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FORWARD

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TECHNICAL CHANGE, LABOR USE AND SMALL FARMER DEVELOPMENT: EVIDENCE FROM SIERRA LEONE

In large areas of Africa where land-labor ratios are high and use of capital is minimal (usually less than ten dollars per farm annually) labor is the dominant factor of production. Effective use of labor is then a key element in any program to increase output and incomes among small farmers. Following Hayami and Ruttan [1971], technical change appropriate to these factor endowments would involve adoption of labor saving technology for peak season operations to raise labor productivity. Where the labor bottleneck occurs at planting time as is common in tropical Africa, this translates into mechanization of planting operations particularly land preparation to enable expanded acreage. However, because labor constraints are only seasonal, conventional land saving technologies may also be appropriate. If planting labor is the bottleneck, biological-chemical technologies which increase yields per acre and hence increase weeding and harvesting labor but leave planting labor unchanged will in fact be labor saving with respect to labor at the peak season. Thus it is not uncommon to observe both mechanical and biological-chemical technologies being adopted side by side in high land-labor ratio areas in Africa.

These interrelationships between technical change and demand for labor must also be examined within the context of available labor supply. Where there is no class of landless laborers--because of the land surplus situation--labor supply to agriculture depends primarily on the time input and allocation of family members, particularly at the peak season. Competition with nonfarm activities has been shown to be one important component of labor supply to farming [Norman, 1973; Byerlee and Eicher,

1974]. Recently there has also been interest in the role of female labor supply in both traditional and improved farming systems.

Despite the obvious importance of these labor supply and demand relationships to small farmer development there are relatively few detailed studies of labor utilization in traditional African agriculture and almost none that examine labor use under improved technologies. The objectives of this paper are then to briefly highlight some findings based on a detailed farm survey, with respect to labor use in two contrasting situations--one employing mechanical cultivation and the other improved biological-chemical technology--in rice production in Sierra Leone.

Specifically we shall first examine labor use from the demand side noting the impact of the different technological packages on resource combination and returns to labor. We then examine labor use from the supply side by analyzing the impact of technical change on household family labor inputs and the differentiation of labor use by sex.

Data Sources

Data reported in this paper were obtained as part of a nationwide farm management survey we conducted during 1974/75 of five hundred rural households in twenty-four enumeration sites in Sierra Leone, chosen on a stratified random basis. Data were obtained by locating enumerators at each survey site and interviewing farmers twice weekly over a twelve month period [Spencer and Byerlee, 1976]. In this paper we discuss data from only two survey areas. The first area is situated in the center of the Boliland area where rice is grown in infertile swamp grasslands. Extensive mechanical cultivation is practiced in the area through a government hire tractor scheme which charges a subsidized price for tractor services.[1] The second study area is located in the Moa Basin region

in an area served by an Integrated Agricultural Development Project (IADP) established in late 1973 with major emphasis on improved biological-chemical technology for production of inland swamp rice. Each farmer participating in the project receives credit, improved seed, fertilizer and tools as well as extension advice on constructing water control facilities. No mechanical cultivation is practiced in the area.

Technical Change and Labor Use in Rice Production

Labor inputs for rice production using varying technologies are shown in table 1. In the IADP area, farmers previously grew upland rice using traditional bush fallow cultivation where a new piece of land is cleared each year. Some farmers also grew swamp rice under traditional methods where land is continuously cultivated. These two production systems are used as benchmarks for the "without" project situation to be compared with the improved seed, fertilizer and water control methods used by farmers in the project. In the Bolilands labor use under hand cultivation is compared with mechanical cultivation. It should be noted that we are comparing enterprises--not farms. In the IADP area farmers often produce traditional upland rice in combination with traditional swamp rice while farmers in the IADP for the first year usually continue to produce upland rice in combination with improved swamp rice production. Farmers in this area also produce tree crops particularly cocoa, coffee and oil palm. In the Bolilands over half of our sample practiced both hand and mechanical cultivation of rice but few other crops were produced.

Labor inputs are computed in person-hour equivalents assuming that the ratio of wage rates for hired men, women and children accurately reflect the marginal rate of substitution between labor of different types. In the IADP area labor inputs per acre have increased substantially as

Table 1
Labor Inputs and Yields in Rice Production Under Differing Technologies in Sierra Leone, 1974/75

	Labor Input Per Acre[a/]			Yield Per Acre
	Family	Hired	Total	
	(Person Hours Per Year)			(Pounds Per Acre)
IADP Area				
Traditional upland	884	60	953	798
Traditional swamp	697	39	736	1,260
Improved swamp[b/]	1,125	256	1,393	1,734
Bolilands				
Hand cultivation	270	47	317	858
Mechanical cultivation	153	40	193	1,008

Source: Survey data.

[a/] Person hour equivalents computed by applying weights of 1.0, .75, .5 to men, women and child labor respectively in the IADP area and weights of 1.0, 1.0 and 0.5 to men, women and child labor in the Boliland area. Weights reflect relative wage rates in those areas as discussed in Spencer and Byerlee [1976].

