PN-ABL-538
77785

République du Niger
Ministère de l'Agriculture
Institut National de Recherches Agronomiques du Niger
Département de Recherches en Economie Rurale
Département de Recherches Agricoles

Niger Cereals Research Project
(USAID Contract No. 683-0225-82-01)

Purdue University
International Programs in Agriculture
Department of Agricultural Economics

Alabama A&M University
Department of Agronomy

Labor Management Effects on the Relative Profitability of Alternative Millet-Cowpea Intercrop Systems in Niger

by

Krause, M.A., X. Maliki, K.C. Reddy, R.R. Deuson, and M. Issa

Paper presented at the 1987 Farming Systems Research Symposium, October 18-21, 1987, in Fayetteville, Arkansas, sponsored by the University of Arkansas in collaboration with Winrock International Institute for Agricultural Development.

TABLE OF CONTENTS

ABSTRACT ii

ACKNOWLEDGMENTS iii

THE AUTHORS iii

INTRODUCTION 1
- ON-FARM TRIALS: 1985-86 2
- LINEAR PROGRAMMING 3

METHODOLOGY 5
- MODELING THE PRODUCTION PROCESS 5
- YIELD ADJUSTMENT COEFFICIENTS 6
- OBJECTIVE FUNCTION AND CONSTRAINTS 7

RESULTS AND DISCUSSION 9
- TIMING OF OPERATIONS 9
- SHADOW PRICE OF LABOR 9
- LABOR AVAILABILITY AND TREATMENT CHOICE 10
- REPLANTING REQUIREMENTS 12
- INTEREST RATES 14
- PRODUCTION RISKS 17
- RECOMMENDATION 19

CONCLUSIONS 20

REFERENCES 22

APPENDIX TABLES 23

END OF TABLE

ABSTRACT

The Institut National de Recherches Agronomiques du Niger (INRAN) installed a set of on-farm trials in 1985 and 1986 to evaluate the potential for adoption of alternative millet-cowpea intercrop systems by Nigerien farmers. Treatments included: (1) traditional practices and millet varieties with an improved cowpea variety; (2) traditional practices with improved millet and cowpea varieties; (3) the improved varieties with increased plant densities; and (4) the improved varieties with increased plant densities and applications of fertilizer. Results from the 1985 and 1986 on-farm trials show a significant agronomic response and high economic potential for the fourth treatment. Budget analyses also indicate that the cost of labor has a critical effect on the relative profitability of the crop systems with high plant densities. However, participating farmers rarely hired labor and had few opportunities to earn non-farm income, so budget analyses which include labor costs based on wage rates may not be appropriate. Therefore, a linear programming model of the four millet-cowpea intercrop systems on a representative farm was used to analyze the effect of labor requirements and labor availability on the relative profitability of the alternative systems. The model incorporates regression results on the relationship of crop yields to crop operation dates.

Results of the linear programming analyses indicate that increased labor requirements and delays in completing crop operations tend to limit the proportion of fields planted to the fourth, most intensive treatment. Farmers can increase profits by hiring labor in some periods and planting more of the fourth treatment. High capital costs also influence the choice of crop technology by reducing the initial profit margin for the fourth treatment, and by reducing the profitability of hiring labor.

ACKNOWLEDGMENTS

The authors express their deep appreciation to Roger Sharp, a Peace Corps statistician at INRAN, for his programming assistance, Dr. John Sanders at Purdue University for providing the LINDO linear programming software and many ideas for the analysis, and Barry Shapiro, research associate at INRAN, for his many helpful suggestions. The authors also thank the many people at INRAN who collected and helped to check and summarize the data.

THE AUTHORS

Mark Krause is an agricultural economist on the staff at Purdue University and currently with the Niger Cereals Research Project in Maradi, Niger.

Maliki Kadi and Issa Mahamane are agricultural economists in the Department of Rural Economic Research (DECOR) at the National Institute of Agronomic Research of Niger (INRAN).

Chandra Reddy is an agronomist on the staff of Alabama A&M University and currently with the Niger Cereals Research Project.

Robert Deuson is an agricultural economist on the staff at Purdue University and, until February 1987, he was the Senior Economist on the Niger Cereals Research Project, in Niamey, Niger.

INTRODUCTION

Increasing food production is an essential goal of the government of Niger, a West African country located the the north of Benin and Nigeria. Only about 24% of Niger receives enough rainfall to grow crops, and only half of this is considered cultivatable (Club du Sahel, 1982). Most of the cultivatable area lies in the Sudano-Sahelian zone which has an average rainfall of 350 to 700 mm and frequent droughts. Most of the soils in the cultivatable zone consist of at least 90% sand, and less than 0.3% organic matter, so they have minimal water and plant nutrient holding capacity. Soil nutrient levels are low and declining.

In 1984, agronomists and agricultural economists at the Institut National de Recherches Agronomiques du Niger (INRAN) initiated an intercrop production systems research program (Reddy and Gonda, 1985, Reddy and Oumara, 1985, and Ly et al., 1986). A 1982 survey of 348 farms in the Madarounfa arrondissement[1] (one of the three regions chosen by INRAN for farming systems research) showed that 79% of the fields were intercropped (Swinton et al., 1984). The primary crop associations included millet and cowpea sometimes combined with sorghum and peanuts. By these observations, agronomists at INRAN conducted on-station research trials to evaluate alternative plant varieties, plant spacings, and fertilizer application rates for intercropped millet and cowpea.

