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ANALYSIS OF THE COMPETITION FOR LABOR BY DRYLAND AND IRRIGATED CROPS: THE CASE OF RICE AND MILLET IN NIGER

by

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INTRODUCTION

Rice production in the irrigated perimeters along the Niger River is an important part of the food self-sufficiency and agricultural development plan of the government of Niger (Rep. of Niger, 1987). But in spite of large investments in infrastructure, research and extension, the production on these perimeters has not lived up to expectations. One of the key problems has been the competition for labor between rainfed and irrigated crops (Maikoréma, Rassas and Loute, Anders et al., Rep. of Niger, 1989a). During the rainy season, farmers are observed to neglect rice production in favor of allocating labor to dryland crops, primarily millet. The hypothesis that is tested in this analysis is that millet production is favored because the marginal value product of labor is higher for millet than it is for rice in the critical periods. The analysis uses production functions estimated with ordinary least squares (OLS) from farm survey data. The results are useful to policymakers, researchers and extension workers concerned with the Niger River region and similar areas in West Africa.

The Republic of Niger is a landlocked country in the Sahelian region of West Africa. It shares borders with Nigeria and Benin on the south, Chad on the east, Burkina Faso and Mali on the west, and Algeria and Libya on the north. More than 60% of Niger is in the Sahara Desert zone with less than 200 mm of rain per year. Most of the country's agricultural land is in a narrow band within 150 km of the Nigerian border. The average annual rainfall in this band is in the 300-800 mm range. Millet is planted on over 70% of the dryland crop area, often intercropped with cowpeas and sorghum. The average millet yield in the 1980's was 409 kg ha^{-1} (Rep. of Niger, 1989b).

Currently less than 1% of the crop area of Niger is irrigated. The predominate irrigated crop is rice, with smaller areas devoted to cotton, sorghum, onions and other crops. Two rice crops are produced per year with the crop calendar determined by climatic and river flow factors. A rainy season crop is transplanted in July or August and harvested in November or December. A dry season crop is transplanted in December or January and harvested in April or May. In 1988 irrigated rice occupied about 5000 ha in each season (Rep. of Niger, 1989a), but this area is expected to rise rapidly with the construction of new perimeters. Potentially 140,000 ha could be irrigated in the rice growing area of the Niger River valley (Rep. of Niger, 1989a). Average yields for irrigated rice have been about 4000 kg ha^{-1} in the 1980's (Rassas and Loutte, 1989), substantially less than the 6000 kg ha^{-1} average commonly observed in Asia.

Nigerien farmers also grow about 12,000 ha of traditional rice varieties in naturally occurring swamps and depressions without the benefit of controlled irrigation. Traditional rice can be very profitable, but the naturally suitable areas are limited and because water is not controlled, crop failure is common. Because of the small area and low labor methods, there is relatively little competition for labor between traditional and irrigated rice (Bomans, 1986). This article is concerned exclusively with irrigated rice.

Currently, rice makes up about 4% of the total cereals production of Niger, but it is more important in the national strategy than the level of production would indicate. Irrigated rice has the potential of stabilizing the grain supply; rice yields can be good even in the drought years when the millet crop fails. In addition, domestically produced rice can help satisfy the growing demand for rice in the urban areas and at the same time provide a

source of cash income for farmers. Domestically produced rice satisfies about 50% of the demand in Niger (Rep. of Niger, 1989a).

The competition for labor affects rice yields in several ways. In the rainy season, late planting of nurseries and transplanting of seedlings can push the rice maturity period into the cool season when night temperatures can drop as low as 5°C. The low temperatures cause rice grains to abort. In some cases, rice seedlings are left in the nursery too long before transplanting. This reduces tillering and hence yield. Weeding may be done late and incompletely, resulting in heavy weed pressure. An indirect effect of labor competition is that farmers choose lower yielding, but flexible, rice varieties, instead of the higher yielding varieties which are more sensitive to transplanting date, nursery time and weed competition.

Alternative hypotheses about why farmers allocate labor to millet instead of rice focus on food preferences, relative profitability and risk (Maikoréma, 1986; Rassas and Loutte, 1989; Anders et al., 1984). Relatively little of the irrigated rice is consumed by farm families. Millet is the staple food in their diet. Rice is consumed mainly on holidays and ceremonial occasions, such as weddings, christenings, etc. and for these events, the traditional rice varieties are preferred. Irrigated rice is often treated as a cash crop produced for urban consumers. In this situation, if the farmer's primary objective is to secure the family millet supply, with cash income as a secondary goal, labor would be allocated first to millet and only to irrigated rice when millet needs are satisfied.

Several budgeting studies have shown rice to be moderately more profitable than millet (Maikoréma, 1986; Bomans, 1986; Rassas and Loutte, 1989; Anders et al., 1984), but it is not clear that the additional profits are

sufficient to compensate for the extra financial and marketing risk. With irrigated rice, yield risk is relatively low, but financial risk is high because of the need for purchased inputs. Traditionally, millet production in Niger uses few purchased inputs, so the financial risk is negligible. Rice is purchased by the parastatal company *Riz du Niger* (RINI) at official prices which are often higher than world market prices, but RINI does not buy all of the production. About one-third of the irrigated rice production must be sold privately, but private marketing channels are not well developed for this product. Marketing channels for millet and the traditional rice varieties are well developed. Thus, it is argued that farmers allocate labor to millet production because rice is not sufficiently more profitable than dryland crops to justify the risk and marketing problems.

