. In Proceedings; Appropriate technologies for farmers in semi-arid West Africa. H.W. Ohm and J.G. Nagy (eds). International Programs in Agriculture, Purdue University, West Lafayette, Indiana.

Kowal, J.M. and A.H. Kassam. 1978. Agricultural ecology of savanna: a study of West Africa. Oxford University Press, Oxford, England.

Lang, Mahlon G., Ronald P. Cantrell, and John Sanders. 1983. Identifying farm level constraints and evaluating new technology in Upper Volta. Staff Paper, Department of Agricultural Economics, Purdue University, West Lafayette, Indiana.

Lang, Mahlon G., Ronald P. Cantrell, Herbert W. Ohm and Sibiri Sawadogo. 1984. FSU/SAFGRAD 1983 Annual Report. International Programs in Agriculture, Purdue University, West Lafayette, Indiana.

Nagy, J.G., H.W. Ohm, L.L. Ames and L.D. Schaber. 1986. Analysis of the IITA/SAFGRAD mechanical ridge tier. International Programs in Agriculture, Purdue University, West Lafayette, Indiana.

Nagy, J.G., L.L. Ames and H.W. Ohm, 1985. Technology evaluation, policy change and farmer adoption in Burkina Faso. International Programs in Agriculture, Purdue University, West Lafayette, Indiana.

Ohm, Herbert W., Joseph G. Nagy and Christopher R. Pardy. 1985a. FSU/SAFGRAD 1984 Annual Report. International Programs in Agriculture, Purdue University, West Lafayette, Indiana.

Ohm, Herbert W., Joseph G. Nagy and Sibiri Sawadogo. 1985b. Complimentary effects of tied ridging and fertilization with cultivation by manual and donkey and ox traction. In Proceedings; Appropriate technologies for farmers in semi-arid West Africa. H.W. Ohm and J.G. Nagy (eds). International Programs in Agriculture, Purdue University, West Lafayette, Indiana.

Roth, Michael , Phil Abbot, Lance McKenzie, Joseph G. Nagy and J. H. Sanders. 1984. New technology evaluations for farms on the Central Mossi Plateau of Upper Volta. Department of Agricultural Economics, Purdue University, West Lafayette, Indiana. Mimeo.

Roth, Michael and John H. Sanders. 1984. An economic evaluation of selected agricultural technologies with implications for development strategies in Burkina Faso. International Programs in Agriculture, Purdue University, West Lafayette, Indiana.

Sanders, J.H. and M. Roth. 1985. The development and evaluation of new systems of agricultural production: some field model results from Burkina Faso for tied ridges and fertilization. In Proceedings; Appropriate technologies for farmers in semi-arid West Africa. H.W. Ohm and J.G. Nagy (eds). International Programs in Agriculture, Purdue University, West Lafayette, Indiana.