---

1 Each of the main subdivisions of a department in the Nigerien administration.

ON-FARM TRIALS: 1985-86

In 1985, the most promising of the plant varieties, plant spacings, and fertilizer application rates were included in an on-farm trial in which the first treatment represents traditional practices and other treatments each introduce a new technology (Appendix Table A-1). The second treatment introduces an improved millet variety. The third treatment includes the improved variety and introduces increased plant densities. The fourth treatment includes the improved variety and increased plant densities, and introduces fertilizer applications.

The agronomic results from 1985 and 1986 (Table 1) indicated a significant response by millet and cowpea to the application of fertilizer (included in the fourth treatment) and a significant response by cowpea to increased density (introduced in the third treatment).

Table 1. Average yields per hectare for millet grain, cowpea grain, and cowpea hay, by treatment and by village, 1985 and 1986 on-farm trials

Item	Yield by treatment (kg/ha)			
	T1	T2	T3	T4
	local Mil INRAN cowpea local spacing/density ← "	INRAN Mil → " cp. → "	spacing: 2 x 2 rows density: 9Km / 18Kcp →	→ → → →
1985 on-farm trials:				
Maiguéro:				50 kg P 25 kg Urea @ tillering " " " heading
Millet grain	284 b	358 b	309 b	590 a
Cowpea hay	778 c	787 c	1069 b	1387 a
1986 on-farm trials:				
Maiguéro:				
Millet grain	279 bc	310 b	238 c	627 a
Cowpea grain	67 c	84 c	150 b	245 a
Rigial Oubandawaki:				
Millet grain	200 b	184 b	162 b	325 a
Cowpea grain	113 c	140 bc	196 b	348 a

NOTE: Yields with different letters are significantly different at the 5% confidence level, based on the Duncans multiple range test.

Budget analyses of the 1985 and 1986 data (Tables 2-3) indicate substantial increases in returns to labor and management (measured by gross revenues minus cash costs) for the increased density (treatment 3) and fertilizer applications (treatment 4). However, labor requirements were also much higher for treatments 3 and 4 than for treatments 1 and 2 (Appendix Table A-4). As a result, net cash revenue per day worked and returns to management (measured by gross revenues minus cash costs and the opportunity cost of labor) were often lower for treatments 3 and 4 than for treatments 1 and 2. Based on the prevailing daily wage rate, the opportunity cost of labor considerably outweighed cash costs in the calculation of returns to management. Yet participating farmers rarely hired labor, and surveys in 1984 and 1985 indicated few opportunities to earn off-farm income (Swinton, 1985 and unpublished data). This uncertainty regarding the value of labor has made it difficult to draw clear conclusions from the budget analyses.

LINEAR PROGRAMMING

The present analysis uses linear programming to evaluate the effects of labor availability and allocation on the choice of crop technology. Linear programming is used to select a set of intercropped millet-cowpea production activities which maximizes total net cash revenue subject to land, labor-time, and consumption constraints. It is hypothesized here that labor constraints during critical periods of the crop season and the allocation of scarce labor will largely determine the choice of crop technology. It also is hypothesized that an analysis of the effects of labor allocation on the choice of technology will provide appropriate indications of labor value in crop production.

Table 2. Budget analysis of millet-cowpea intercrop treatments, based on prices at harvest, Maiguéro on-farm trials, 1986

Item	Treatment (FCFA/ha)			
	T1	T2	T3	T4
Gross revenue	13,610	16,007	19,119	38,374
Variable input costs:				
Cash input costs	624	1,000	2,080	10,330
Opportunity cost of labor	16,908	16,320	22,344	30,036
Total	17,532	17,320	24,424	40,366
Returns to:				
Labor and management[a]	12,986	15,007	17,039	28,044
Labor, per day of work[b]	461	552	458	560
Management[c]	-3,922	-1,313	-5,305	-1,992

(a) Gross revenue minus cash input costs.
(b) Measured in francs CFA per man-day equivalent.
(c) Gross revenue minus total variable input costs.

Table 3. Budget analysis of millet-cowpea intercrop treatments, based on prices at harvest, Rigial Oubandawaki on-farm trials, 1986

Item	Treatment (FCFA/ha)			
	T1	T2	T3	T4
Gross revenue	14,836	16,688	20,562	37,626
Variable input costs:				
Cash input costs	624	1,000	2,080	10,330
Opportunity cost of labor	17,322	18,072	23,988	31,392
Total	17,946	19,072	26,068	41,722
Returns to:				
Labor and management[a]	14,212	15,688	18,482	27,296
Labor, per day of work[b]	492	521	462	522
Management[c]	-3,110	-2,384	-5,506	-4,096

(a) Gross revenue minus cash input costs.
(b) Measured in francs CFA per man-day equivalent.
(c) Gross revenue minus total variable input costs.

METHODOLOGY

The linear programming model used in this analysis is based on 1984 farm survey data and 1986 on-farm trial data from three villages in the arrondissement of Madarounfa, situated in south-central Niger. Maiguéro and Rigial Oubandawaki are both predominantly Hausa villages with sandy soils. However, Maiguéro lies in a river valley where some irrigated crop production is possible, so it is more densely settled than Rigial Oubandawaki.

The linear programming model used here is not a whole-farm model. Only millet and cowpea production are represented, whereas sorghum and peanuts are also important crops, and most farmers cultivate other minor crops. However, INRAN does not yet have sufficient data relating to labor requirements and effects of operation dates for these other crops to accurately represent them. Household, non-farm activities, and livestock management are not represented, except to the extent that they reduce labor-time availability for fieldwork. The effects of labor availability on the choice of crop production technology are evaluated by using various assumptions for family labor availability and by allowing labor to be hired.