[b/] IADP package of fertilizer, seed and water control.

a result of participation in the project (significant at the 1 percent level). The increased labor per acre is due to improved land preparation and a larger harvest.[2]

In the Bolilands labor inputs per acre declined by 40 percent as farmers substitute capital for labor in land preparation activities. To further understand these production relationships a constant elasticity of substitution production function was fitted to farm data for the Bolilands with the form,

$$\ln Y = V/P \; [\ln \; (S_1 L^P + S_2 K^P)]$$

where Y is total value added in rice production, L is input of labor (in person-hours), K is payment for the tractor hire services, V is the returns to scale parameter and P is the substitution parameter such that the elasticity of substitution is 1/(1-P) and S_1 and S_2 are distribution parameters. The value of P estimated was 1.0 with standard error .82 indicating a high elasticity of substitution.[3]

Although land is not included in this equation the returns to scale denoted by V is .99 indicating constant returns to scale on labor and capital services. This provides evidence that land is not a limiting factor. In fact because land is relatively abundant in this area farmers expand acreage with mechanical cultivation. The average size farm for those farmers with only hand cultivation was 8.4 acres compared to 12.7 acres for farmers using mostly mechanical cultivation. These results indicate that substantial flexibility exists to substitute capital for labor in the Bolilands. However, it is important to note that this substitution enables an expanded acreage to be cultivated and hence although labor saving technology is employed, it is not necessarily labor displacing.

Yields of rice per acre are also presented in table 1. In the IADP area yields per acre of improved swamp rice are more than double yields on traditional upland rice and 37 percent higher than under traditional swamp rice. In the Bolilands yields per acre are slightly higher on mechanically cultivated farms, but regression analysis of yield data indicated that this was due to higher fertilizer applications on mechanically cultivated fields and not due to any effect of mechanization per se.[4]

Enterprise budgets for each farming system are constructed in table 2. In the IADP area, returns per acre are increased on improved swamp rice farms compared to traditional systems. However, returns per man-hour of labor input are lower on improved swamp rice compared to traditional swamp rice production, although 50 percent higher than on upland rice production. Adoption of the IADP package to improve swamp rice has resulted in increased returns to land, but because of the added labor, returns per unit of labor are lower than under traditional swamp cultivation systems.

In the Bolilands returns per unit of land are virtually the same for both hand and mechanical cultivation. However, returns per unit of labor are substantially higher under mechanical cultivation.[5] Moreover the marginal value product of labor estimated from the constant elasticity of substitution production function fitted above is Le .19 per hour--almost identical to average returns to labor on hand cultivated fields.

In Sierra Leone mechanical services and fertilizer are both heavily subsidized. To assess the economic returns in both projects, returns to labor were recomputed using unsubsidized prices.[6] For the IADP area, returns are virtually unchanged, but in the Bolilands hand cultivation is now considerably more profitable than mechanical cultivation. In fact,

Table 2
Enterprise Budgets for Different Systems of Rice Production
in Sierra Leone, 1974/75

	IADP Area			Bolilands	
	Traditional Upland	Traditional Swamp	Improved Swamp[f/]	Hand Cultivation	Mechanical Cultivation
	Average Per Acre				
Output-value (Le.)[a/]	67.0	105.0	144.0	61.4	72.1
Variable costs (Le.)					
Land payment	0.0	0.0	.7	.3	2.1
Seed	5.3	4.4	5.1	4.5	3.8
Fertilizer	0.0	0.0	1.5	.8	1.2
Mechanical service	0.0	0.0	0.0	0.0	6.8
Hired labor[b/]	6.5	4.7	23.9	3.1	3.1
Others	0.0	0.0	2.2	0.0	0.0
Total variable cost	11.8	9.1	33.4	8.6	16.9
Interest on total costs[c/]	2.3	1.8	6.7	1.7	3.4
Enterprise gross margins[d/]					
Per acre	52.6	94.1	103.3	51.1	51.9
Per hour of family labor	.06	.13	.10	.18	.34
Gross margins per hour family labor with unsubsidized costs [e/]	.06	.13	.09	.18	.06

Source: Survey data.

[a/] Le. 1.00 = $1.10 U.S. in 1974/75.

[b/] Valued at wage rate specific to the area.

[c/] Assumes 20 percent opportunity cost.

[d/] Output value less variable costs less interest on variable cost.

[e/] Assumes fertilizer subsidy of 67 percent and mechanical ploughing subsidy of 85 percent.

[f/] IADP package of seed, fertilizer and water control.

the previously high returns to labor under mechanical cultivation are reduced to a level below that of improved swamp cultivation in the IADP area. The results indicate that neither the biological-chemical technology of the IADP nor the mechanical technology of the Bolilands is particularly successful as measured by returns to the limiting factor--labor. If returns are to be increased in the IADP area, either labor inputs must be reduced or yields increased.[7] In the Bolilands the increase in cultivated area resulting from mechanization has occurred at substantial cost given the current high cost of operating the government tractor hire scheme.