Data and Methods

The data for this study were collected in the 1984 rainy season in five villages on the east bank of the Niger River about 50 km north of the capital city of Niamey. They are: Koutoukalé Kado, Koutoukalé Kourthey, Koutoukalé Tegui, Koutoukalé Zeno, and Zamakwara Zeno. The Koutoukalé perimeter has been in operation since 1966. These villages were chosen on the basis of the following criteria: a) isolation from main urban centers, b) experience with irrigated agriculture to avoid the "learning curve" bias common with introduction of a new technique, and c) relative ease of access, to permit regular and frequent supervisory visits.

The sample size is 50 farmers, with a total of 1890 hectares in 272 fields. In each village 20 volunteers were identified and a sample of 10 farmers per village was chosen at random from among the volunteers. A

completely random sample was not used because experience in the study area indicated that farmers forced to participate in such a study provide data of dubious quality. This approach yielded a very complete data set. Out of the 516 farmer-months of data, only 10 farmer-months of data were lost and that was due to enumerator error. One field enumerator was assigned to each village.

All data collected were identified by field and farm. The data include both physical inputs and output, and some accounting data of expenses. Labor time records include working hours, type of worker, operation and salaries for hired labor. Worker types include family labor, hired labor and community labor. Labor is divided into three groups: adult male, adult female and child. The worker type "communal labor" is used for unpaid labor provided by friends and neighbors.

The descriptive statistics (Table 1) show a farming system in which the majority of the crop area is devoted to millet and other dryland crops, but the majority of the labor use, grain production, and income comes from the irrigated area. Only 12% of the farm area is in irrigated rice, but it uses 65% of the labor, yields 62% of the grain and produces 69% of the total value of crops.

Most of the work on both dryland crops and rice is done by family labor. Overall, about 16% of all labor is hired. About 62% of all hired labor is used in rice production, with about 72% of all hired labor for rice production being used in harvest and postharvest operations. Most of the hired labor for dryland crops is used in millet weeding. Except for millet planting and rice threshing, women seldom do field work at Koutoukalé.

Table 1. Land, labor, crop mix, dates of field operations, yields, costs and returns, Koutoukalé perimeter, Niger, rainy season, 1985.

Item and units	Mean[1]	Minimum	Maximum
FAMILY SIZE:			
Men	1.9	0.6	3.0
Women	2.1	0.3	3.2
Boys	2.3	1.0	3.1
Girls	2.1	1.0	3.0
Elderly	0.3	0.0	1.0
LAND PER FARM:			
Monocrop millet, ha	2.2	0.1	5.9
Millet intercrop, ha	1.12	0.09	5.2
Other dryland crops, ha	0.2	0.02	0.5
Irrigated rice, ha	0.5	0.03	0.73
YIELDS:			
Monocrop millet, kg ha^{-1}	367.8	104.4	990.1
Irrigated rice, kg ha^{-1}	3789.9	2343.7	5207.3
CASH COSTS FOR IRRIGATED RICE:			
Water use, FCFA ha^{-1}	58171.0	58171.0	58171.0
Fertilizer, FCFA ha^{-1}	15059.8	0.0	26556.3
Hired labor, FCFA ha^{-1}	7618.3	1250.0	39750.0
TOTAL LABOR USE:[2]			
Monocrop millet, PDE^{-1}	63.1	8.2	296.4
Irrigated rice, PDE^{-1}	364.6	206.9	812.8
RETURNS PER HECTARE:[3]			
Millet, FCFA ha^{-1}	29560.5	2077.7	171053.0
Rice, FCFA ha^{-1}	373858.0	108355.1	272727.2
RETURNS PER DAY:			
Millet, FCFA ha^{-1}	782.5	49.8	2795.5
Rice, FCFA ha^{-1}	2452.1	706.6	8635.5

[1]The arithmetic means reported here may differ from the geometric means reported in Table 4.
[2]The weighted mean date is used. The weights were the proportion of labor used on a given day. Labor is measured in "person-day equivalents" (PDE) assuming 8 working hours per day.
[3]Returns were calculated by Bomans 1986. Costs include hired labor, fertilizer and cooperative charges, which include water use and rice seed. The opportunity cost of family labor is not subtracted.

The planting, transplanting and weeding date statistics (Table 2) show that the periods for these operations overlap. The labor bottleneck which causes the most problems is in late July and early August when both millet weeding and rice transplanting should be done (Maikoréma, 1986; Bomans, 1986). The date of millet planting is determined primarily by the onset of rains. Though millet planting and replanting extends over a long period, most of the millet area is planted for the first time within a few days of the onset of the rains, and thus the conflict with rice operations is relatively small. Rice weeding is done mainly during a period before millet harvest, but after millet weeding.

It can be assumed that all farmers in the sample use the same technologies, though with varying input levels. They all used the traditional

Table 2. Critical periods in rainy season rice and millet production, Koutoukalé, Niger, 1985.