MODELING THE PRODUCTION PROCESS

The model of intercropped millet and cowpea production represents the critical first two months of the crop season with a series of 8 high-moisture periods (H1-H8) alternating with 7 low-moisture periods (S1-S7). The high-moisture periods are two days long, immediately following a rain sufficient for planting (usually 10 mm or more). Although the periods between planting rains are highly variable, in 1985 and 1986 the planting rains in the three Madarounfa villages were an average of about 7 days apart. Therefore, the initial model assumes that the 7 low-moisture periods are each 5 days long.

Planting is permitted only in the high-moisture periods following a planting rain. Millet may be planted in the first two such periods (H1 and H2). Cowpea may be planted in the third through the fifth high-moisture periods (H3, H4, and H5). Following the on-farm trial protocol, cowpea planting must follow millet planting by at least two weeks to give the millet sufficient time to establish itself without competition from the cowpea. It is assumed in the initial model that 10% of the planted area must be replanted in the next high-moisture period. More substantial replanting requirements are always a possibility in Niger, due to high soil temperatures, frequent delays before the next rain, sandstorms, and occasional rodent problems. Therefore, the effects of assuming 20% and 33% replanting requirements are also examined.

Weeding may be done either in a high or low-moisture period. The first weeding is permitted in the third through the sixth high-moisture periods (H3, H4, H5, and H6) and in the succeeding low-moisture periods (S3, S4, S5, and S6). The second weeding is assumed to follow four weeks behind the first weeding. The two urea applications are made in the high-moisture period immediately following each weeding.

YIELD ADJUSTMENT COEFFICIENTS

A multiple linear regression analysis of 1986 data showed a tendency for millet and cowpea yields to decline as planting and first weeding dates were delayed at Maiguéro and Rigial Oubandawaki (Appendix Tables A-3 and A-4). Regression coefficients for the effect of millet planting date on millet yield were significant at a 5% level of confidence for each treatment. Regression coefficients for the effects of the number of days before first weeding on millet yields, cowpea planting date on cowpea yields, and days before first weeding on cowpea yields were not statistically significant, but are supported

by on-station trial results. However, no relationship was found between cowpea planting date and cowpea yield for the third treatment.

Based on the regression results for the effect of planting and first weeding dates on millet and cowpea yields, yield adjustment coefficients were calculated for each possible combination of planting and first weeding periods. Twenty-eight alternative production activities are included in the model for each treatment. Separate versions of the model were created for Maiguéro and Rigial Oubandawaki based on the average treatment yields in 1986 for each village. Since the Kandamao crop yield data did not show the same relationships to operation dates as the data for the other two villages and were not sufficient for a separate analysis, no version of the model was created for Kandamao.

OBJECTIVE FUNCTION AND CONSTRAINTS

Other activities included in the model are millet sales, cowpea sales, millet consumption, cowpea consumption, and millet purchases for consumption (in case the millet consumption constraint cannot be met from on-farm production). Millet is sold for 30 francs CFA per kg and cowpea are sold for 80 francs CFA per kg, which were the respective harvest-time prices at a nearby village market (Gabi). Millet may be purchased for 30 francs in the model. Millet and cowpea consumption are not given a value. The consumption requirements of 220 kg of millet and 30 kg of cowpea per person (Arnold, 1986; Stoop, 1981) only reduce crop sales.

The net cash revenue function includes the prices for millet and cowpea sales and millet purchase for consumption, plus the costs for each production activity. The improved seed and fertilizer are valued at their official Nigerien Ministry of Agriculture prices for 1986. Extensions of the model include a capital cost for improved seed and fertilizer purchases, since money

must either be borrowed or diverted from other potential uses to purchase them. Following the recommendation of Perrin et al. (1976), results using a 40% and a 100% annual interest rate are compared to the initial model results. It is assumed that money is borrowed or diverted for six months, so the effective costs of capital are 20% and 50%.

Land and family labor constraints for the Maiguéro and Rigial Oubandawaki model versions are based on a survey of 25 farms in each village conducted by INRAN in 1984 (Swinton, 1985). The average farm size for Maiguéro is 4 ha and the average farm size for Rigial Oubandawaki is 6.5 ha. Maiguéro has an average of 1.3 adult men, 1.5 adult women, 0.4 adolescents (10-13 years) and 2.1 children (0-9 years) per farm. Rigial Oubandawaki has an average of 2.4 adult men, 2.6 adult women, 0.7 adolescents (10-13 years) and 3.7 children (0-9 years). The total number of men, women and adolescents determines labor availability during the high-moisture periods. Labor availability in other periods is determined by adding the number of men to 60% of the number of women and 50% of the number of adolescents (the same coefficients were used to calculate labor requirements by operation). The initial model assumes that farmers are willing to do 6 days of fieldwork per week. Extensions of the model examine the effect of 5 and 7 days of fieldwork per week.

Labor hiring is considered in extensions of the model. Since hired labor is rarely available during the initial planting periods, labor hiring is considered first for all periods, then only for periods following the third moisture period (H3). A 20% or 50% capital cost is included in all of the analyses which consider hiring labor.

The sensitivity of the choice of crop technology to risk perceptions is analyzed by substituting the average crop yields for the individual plots with the lowest 25% of gross revenues per hectare. The effects of assuming these

reduced yields are evaluated for the case of 6 days of fieldwork per week, once without an interest charge, and again with a 50% interest charge.