Operation	June	July	August	Sept.	Oct.
Millet planting and replanting	June 18 - August 9 mean = June 29				
Millet first weeding		July 8 - Aug. 13 mean[1] = July 28			
Rice transplanting			July 24 - Sept. 20 mean = Aug. 22		
Rice weeding				August 27 - Oct. 24 mean = Sept. 24	

[1]The mean reported here is the weighted average in which the weights are the proportions of the total labor allocated to an operation expended on a given day.

millet production system. All large perimeters in Niger are managed by ONAHA (*Office National des Aménagements Hydro-Agricoles*), which prescribes recommended production practices. Though these recommendations are not followed to the letter, they create a certain consistency in rice production technology among farmers; for instance, in variety choice.

The model - A production function approach was chosen as the simplest approach that could test the hypothesis posed. The popular dual approach was not used because the hypothesis concerns the magnitude of the marginal value of the physical production response to labor allocation and because the available data were primarily in the form of physical inputs and outputs. The dual approach would require accounting data. In general, relatively good data on physical inputs and output can be collected in Niger. Accounting data on expenses and returns are usually less reliable than physical input and output data. The primary input, family and community labor, is hard to value. A large part of the production is consumed at home. Farmers are reluctant to discuss their cash transactions. Also, the dual approach often entails multi-equation estimation.

A programming model analysis would be a useful approach, but it would not be the simplest method to test the hypothesis. Development of a representative farm programming model would have required substantially more time, data and expertise than were available. A complete analysis of the management effects of the production response to labor timing would require a representative farm programming model. Determination of the magnitude of the physical response could be seen as a step in this more complete analysis.

The decision framework of this analysis is the maximization of expected results in terms of food value or monetary value. It is commonly observed that Nigerien farmers want both food self-sufficiency and cash income; thus both aspects are considered. In mathematical terms, the problems are identical. In one case, the inputs and outputs are measured in terms of food value (kilograms of grain, calories, etc.) and in the other case, in terms of money. Zellner et al. (1966) show that simple, single-equation production function estimates with survey data can be consistent and unbiased if it can be assumed that the production process is risky and that this fact is recognized in the choice of input levels; assumptions which seem to hold for Niger.

Functional form - A Cobb-Douglas production function is used for simplicity and to economize on the number of parameters to be estimated. This functional form is used as a convenient summary representation of the production process. Real production systems are, of course, much more complicated. The form is assumed to be adequate for the range of data observed, but not to represent the entire possible range of input levels. The properties of this functional form are well-known and have been discussed in detail by Heady and Dillon (1961), and by Beattie and Taylor (1985). All data are transformed to natural logarithms; thus, linear estimation using OLS is possible. The estimated equation was:

(1) $$YR_i = a_o + a_1\ RHA_i + a_2*RLAB_i + a_3*FER_i + a_4*RPDAY_i + a_5*RWDAY_i + er_i$$

(2) $$YM_j = b_o + b_1*MHA_j + b_2*MLAB_j + b_3*MPDAY_j + b_4*MWDAY_j + em_j$$

where: YR_i is the rice yield (kg ha^{-1}) from field i,

YM_j is the millet yield (kg ha^{-1}) from field j,

RHA_i is the area (ha) of rice field i,

MHA_j is the area (ha) of millet field j,

$RLAB_i$ is the total labor used in rice field i,

$MLAB_j$ is the total labor used in rice field j,

FER_i is the total fertilizer expense for rice field i,

$RPDAY_i$ is the rice transplanting date for field i,

$MPDAY_j$ is the millet planting date for field j,

$RWDAY_i$ is the date of first weed for rice field i, and

$MWDAY_j$ is the date of first weeding for millet field j,

er_i and em_i are error terms for the rice and millet functions, respectively.

The total labor per field is the weighted sum of family, hired and communal labor. The weights were: adult males, 1; adult females, 0.85; and children, 0.65. Labor is measured in "person-day equivalents" (PDE) assuming 8 working hours per day.

The weighted average date of a field operation was used as a single valued index of the timeliness of that operation. The weighted average was calculated as the sum of Julian dates multiplied by the proportion of the total labor for that operation used on that date:

$$\text{(3)} \quad \textit{Weighted Average Date} = D_1 * \frac{L_1}{TL} + D_2 * \frac{L_2}{TL} + D_3 * \frac{L_3}{TL} + \ldots + D_n * \frac{L_n}{TL}$$

where: D_i = the Julian date,

L_i = the labor used on that date for a given operation,

n = the total number of fields, and

TL = the total labor used for that operation.

Rice transplanting day is measured as the weighted mean number of days after the first field transplanted in the sample. Millet planting date is measured as the weighted mean number of days after the first millet field planted in the sample. The rice and millet weeding days are measured as the weighted mean number of days after the first field of each crop is weeded.

The labor variables were chosen to embody the maximum information in a parsimonious form. Based on the results reported by Maikoréma (1986) and by Bomans (1986), completion of millet planting, rice transplanting and weeding of both crops were identified as the important elements in timing of field operations. Measuring the planting, transplanting and weeding dates from the earliest planting, transplanting and weeding dates in the sample controls for environmental conditions, such as the onset of rains, that determine the cultural calendar in any given year. It is expected that the estimated coefficient for total labor input (RLAB, MLAB) will be positive. Labor is relatively abundant in rural Niger, but it is unlikely that farmers would use labor beyond the point of positive marginal product, even if that labor is low cost. The planting, transplanting and weeding variables are expected to have negative signs. Agronomic reasoning suggests that delays in these operations in the range of dates observed in the sample will have negative effects on yield. Very early planting dates, which could have negative effects because of high temperatures, are not observed in the sample.

The other variables were chosen to control for as much of the remaining variation as possible, given the data collected. The field size variable is intended to capture management problems associated with labor utilization and water distribution. Field observations suggest that both labor and water management become more difficult with larger field sizes. Thus, the field size coefficient is expected to have a negative sign for both millet and rice. The fertilizer coefficient is expected to be positive.

Only the millet monocrop data was used in the estimation of the millet production function. Monocrop millet occupied 65% of the total millet area in the sample. Intercropping with sorghum, cowpeas and sesame introduces complicating factors that are not directly related to labor allocation. In addition, the small number of observations on each crop association other than monocrop millet (millet-cowpea, millet-sorghum, millet-sorghum-cowpea, etc.) does not permit reliable estimation.

Interpretation - Analysis focuses on the millet weeding date and rice transplanting coefficients. Other estimates are considered to the extent that they complete the labor allocation picture. The marginal physical products (MPP) and marginal value products (MVP) are calculated. The MPP can be interpreted as the yield or food value impact of a one unit change in a factor of production. Mathematically, the MPP is the first derivative of the production function with respect to the factor. The MVP can be interpreted as the monetary value of the yield change due to a one unit change in a factor. Mathematically, the MVP is the MPP multiplied by the output price. Consistent with the logic of the logarithmic transformation of the data, the central

tendency of the marginal products is calculated at the geometric means instead of the arithmetic means (Heady and Dillon, 1961).

The MPP and MVP for the millet weeding and rice transplanting dates are calculated, both in terms of calendar days and person-day equivalents (PDE). The variables (RPDAY, MWDAY) are in terms of calendar days; hence the usual calculation would be in terms of the impact of a one calendar day change in the weighted average date. Testing the hypothesis about the relative magnitude of these terms requires comparison of the marginal products of the two operations. Comparison of the MPPs and MVPs calculated on a calendar date basis is of limited relevance because the amount of labor represented by a one calendar day change in date differs between the operations. In the sample, the first weeding of one hectare of millet requires an average of 12 PDE, while the transplanting of one hectare of rice requires 59 PDE. The impacts in terms of PDEs are calculated by dividing the calendar day MPPs and MVPs by their respective labor requirements.

In the typical one-crop profit maximization problem, the optimality conditions require that the MVP of an input be equal to the cost of that input. In the two-crop case, the additional requirement is added that the MVPs of the two factors be equal. These typical conditions do not hold true with respect to the millet weeding and rice transplanting date variables, because they are expected to have a negative impact on yield; a larger date value results in a lower yield. Mathematically, this means that the function is convex in the transplanting and weeding dates, not concave as is required for maximization. Hence, in this case, the equality of the MVP is a condition for a minimum.

The maximum for this type of problem often takes an all-or-nothing form (corner solution). This type of solution is found iteratively by checking candidate solutions and choosing the maximum. For example, if during the overlap period the marginal product of the millet weeding date is consistently higher than that of rice transplanting, a candidate for the maximizing solution might be to allocate all labor to millet weeding until it is finished and then start on rice transplanting. If the opposite situation occurs and the rice transplanting marginal product is higher, then a candidate solution would be to allocate all labor to rice early in the overlap period and weed the millet only after the rice is in the paddy.

These maximization results can be used in interpreting the magnitudes of the estimated coefficients. For the variables with positive coefficients, such as fertilizer and labor, average marginal products which are approximately equal to the opportunity cost of the input indicate that input levels are such that they maximize expected results. Given the tendency of the Nigerien farmer to allocate labor to millet weeding instead of to rice transplanting, one would expect to find that the marginal products of millet weeding are larger than those of rice transplanting, if maximization of food or monetary value is indeed the objective. If the magnitudes of the marginal products do not correspond to the hypothesis, it may be that they reflect an optimization, but not of the total food or monetary value. The alternative hypotheses suggest that the objective might be maximization of millet production or a risk-adjusted optimization.

RESULTS AND DISCUSSION

The estimation results are reported in Table 3. The F statistics are significant at the 5% level for both crops. All of the estimated coefficients have the expected signs, except for the coefficient of the total labor used in rice production, and that coefficient is not significantly different from zero, even at the 10% level. For rice, the coefficient estimates for field size, fertilizer and transplanting day are statistically significant at the 5% level. For millet, field size and total labor use coefficients are significant at the 5% level. The planting day and weeding day are significant at the 10% level for millet. Because of the logarithmic transformation, the estimated coefficients can be directly interpreted as elasticities, that is as the percentage change in yield for a 1% change in the input level. For example, a 1% change in either the millet weeding date or the rice transplanting date results in about a 0.14% change in yield. Because of the higher rice yields, the per calendar day response of rice to transplanting date appears more dramatic than that of the response of millet to weeding date (Figure 1), but the percentage response is almost the same for the two.

The average calendar days MPP and MVP of rice transplanting are greater than the average MPP and MVP of millet weeding (Table 4). Each day translates into a 17.8 kg ha^{-1} yield loss for rice, but only a 3.6 kg ha^{-1} loss for millet. In monetary terms, this is about 1307 FCFA per calendar day for rice transplanting and about 307 FCFA per day for millet weeding. These impacts reflect only the change in yield and revenue due to labor allocation. The return to labor itself is captured in the total labor coefficient (RLAB, MLAB).