RESULTS AND DISCUSSION

TIMING OF OPERATIONS

The linear programming analysis shows that yield penalties for delays in completing planting and first weeding operations reduce the optimal land area for the highest yielding, but most labor intensive technology (treatment 4). In the initial model which assumes 6 days per week for fieldwork and no interest charge, 63% of the fields at Maiguéro are planted to the fourth treatment, and 37% are planted to the second treatment (Table 4). At Rigial Oubandawaki, 57% of the fields are planted to the fourth treatment, 32% are planted to the third treatment, and 11% are planted to the second treatment. Most of the labor available in the early periods of the crop season is allocated to the fourth treatment (Table 5), but by the time of the fifth rain (H5) the model shifts most labor to less intensive treatments. These allocations of available labor determine the relative proportions of land planted to each treatment.

SHADOW PRICE OF LABOR

The results for the initial model also demonstrate that labor is a valuable commodity during planting and first weeding periods (Table 6). The implicit value (shadow price) of an additional man-day of labor is greater than the 600-franc daily wage rate for every planting and first weeding period at Maiguéro except the second millet planting period (H2). The implicit value

Table 4. Proportion of total farm area planted to each treatment and resulting net cash revenue, assuming 5, 6, and 7 days of field work and no interest charge, by village, on-farm trials, 1986

Village and Days of Fieldwork	Proportion of Total Farm Area (%)			Net Cash Revenue (FCFA)
	T2	T3	T4	
Maiguéro:				
5 days	69.9	---	30.1	13,910
6 days[a]	36.9	---	63.1	24,400
7 days	3.0	---	97.0	33,376
Rigial Oubandawaki:				
5 days	52.8	11.7	35.6	23,395
6 days[a]	10.8	32.2	57.0	38,740
7 days	---	22.1	77.9	47,506

(a) Initial model assumptions.

of an additional man-day of labor at Rigial Oubandawaki is greater than the daily wage rate for periods H3-H5 and S1-S3. At both villages the implicit value of another man-day of labor during the first period permitted for planting cowpea and weeding (H3) is more than double the prevailing daily wage rate.

LABOR AVAILABILITY AND TREATMENT CHOICE

The number of days per week assumed available for fieldwork has a strong influence on the choice of treatments by the model. This assumption is doubly important because economic theory suggests that the availability of labor will increase if the remuneration to labor increases, whereas some anthropologists argue that in primarily subsistence agricultural societies the amount of time worked does not follow standard economic theory (Sahlins, 1972, Arnould, 1986). Thus, economists might argue that if the most labor-intensive technology (treatment 4) is sufficiently profitable, farmers will work up to seven days a week in order to use it. The anthropological argument is that

Table 5. Allocation of labor time among treatments and crop operations, by time period and by village, assuming 6 days of field labor per week and no interest charge, on-farm trials, 1986

Village and Time Period	man-day	operation and treatment	man-day	operation and treatment	man-day	operation and treatment
Maiguero:						
H1 (humid)	4.74	Plant T4 Millet	1.74	Plant T2 Millet		
H2 (humid)	1.34	Plant T4 Millet	0.47	Replant T4 Millet	0.17	Replant T2 Millet
H3 (humid)	5.38	Plant T4 Cowpea	0.97	Plant T2 Cowpea	0.13	Replant T4 Millet
S3 (dry)	9.71	Weed T4				
H4 (humid)	3.56	Plant T4 Cowpea	1.49	Apply T4 Urea	0.58	Plant T2 Cowpea
	0.54	Replant T4 Cowpea	0.22	Weed T4	0.10	Replant T2 Cowpea
S4 (dry)	9.71	Weed T4				
H5 (humid)	4.55	Weed T4	1.52	Apply T4 Urea	0.36	Replant T4 Cowpea
	0.06	Replant T2 Cowpea				
S5 (dry)	9.64	Weed T2	0.07	Weed T4		
H6 (humid)	5.77	Weed T2	0.71	Apply T4 Urea		
S6 (dry)	9.71	Weed T4				
Rigial Oubandawaki:						
H1 (humid)	8.93	Plant T4 Millet	1.60	Plant T3 Millet	0.83	Plant T2 Millet
H2 (humid)	3.34	Plant T3 Millet	0.89	Replant T4 Millet	0.16	Replant T3 Millet
	0.08	Replant T2 Millet				
H3 (humid)	10.29	Plant T4 Cowpea	0.74	Plant T2 Cowpea	0.33	Replant T3 Millet
S3 (dry)	17.12	Weed T4				
H4 (humid)	2.83	Plant T4 Cowpea	2.62	Apply T4 Urea	2.60	Weed T4
	2.21	Plant T3 Cowpea	1.03	Replant T4 Cowpea	0.07	Replant T2 Cowpea
S4 (dry)	17.12	Weed T4				
H5 (humid)	4.59	Plant T3 Cowpea	3.24	Weed T4	3.02	Apply T4 Urea
	0.28	Replant T4 Cowpea	0.22	Replant T3 Cowpea		
S5 (dry)	9.79	Weed T4	7.34	Weed T2		
H6 (humid)	8.91	Weed T3	1.99	Apply T4 Urea	0.47	Weed T3
S6 (dry)	17.12	Weed T3				

economic objectives in subsistence agricultural societies are defined primarily by a person's social relationships and obligations within the village. As a result, few farmers have sufficient incentives to work even 5 full days per week. In either case, farmers are observed to frequently take time away from fieldwork to go to market, go to the mosque, prepare food, talk to friends, look after children, and rest at home.