Table 3. Elasticity estimates for rice and millet production functions in terms of yield per hectare, Niger, 1985

Independent variable	Dependant variable	
	Rice (t-statistic)	Millet (t-statistic)
Intercept	9.2099 (16.373)**	5.6683 (11.333)**
Field Size	-0.2564 (-2.184)**	-0.1537 (-2.078)**
Labor	-0.1491 (-1.448)	0.2511 (2.584)**
Fertilizer	0.0270 (2.352)**	-
Planting or transplanting day	-0.1396 (-2.322)**	-0.2513 (-1.722)*
Weeding day	-0.277 (-0.499)	-0.1389 (-1.612)*
F	2.02	6.822
MSE	0.038	0.2747
N	54	113

* Significant at the 0.10 level
** Significant at the 0.05 level

For both crops, labor appears to be near the point of zero marginal return. In the case of rice, the coefficient is negative and not significantly different from zero. For millet, the marginal physical product of about 1.5 kg per hectare per day approaches the amount of grain needed to feed a laborer for one day. The marginal value product of labor in millet is only 128 FCFA day^{-1}, substantially less than the average wage rate for adult males in the area in 1985 of about 400 FCFA day^{-1} (Bomans, 1986). It should be remembered, however, that for some of the family labor used in millet production, the opportunity cost may be lower than the adult male wage. Women

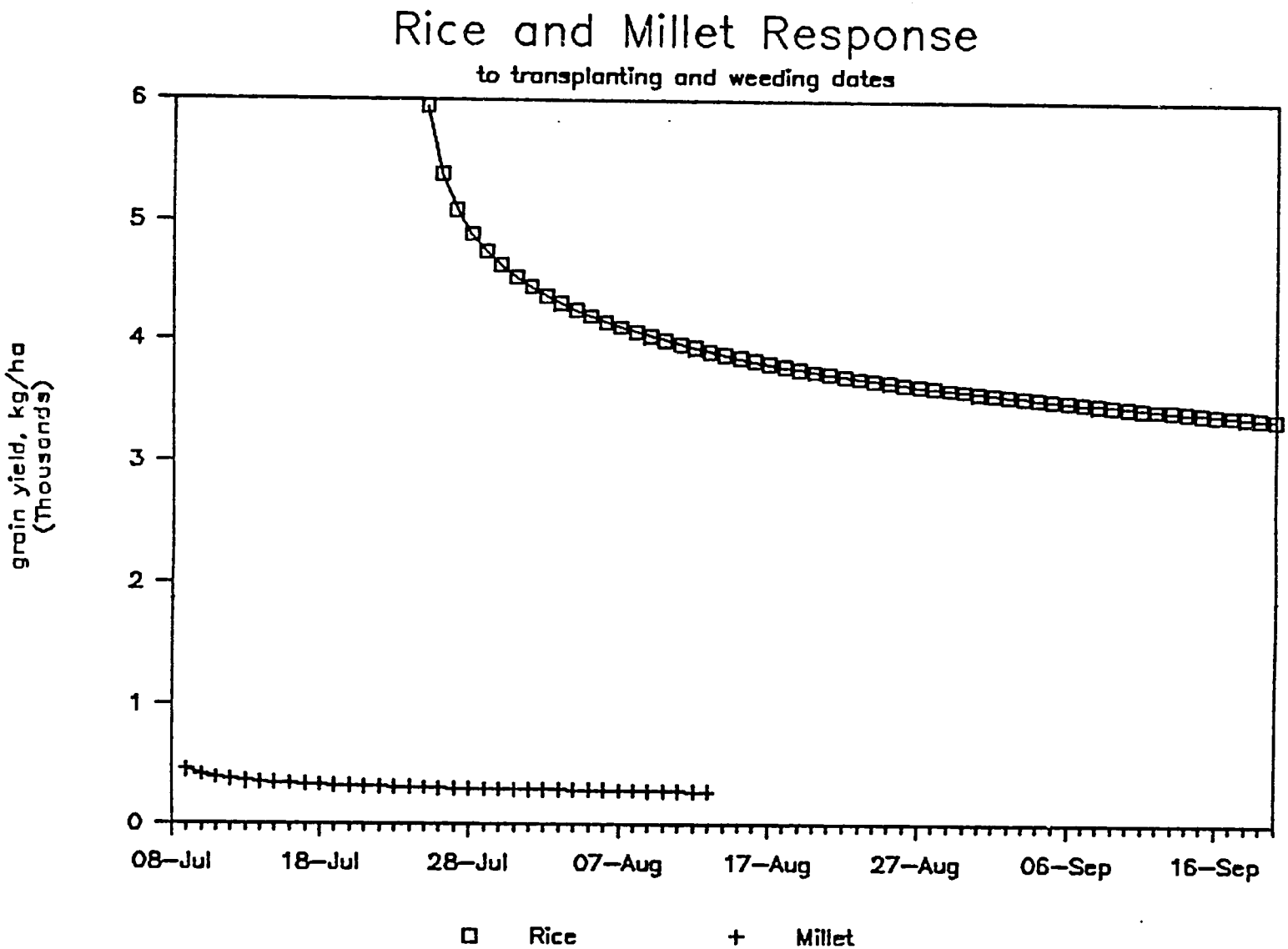

Figure 1. Rice response to transplanting date and millet response to weeding date for Koutoukalé, Niger, 1985, estimated with a Cobb-Douglas production function.

Table 4. Input means, estimated marginal physical products and estimated marginal value products for rice and millet, Koutoukalé, Niger, 1985.

Means and marginal products by factor	Unit	Rice	Millet
MEAN INPUT LEVELS:			
Field size	ha	0.46	0.81
Labor	PDE ha^{-1}	346.45	52.87
Fertilizer	FCFA	8059.71	0.00
Planting or transplanting day	day	29.12	10.95
Weeding day	day	28.69	12.19
MARGINAL PHYSICAL PRODUCTS:[1]			
Field size	kg ha^{-1}	-2088.81	-59.43
Labor	kg ha^{-1}	-1.60	1.49
Fertilizer	kg ha^{-1}	0.01	-
Planting or transplanting day	kg ha^{-1}	-17.79	-7.20
Weeding day	kg ha^{-1}	-3.58	-3.57
MARGINAL VALUE PRODUCTS:[2]			
Field size	FCFA day^{-1}	-162927.00	-5110.99
Labor	FCFA day^{-1}	-124.60	128.09
Fertilizer	FCFA day^{-1}	0.78	-
Planting or transplanting day	FCFA day^{-1}	-1307.28	619.03
Weeding day	FCFA day^{-1}	278.99	307.15

[1]The marginal physical products are calculated as dY/dX=e*MY/MX, where Y is the yield, X is the input, e is the estimated coefficient, MY is the mean yield in the sample and MX is in mean input for the sample.
[2]The marginal value products are the marginal physical products multiplied by the average local market price in 1985: paddy rice, 78 FCFA/kg; millet, 86 FCFA/kg. The markets used were at Karma and Namaro.

and children in the study area seldom work for wages, but some evidence indicates that earnings from traditional activities, such as basket making, may be in the range of 100 to 200 FCFA per day. The near zero marginal return to labor at the mean input levels does not necessarily indicate inefficient use of labor, but may simply be a reflection of the low marginal cost of family labor.

The per person-day MPPs and MVPs for rice transplanting and millet weeding were calculated by dividing the MPPs and MVPs by their labor coefficients (59 days ha^{-1} for rice transplanting and 12 days ha^{-1} for millet weeding). At the geometric means, the MMPs and the MVPs of millet weeding and rice transplanting are about equal (Table 5). At most feasible combinations of weighted average millet weeding and transplanting dates, the marginal value product of millet weeding is not greater than that of rice transplanting, and for many feasible date combinations it is the rice transplanting marginal value product that is larger (Figure 2).

Table 5. Marginal physical product and marginal value product per person-day equivalent for each operation.

Operation	MPP (kg PDE^{-1})	MVP (FCFA PDE^{-1})
Millet weeding	-0.30	-26
Rice transplanting	-0.31	-24

Feasible date combinations depend on the amount of labor available, the work rate and the area. In creating a mental image of the distribution of weeding or transplanting dates, it is useful to assume that the labor per day in a given activity is about equal; thus about half of the labor needed to accomplish a task would have to occur before the weighted average date. For example, if the average farmer has 2.16 hectares of monocrop millet, it takes 12 PDE of labor to weed a hectare. If the farmer has available one PDE of labor per calendar day, then millet weeding would have to start about 13 days before the weighted average date. It should be noted that the PDE concept assumes an 8 hour work day, but in fact the farmers at Koutoukalé often work 4