A reduction in labor availability from 6 to 5 days per week greatly reduces the proportion of fields the model plants with the fourth treatment (Table 4). At Maiguéro this reduction in labor availability reduces the proportion of fields planted to the fourth treatment from 63% to 30%. At Rigial Oubandawaki the reduction in labor availability reduces the proportion of fields planted to the fourth treatment from 57% to 36%. On the other hand, an increase in labor availability from 6 to 7 days per week raises the proportion of fields planted to the fourth treatment to 97% at Maiguéro and 78% at Rigial Oubandawaki (Table 4).

REPLANTING REQUIREMENTS

Greater replanting requirements significantly reduce the proportion of fields the model plants with the third treatment (high density without fertilizer) at Rigial Oubandawaki and the proportion of fields the model plants with the fourth treatment at Maiguéro (Table 7). Increasing the replanting requirements from 10% to 33% at Rigial Oubandawaki reduces the proportion of fields planted to the third treatment from 32% to 14% and increases the proportion planted to the second treatment from 11% to 26%. At Maiguéro, the proportion of fields planted to the fourth treatment falls from 63% to 55% as replanting requirements are increased from 10% to 33%.

Table 6. Implicit labor values (shadow prices) by period and by village, for 5, 6, and 7 days of fieldwork per week and no interest charge, on-farm trials, 1986

Village and Time Period	Implicit labor values (FCFA/day) for --		
	5 days	6 days	7 days
Maiguéro:			
H1 (humid)	0	824	875
H2 (humid)	0	0	0
H3 (humid)	1823	1645	1665
S3 (dry)	1509	1240	1162
H4 (humid)	1495	1238	1212
S4 (dry)	1384	1099	1026
H5 (humid)	1276	942	883
S5 (dry)	1195	847	754
H6 (humid)	1102	757	693
S6 (dry)	1006	721	661
Rigial Oubandawaki:			
H1 (humid)	212	158	503
H2 (humid)	0	0	0
H3 (humid)	1937	1760	1344
S3 (dry)	1270	1145	638
H4 (humid)	1290	1174	686
S4 (dry)	1124	1108	499
H5 (humid)	998	827	351
S5 (dry)	910	675	199
H6 (humid)	802	569	0
S6 (dry)	712	548	0

Table 7. Proportion of total farm area planted to each treatment, by village, and resulting net cash revenue, assuming 6 days of field work, 3 replanting rates, and no interest charge, on-farm trials, 1986

Village and Days of Fieldwork	Proportion of Total Area (%)			Net Cash Revenue (FCFA)
	T2	T3	T4	
Maiguéro:				
10% replanting[a]	36.9	---	63.1	24,400
20% replanting	40.5	---	59.5	23,049
33% replanting	44.7	---	55.3	21,435
Rigial Oubandawaki:				
10% replanting[a]	10.8	32.2	57.0	38,740
20% replanting	20.6	17.0	62.4	36,362
33% replanting	26.2	14.1	59.7	33,538

(a) Initial model assumptions.

INTEREST RATES

Interest rates seem to have little effect on the choice of technology when labor availability is a serious constraint, but a 50% effective interest rate has a great effect on the choice of technology in cases where labor availability is less of a constraint. A 20% effective interest rate has very little effect on the choice of crop production technology (Table 8). Increasing the effective interest rate from 20% to 50% when 5 days per week are available for fieldwork has no effect on the allocation of fields at Maiguéro and a negligable effect at Rigial Oubandawaki (Table 9). However, when 6 days per week are available for fieldwork, the addition of a 50% effective interest rate reduces the proportion of fields planted to the fourth treatment from 63% to 47% at Maiguéro and from 57% to 47% at Rigial Oubandawaki. Similarly, when 7 days per week are available for fieldwork, the addition of a 50% effective interest rate reduces the proportion of fields planted to the fourth treatment from 97% to 69% at Maiguéro and from 78% to 53% at Rigial Oubandawaki.

Table 8. Proportion of total farm area planted to each treatment, by village, and resulting net cash revenue, assuming 5, 6, and 7 days of field work and a 20% interest charge, on-farm trials, 1986

Village and Days of Fieldwork	Percentage of Total Farm Area (%)			Net Cash Revenue (FCFA)
	T2	T3	T4	
Maiguéro:				
5 days	72.3	---	27.7	10,940
6 days	37.5	---	62.5	18,889
7 days	3.9	---	96.1	25,362
Rigial Oubandawaki:				
5 days	51.6	14.4	34.0	17,748
6 days	10.8	32.2	57.0	30,074
7 days	---	23.5	76.5	36,742

Table 9. Proportion of total farm area planted to each treatment, by village, and resulting net cash revenue, assuming 5, 6, and 7 days of field work and a 50% interest charge, on-farm trials, 1986

Village and Days of Fieldwork	Percentage of Total Farm Area (%)			Net Cash Revenue (FCFA)
	T2	T3	T4	
Maiguéro:				
5 days	72.3	---	27.7	6,640
6 days	33.2	19.5	47.3	11,314
7 days	---	31.3	68.7	14,770
Rigial Oubandawaki:				
5 days	51.0	15.9	33.2	9,373
6 days	3.1	50.1	46.8	18,419
7 days	---	47.5	52.5	22,300

Use of hired labor can greatly increase the proportion of fields on which the fourth treatment can be planted and weeded in a timely manner. At Maiguéro, assuming a 20% interest rate, use of hired labor in the optimal planting and first weeding periods causes all fields to be planted to the fourth treatment (Table 10). At Rigial Oubandawaki, assuming a 20% interest rate, use of hired labor during periods H3 and H4 increases the proportion of fields planted to the fourth treatment from 57% to 72%. A total of 13.9 man-days of labor are hired at Maiguéro and 9.5 man-days are hired at Rigial Oubandawaki. They are used primarily for planting and replanting.

However, limited availability or a high interest rate may greatly reduce the amount of labor which can profitably be hired. It is rarely possible in the Madarounfa villages to hire labor in the first planting periods of the crop season because nearly all of the adults are planting their own individual or collective fields. Elimination of the possibility of hiring labor in periods H1-H3 reduces the amount of labor hired to 11.1 man-days at Maiguéro and 5.8 man-days at Rigial Oubandawaki (Table 10). However, as long as the

interest rate remains at 20%, the proportion of fields planted to the fourth treatment is little affected by the elimination of hired labor during periods H1-H3. A 50% effective interest rate limits hired labor to 2.5 man-days at Maiguéro and eliminates the use of hired labor at Rigial Oubandawaki (Table 10). Only in the first planting period for cowpea (H3) is it profitable at Maiguéro to hire labor when the interest rate is 50%. Therefore, if hired labor were unavailable in this period, none would be hired in any period.

Table 10. Proportion of total farm area planted to each treatment, by village, and resulting net cash revenue, assuming labor is hired and 3 interest rates are applied, on-farm trials, 1986

Village and Days of Fieldwork	Labor Hired by period (man-day)	Percentage of Total Farm Area (%)			Net Cash Revenue (FCFA)
		T2	T3	T4	
Maiguéro:					
20% cost of capital, Hiring in all periods	3.16 in H1 10.75 in H3	---	---	100.0	24,534
20% cost of capital, Hiring after H3	5.70 in S3 5.35 in H4	---	---	100.0	21,471
50% cost of capital, Hiring in all periods[a]	2.54 in H3	25.0	20.0	55.0	11,718
Rigial Oubandawaki:					
20% cost of capital, Hiring in all periods	6.33 in H3 3.14 in H4	---	27.5	71.9	34,116
20% cost of capital, Hiring after H3	5.83 in H4	---	31.0	69.0	31,278
50% cost of capital, Hiring in all periods[b]	none	3.1	50.1	46.8	18,419

(a) If hired labor is only available after H3, none is hired.
(b) No labor is hired in this case.

It is important to note that the interest rate appears to influence the choice of crop technology: (1) by reducing the profitability of planting and weeding the fourth treatment in periods which have substantial yield

penalties, and (2) by reducing the profitability of hiring labor to overcome labor availability constraints. A review of the budgets presented in Tables 2-3 reveals that the fourth treatment would continue to offer the highest returns to labor and management in each village if a 50% interest rate were added. The model results reflect this by consistently allocating most available family labor to the fourth treatment in the earliest planting and weeding periods, regardless of capital cost. However, when yield penalties for late operations and the greater labor-time requirements for the fourth treatment are considered, a 50% interest rate makes it less profitable to plant and weed the fourth treatment in the later periods than to plant and weed other treatments.

PRODUCTION RISKS

A simple analysis of production risk indicates that the choice of crop technology is not very sensitive to risk perceptions at Maiguéro, but is very sensitive to risk perceptions at Rigial Oubandawaki, particularly when a 50% interest rate is assumed. Using the yields which provide the lowest 25% of gross revenues per hectare, and assuming 6 days of fieldwork per week and no interest rate, there is no change in the allocation of fields among treatments at Maguéro, but at Rigial Oubandawaki, the proportion of fields planted to the third treatment falls from 33% to 18% and more land is planted to both the second and fourth treatments (Table 11). Also, the first treatment enters the optimal farm plan at Rigial Oubandawaki for the first time. In the case of a 50% interest rate, the proportion of fields at Maiguéro planted to the third treatment increases from 20% to 32% and proportions planted to the second and fourth treatments decline. But at Rigial Oubandawaki, the combination of low yields and 50% interest rate causes the first treatment of traditional practices and millet varieties to be planted exclusively. In both villages,

basing the choice of crop technology on the lowest yields generally favors the less-intensive technologies.

Table 11. Area planted to each treatment and net cash revenue for yields providing the lowest 25% of gross revenue, assuming 6 days of fieldwork per week and two interest rates, by village, on-farm trials, 1986

Village and Interest Rate	Proportion of Total Farm Area (%)				Net cash revenue (FCFA)
	T1	T2	T3	T4	
Maiguéro:					
no interest charge	---	36.9	---	63.1	-9,215
50% interest rate	---	27.9	32.0	40.1	-20,957
Rigial Oubandawaki:					
no interest charge	4.6	14.9	17.6	62.9	-32,926
50% interest rate	100.0	---	---	---	-37,206

The results of this analysis may help explain much of the reluctance of farmers in the Madarounfa arrondissement of Niger to use chemical fertilizers. Despite having many years of contact with extension agents who have promoted fertilizer use, none of the farmers surveyed in these two villages used any chemical fertilizer in 1984 or 1985, and only a few have since then. As in the model results, most of the farmers the authors have worked with seem to have little trouble planting in a timely manner, but many have trouble completing weeding operations in a timely manner. The treatment including the use of fertilizers in the millet-cowpea intercrop trial requires an application of urea during the optimal periods for first weeding and slightly increases the time required for first weeding. Those farmers who already have trouble completing their weeding in a timely manner may be discouraged by the additional delays expected for the technology represented by the fourth treatment.

Hired labor, which could eliminate labor bottlenecks associated with fertilizer applications, is rarely used by the farmers observed in these villages. As demonstrated in the model results, capital costs may greatly limit the use of hired labor, since credit institutions do not exist near these villages and the effective interest rates for informal loans run as high as 100%.