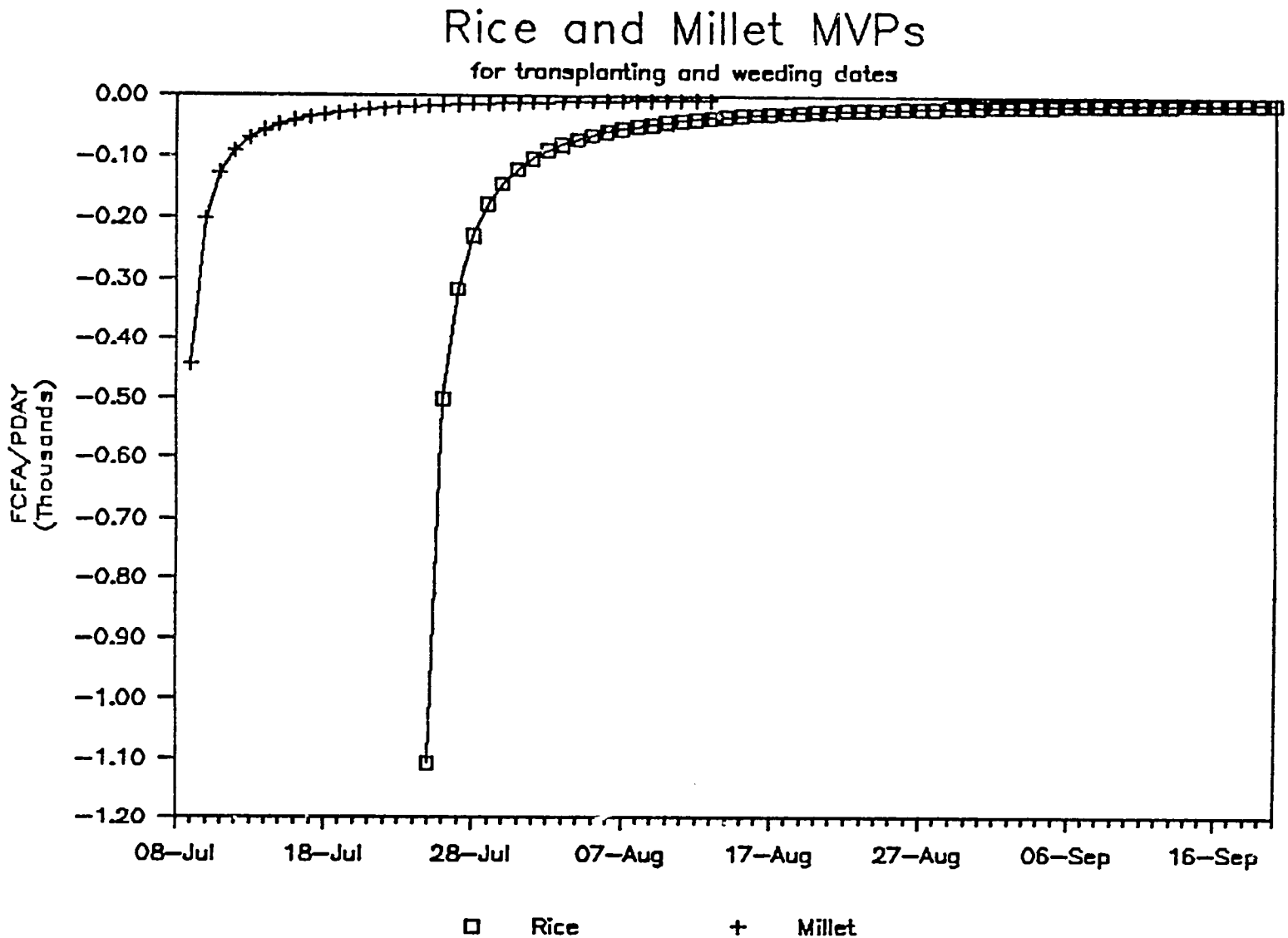

Figure 2. Marginal value product of the rice transplanting date and millet weeding date on a per person day basis for Koutoukalé, Niger, 1985, estimated with a Cobb-Douglas production function.

to 5 hours in the fields and spend the rest of the day in household chores, taking care of livestock and other activities. The relatively short field work day can also be linked to poor health and nutrition. Thus, the one PDE labor used in the example may represent the work of 2 individuals.

To illustrate the structure of the agronomic and economic tradeoffs in the labor allocation decision, the MPPs, MVPs, yields and returns for several feasible combinations of weeding and transplant dates are given in Table 6. The calculations assume 0.54 ha of irrigated rice and 2.16 ha of monocrop millet. It is further assumed that 1 PDE of labor is available each calendar day for either millet weeding or rice transplanting. All inputs other than the millet weeding or rice transplanting day are held at their geometric mean levels. The work schedule for example 1 has all labor allocated to millet until millet weeding is finished, and then it allocates labor to rice transplanting. Example 1 has weighted average millet weeding and transplanting days close to those found in the sample. Example 2 is like example 1 except that the beginning of rice transplanting is moved up one day from July 24 to July 23, and July 24 is allocated to millet weeding. Example 3 is like example 2 except that instead of moving up rice transplanting 1 day, it is moved up 10 days. Example 4 shows the effect of giving priority to rice so that rice is transplanted at the earliest transplant day and millet operations are done only in between times.

The examples indicate that as labor is allocated to rice transplanting earlier in the season, total grain production and net revenue rise modestly, but expected millet yields fall. The marginal products of rice transplanting are above those of millet weeding for all the examples. Because of the negative sign of the millet weeding and rice transplanting response, the

Table 6. Expected marginal products, yields and returns from millet and rice production under alterative weeding and transplanting schedules.[1]

Item	Sample averages	Example 1	Example 2	Example 3	Example 4
DATES:					
Rice trans-planting	Aug. 22	Aug. 19	Aug. 18	Aug. 15	Aug. 9
Millet weeding	July 20	July 21	July 21	July 24	Aug. 2
YIELDS:					
Rice, kg ha^{-1}	314	311	311	299	284
Millet, kg ha^{-1}	3711	3770	3791	3859	4035
MPPs:					
Rice, kg PDE^{-1}	-0.31	-0.35	-0.36	-0.42	-0.60
Millet, kg PDE^{-1}	-0.30	-0.28	-0.28	-0.22	-0.13
MVPs:					
Rice, FCFA PDE^{-1}	-24	-27	-28	-33	-47
Millet, FCFA PDE^{-1}	-26	-24	-24	-19	-11
TOTAL GRAIN, kg	2682	2708	2719	2736	2792
NET REVENUE[2], FCFA	178871	180799	181684	182876	186945

[1]Calculated with the estimated rice and millet production functions, assuming 0.54 ha of irrigated rice, 2.16 ha of millet monocrop, and labor available is 1 PDE per calendar day. The transplanting and weeding dates used to calculate the weighted average dates are:

Example 1: millet weeding from July 8 to August 2, rice transplanting from August 3 to September 3.
Example 2: millet weeding from July 8 to August 1 and on August 3, rice transplanting on August 2 and from August 4 to September 3.
Example 3: millet weeding from July 8 to July 23 and from August 3 to August 12, rice transplanting from July 24 to August 2 and from August 13 to September 3.
Example 4: millet weeding from July 8 to July 23 and from August 25 to September 3, rice transplanting from July 24 to August 24.