RECOMMENDATION

The results of this analysis support the adoption of the technology represented by the fourth treatment on a limited scale. Except in one case where the crop yields providing the lowest 25% of gross revenues were evaluated together with a 50% effective interest rate, the fourth treatment is included on at least 27% of available fields in every optimal farm plan. The results consistently indicate that labor during the first periods for planting and first weeding should be allocated to the fourth treatment. If labor can be hired without having to borrow money at high rates of interest, the results indicate that it is profitable to hire labor and use it to plant more of the fourth treatment.

The results certainly support the use in economic budget analyses of an opportunity cost for the labor required for planting, replanting, first weeding, and the first urea application. In fact, the suggestion made by Perrin et al. (1976) to value labor during the busiest periods of the season at 125% of the prevailing wage is supported by the implicit labor values provided by the linear programming analyses. This labor value of 750 francs CFA per day was usually met or exceeded by the implicit labor values for periods H3-H5 and S3-S5, even when 20% and 50% costs of capital were considered. Opportunity costs for other crop operations may be minimal, but

cannot be determined from this analysis because so many other agricultural and non-agricultural activities are not considered.

CONCLUSIONS

A linear programming analysis of intercropped millet and cowpea production in the Madarounfa arrondissement of Niger demonstrates how the availability and management of family labor and hired labor may affect the choice of crop technology. Four treatments from a set of on-farm research trials are evaluated in this analysis. The four treatments range from traditional practices and crop varieties (treatment 1) to a combination of fertilizer applications, high plant densities, and improved varieties (treatment 4). Although economic budget analyses of the on-farm trial results indicate that returns to labor and management per hectare for the fourth treatment are superior to those for the other treatments, the linear programming analysis indicates that labor availability may often limit the area on which farmers adopt the package of new crop technologies.

Limits on the proportion of time family members are willing to do fieldwork, consideration of possibly large replanting requirements, consideration of capital costs, and perceptions of substantial production risks all tend to limit the adaption of the labor-intensive crop technology. Capital costs supplement the effect of limited labor availability on the choice of technology, but do not act independently.

Hired labor can greatly increase the land area on which labor-intensive crop technology can profitably be adopted. Hiring labor is profitable during the optimal planting and first weeding periods, provided that it is available and provided that the interest rate is moderate.

It appears that the additional requirements for urea applications during the optimal periods for cowpea planting and first weeding may discourage Nigerian farmers from using fertilizers. If practices which reduce labor requirements for urea applications, cowpea planting, millet and cowpea replanting, and first weeding can be developed, these would tend to increase the use of fertilizer and increase food production. The possiblity of using phosphate fertilizer, applied before the first rains, without urea fertilizer should be investigated, and has been included in INRAN's 1987 on-farm trials for intercropped millet and cowpea.

It also appears that a lack of low-cost credit in rural areas may be limiting the use of fertilizer. A lower interest rate would not only reduce the cost of fertilizer and seed, but also make it profitable to hire more labor in periods when family labor constraints limit fertilizer use. Development of rural credit institutions in Niger could make fertilizer more available to farmers and more profitable to use.

The package of improved crop varieties, increased plant density, and fertilizer applications developed by INRAN for intercropped millet and cowpea has shown a strong potential in on-farm trials for increasing food production. It also appears to provide attractive economic returns to labor and management. However, labor and institutional constraints in rural Niger may limit the adoption of this technology unless changes in economic conditions reduce the effect of these constraints, or until this technology can be better adapted to them.

REFERENCES

Arnould, E.J. 1986. "Rice or millet: the role of sociocultural factors in the success of irrigated agriculture in Niger". Development Anthropology Network. Vol. 4, No. 1. Binghampton, New York. Institute for Development Anthropology.

Club du Sahel, 1982. "Développement des cultures pluviales au Niger". SAHEL D(82)180. Organisation de Coopération et de Développement Economiques (OCDE), Comité Permanent Inter- Etats de Lutte Contre la Sécheresse dans le Sahel (CILSS).

Ly, S.A., R. Deuson, K. Maliki, G. Numa, K.C. Reddy, and S. Swinton 1986. Evaluation des essais en milieu réel sur les cultures associées mil-niébé: résultats de la campagne de 1985. Document No. 14F. DECOR, Institut National de Recherches Agronomiques du Niger. B.P. 429, Niamey, Niger.

Perrin, R.K., D.L. Winkelmann, E.R. Moscardi, and J.R. Anderson, 1976. From agronomic data to farmer recommendation: An economics training manual. Centro Internacional de Mejoramiento de Maïs y Trigo (CIMMYT) Information Bulletin 27, Apdo. Postal 6-641, Mexico 6.

Reddy, K.C. and J. Gonda, 1985. "Recherche en culture associée au Niger". Liason-Sahel. No. 3, Juin 1985, pp. 109-125.

Reddy, K.C. and A. Oumara, 1985. "Le niébé dans les systèmes des cultures au Niger", paper presented at the Workshop on Legumes at Niamey, 19-22 November 1985. Section Agronomie Générale, Institut National de Recherche Agronomique du Niger. B.P. 429, Niamey, Niger.

Sahlins, M. 1972. Stone Age Economics. Chicago. Aldine. 348 pp.

Stoop, W.A. 1981. "Cereal-based intercropping systems for the West-African semi-arid tropics, particularly Upper Volta". In: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). Proceedings of the International Workshop on Intercropping, 10-13 Jan 1979, ICRISAT, Patancheru, A.P. 502 324, India. pp. 61-68.

Swinton, S.M. 1985. "Les ressources agricoles des exploitations dans trois villages représentatifs de l'Arrondissement de Madarounfa en 1984". Document No. 7. DECOR, Institut National de Recherches Agronomiques du Niger. B.P. 429, Niamey, Niger.

Swinton, S.M., G. Numa, and L.A. Samba, 1984. "Farm-level inter- cropping in two regions of Niger: Filingué and Madarounfa". Paper presented at the Regional Workshop on Intercropping in the Sahelian Zone and Sahelo-Sudanian Zone of West Africa, 7-10 November 1984, Niamey, Niger. DECOR, Institut National de Recherches Agronomiques du Niger. B.P. 429, Niamey, Niger.

World Bank, 1985. World Development Report 1985. New York. Oxford University Press.

APPENDIX TABLES

Table A-1. Treatments for 1986 millet-cowpea intercropped on-farm trials.

Treatment	Variable	Description
1	Local millet varieties	chosen by participating farmers.
	Cowpea variety	TN 5-78 provided by INRAN.
	Plant spacing and density	chosen by participating farmers.
2	Millet variety	CIVT provided by INRAN.
	Cowpea variety	TN 5-78 provided by INRAN.
	Plant spacing and density	chosen by participating farmers.
3	Millet variety	CIVT provided by INRAN.
	Cowpea variety	TN 5-78 provided by INRAN.
	Plant spacing	two rows of cowpeas spaced 75 cm apart between every two rows of millet, spaced 150 cm apart.
	Plant density	About 9000 millet plants and 18000 cowpea plants per ha.
4	Millet variety	CIVT provided by INRAN.
	Cowpea variety	TN 5-78 provided by INRAN.
	Plant spacing	two rows of cowpeas spaced 75 cm apart between every two rows of millet, spaced 150 cm apart.
	Plant density	about 9000 millet plants and 18000 cowpea plants per ha.
	Fertilizer	- 50 kg/ha supersimple phosphate (18% P205) broadcast and incorporated before planting millet. - 25 kg/ha urea (42% N) applied in shallow holes beside pockets of millet at time of tillering. - 25 kg/ha urea applied in same manner at time of heading.

Table A-2. Millet Yield Regression Coefficients, Maiguéro and Rigial Oubandawaki, on-farm trials, 1986

Explanation	Constant	Rigial Dummy	P_2O_5	Planting Date	Days before Weeding[a]
Treatment 1[b]:					
Coefficient	2317.38	-249.04	35.79	-10.92	-7.27
Std. error of coeff.	102.10	42.19	14.01	2.22	3.64
R^2 = .60					
d.f. = 43					
Treatment 2[b]:					
Coefficient	1703.35	-242.34	55.78	-8.06	-4.39
Std. error of coeff.	121.43	55.95	17.23	2.81	4.22
R^2 = .42					
d.f. = 41					
Treatment 3[b]:					
Coefficient	1810.19	-185.77	36.53	-9.03	-3.17
Std. error of coeff.	84.00	39.77	12.03	1.88	2.80
R^2 = .49					
d.f. = 40					
Treatment 4:					
Coefficient	2135.64	-429.68	---	-7.97	-4.47
Std. error of coeff.	142.62	48.23		2.53	3.72
R^2 = .60					
d.f. = 54					

(a) Days before weeding defined as first weeding date minus first millet planting date.
(b) For cases where days before weeding are greater than 23.

Table A-3. Cowpea Yield Regression Coefficients, Maiguéro and Rigial Oubandawaki, on-farm trials, 1986

Explanation	Constant	Rigial Dummy	P_2O_5	T2 Dummy	T5 Dummy	Planting Date	Days before Weeding[a]
Treatments 1 and 2:							
Coefficient	404.06	---	6.76	18.22	---	-1.56	-1.97
Std. error of coeff.	58.67		5.00	10.91		0.75	1.12
R^2 = .19							
d.f. = 111							
Treatment 3[b]:							
Coefficient	219.66	48.97	24.23	---	---	---	-5.75
Std. error of coeff.	79.81	27.59	11.31				3.78
R^2 = .20							
d.f. = 38							
Treatments 4 and 5[c]:							
Coefficient	1150.53	---	---	---	81.97	-3.77	-6.61
Std. error of coeff.	146.71				30.27	1.82	4.16
R^2 = .19							
d.f. = 90							

(a) Days before weeding defined as first weeding date minus first millet planting date.
(b) For cases where days before weeding are greater than 20 and less than 36.
(c) For cases where days before weeding are greater than 20 and less than 37, treatment 5 is identical to treatment 4 except that insecticide was applied to treatment 5.

Table A-4. Average labor times per hectare for specified operations, by treatment, on-farm trials, Madarounfa[a], 1986

Operation	Labor times by treatment (MDE/ha)[b]			
	T1	T2	T3	T4
Application of phosphate	0	0	0	2.58
Planting of millet[c]	1.22	1.18	2.36	2.41
Planting of cowpea[c]	0.98	1.05	3.25	3.54
First weeding	11.32	10.44	12.44	13.46
First urea application	0	0	0	2.06
Second weeding	7.78	7.76	8.4	8.48
Second urea application	0	0	0	1.66

(a) From observations of 17 farmers in Maiguéro, Rigial Oubandawaki, and Kandamao.

(b) One man-day equivalent (MDE) equals 8 hours. For all operations except planting, observed times for women are multiplied by 0.6 and times for adolescents are multiplied by 0.5.

(c) Does not include replanting time.