[2]Net revenue is value of grain produced minus the cash costs. Subtracted costs are fertilizer for rice (8060 FCFA ha^{-1}) and the cooperative charges for water use and other costs (58171 FCFA ha^{-1}). It is assumed that all labor is family or community labor. Millet seed is produced by the farmer; rice seed is included in the cooperative charge.

equality of the marginal products of millet weeding and rice transplanting suggests that the observed labor allocation may be minimizing total grain production and net revenue. While the examples support the idea that the sample labor allocation is at a minimum production and net revenue, they also indicate that the cost of choosing the maximum millet production is relatively small under the assumed labor constraints. The difference in total grain production between example 1 and example 4 is only 110 kg. The net revenue difference is 8074 FCFA.

An alternative labor allocation only shows a substantial advantage if rice can be transplanted the first week of the production period. For example, if 28 days of labor are hired so that rice can be transplanted in the period from July 25 to 28, then the estimated total grain production rises by 736 kg to 3418 kg and the expected net revenue is up 46064 FCFA, after subtracting the labor cost. As in all the examples, this estimate assumes that total labor and other inputs are held constant.

Other Variables

Because the fertilizer variable is measured in terms of money spent on this factor, the marginal value product is a cost benefit ratio. It estimates the return for each franc spent on nitrogen fertilizer. The estimate indicates that at the margin farmers receive about 0.78 franc for each franc invested in fertilizer. Thus, the MVP is below the input cost, and productivity is not maximized.

The field size variable marginal products are included in Table 3 for completeness, but because it is, in effect, a proxy for management factors, that coefficient must be interpreted with more than the usual caution. In

particular, the marginal cost of the field size variable is not clear. It is not the cost of land or the land rental rate, because the area assumed by the production function is fixed at one hectare. Suffice it to say that these management effects appear to be important for both crops, but more important for rice than for millet. This may be due to the role of field leveling in irrigation water management and to the fact that it is hard to level a larger field.

Conclusions and Implications

The hypothesis that Nigerien farmers allocate labor to millet production instead of rice production because the marginal product of labor is higher in millet is not supported by this research. The average input levels, the marginal products of labor for millet weeding and rice transplanting, are about equal. It is difficult to find a feasible combination of millet weeding and rice transplanting dates, for which the MPP and the MVP of millet weeding is substantially above those of rice transplanting. Feasible dates were defined as those which allow enough time to complete both tasks given the labor supply.

The alternative hypothesis that Nigerien farmers allocate labor to maximize millet production is supported by the results. Examples using the estimated production functions suggest that it is easy to find alternative labor allocation patterns that modestly increase total grain production and net revenue, but most involve lower expected millet yields. The examples also suggest that yield increases due to alternative labor allocation would be modest unless labor hiring could permit rice to be transplanted very early in the transplanting period. Without hired labor, it would be difficult for most

families to transplant rice early enough in the period to achieve the highest yields. The examples indicate that with family labor alone, even if the farmer puts an absolute priority on rice transplanting, the yield gains over the current system are modest. To achieve the high yields, the estimates suggest that the rice must be transplanted quickly at the beginning of the period.

Analysis of the structure of the labor allocation problem during the millet weeding and rice transplanting period at Koutoukalé suggests that food preferences for millet may play a modest role in reducing rice yields and returns, but that at the heart of the problem is the high demand for transplanting labor for a short period. Even if there were no competition from millet production, this transplanting demand could create labor problems.

There are three basic approaches to reduce this problem: 1) enlarge the supply of labor, 2) increase the effectiveness of the labor supply, and 3) change the cropping system to reduce labor needs. Because climatic and river flow considerations essentially determine that the transplanting period occur during a period when the labor demand for other crop activities is also high, it would not be easy to greatly enlarge the overall labor supply. However, it may be possible to facilitate hiring by providing credit for rice farmers and to more efficiently link workers with employers through public information systems. Farmers often say that they would find it profitable to hire more labor, but they cannot do so because of lack of capital. Krause et al. (1990, forthcoming) suggest that it is possible to structure credit terms to reduce the repayment problems that have plagued Nigerien credit programs. Information travels slowly in rural Niger. An improved agricultural information system, perhaps using radio, could help keep potential workers informed of

crop conditions and labor needs. As with any public information system, effectiveness depends on providing accurate, complete and unbiased information.

The effectiveness of workers doing manual agricultural operations depends largely on their health and nutrition. Because of lack of infrastructure and personnel, health care in rural Niger leaves much to be desired. The rainy season rice transplanting period occurs during the "soudure", the period before the first harvest of the rainy season when food supplies are typically at their lowest. The dry season rice crop helps Koutoukalé farmers through the soudure, but many of their potential workers may suffer from nutrition-related problems. A side benefit of improved health and nutrition is that farmers could work faster and longer.

Potential changes in the cropping system range from direct seeding of rice to switching crops. Sorghum has been mentioned as an alternative crop in the Niger River perimeters (Bomans, 1986). Because it has labor requirements similar to millet, sorghum production would substantially reduce the overall labor requirement in the critical millet weeding period. Rotation of rice with sorghum could break pest cycles. Potentially, improved sorghums could exceed current rice yields, but it is not clear that the market could absorb a large increase in production. Sorghum is part of the traditional Nigerien diet. Increased sorghum production would help meet the goal of food self-sufficiency, but the growing urban market does not demand sorghum as it does rice.

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