The relationships observed here are consistent with theoretical expectations. That is the mechanical technology has increased labor productivity while the biological-chemical technology has increased land productivity. However in each case we have evaluated only one technology among a range of potential alternatives. Thus biological-chemical technologies employing only improved seed and fertilizer but not water control measures may be more appropriate than the IADP package considered here. In fact elsewhere Spencer [1975] has shown that investment in improved seed and fertilizer in upland rice has greater potential for increasing returns to labor than either of the two technologies evaluated here. Likewise tractor cultivation represents only one form of mechanization. In Ghana, Winch [1976] has investigated several technological alternatives for rice production and concluded that a combination of tractor hire for cultivation and improved seed was most profitable although hand cultivation was not considered as an alternative.

Technological Change and Total Household Labor Use

In assessing the impact of technological change on total family labor use, it is necessary to consider all household production activities, since

labor may be shifted between rice production and other crops and between farm and nonfarm activities at different seasons of the year. In addition it is also important to analyze how the introduction of technological change affects the division of labor by sex. In fact, several writers (e.g., Boserup [1970] and Tinker [1975]) assert that new agricultural technologies have an adverse effect on women, since they lead to an increase in women's work loads, while the work loads of men are reduced.

The seasonal profile of total hours worked each month by family members in farm and nonfarm work (excluding domestic duties, such as cooking) for our two survey sites are shown in table 3. In the IADP area, households were divided into three groups: (a) nonparticipants or households who had not joined the IADP, (b) households who were participating in the project for the first year and (c) households who were second year participants in the project. Boliland households are grouped into (a) households using primarily hand cultivation, (b) households using mixed hand and mechanical cultivation and (c) households using primarily mechanical cultivation.

Of course, with cross-sectional data, we cannot always be sure that the difference among groups are the result of the technological adoption or the cause of the adoption. In the following comparison among groups we assume that observed differences are the result of the technological change. Boliland households with and without mechanical cultivation exhibit similar characteristics with respect to age and sex composition of family members. However, in the IADP area heads of nonparticipant households are older than for participant groups so that a priori we expect their labor inputs to be somewhat lower.

As expected there are definite seasonal peaks in labor use at plant-

Table 3
Seasonality of Labor Inputs for Adult Family Members in Sierra Leone Rural Households
Using Differing Agricultural Technologies

Type of Household	Sample Size	Month[a/]												Total Hours for Year[b/]
		May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	
		Average Hours Worked Per Adult Per Month													
IADP Area															
Male															
Nonparticipant	14	67	147	114	141	93	68	67	68	70	81	60	51		1,027
First year participant	10	187	231	228	268	207	140	124	134	151	131	102	125		2,028
Second year participant	14	167	162	232	201	137	92	84	66	82	69	95	85		1,472
Female															
Nonparticipant	21	46	140	145	164	114	106	106	54	74	41	18	29		1,037
First year participant	14	96	145	153	144	116	80	97	80	87	52	19	36		1,105
Second year participant	15	139	156	143	211	143	89	83	60	60	34	22	28		1,168
Bolilands															
Male															
Hand cultivation	10		125	186	231	199	128	137	204	182	97	56	55	80	1,680
Hand and mechanical cultivation	12		95	184	239	179	93	78	157	160	85	38	25	46	1,379
Mechanical cultivation	14		95	181	215	221	158	120	178	145	57	24	42	52	1,488
Female															
Hand cultivation	7		55	108	160	81	53	39	57	88	54	32	20	22	769
Hand and mechanical cultivation	6		60	133	193	103	86	69	99	119	67	50	25	24	1,028
Mechanical cultivation	20		90	158	214	164	84	75	121	107	59	40	25	32	1,169

Source: Survey data.

[a/] Survey from May 1974 to April 1975 in IADP area and June 1974 to May 1975 in Bolilands.

[b/] Differences between groups significant at 5 percent level for males in IADP and for females in Bolilands.

ing time in June to August and harvest time in December and January and well defined slack periods--in October and November and in the dry season from February to May. In the peak month, male adults consistently work over 200 hours per month. The one exception is the nonparticipant group in the IADP area with a peak monthly average of 147 hours. However, this in part reflects the heterogeneity of this group with respect to crops, so that the peak month varies from household to household. When this average is computed using the peak month for each household the male labor input is 190 hours per month.

The high labor input at the peak season is accomplished through working both more days and longer hours per day. For example, in the Bolilands at the peak month of August, male adults worked 28 days at an average of 8.4 hours per day. Moreover, the number of people who did any work in a month changed over the season through the participation of older people and short-term visitors who are (presumably in response to seasonal labor constraints) concentrated at the peak seasons of harvesting and planting. Also work is concentrated on farming activities at the peak season. In the Bolilands the percentage of time of male adults spent on nonfarm activities such as blacksmithing, trading and construction is only 1.6 percent in the peak months (July to September) compared to 40 percent in the slack period (March to May). These results strongly underline the magnitude of the labor constraint at the peak season. The maximum number of people are working in agriculture almost every day for long hours each day during this period.

The technologies examined here have had relatively little impact on the "spread" of labor inputs over the year. In every case the peak season occurs at planting (July through September) with a subsidiary peak at

harvest (December and January). In the IADP area, first year participants in the project have less pronounced slack periods partly because they are still producing some traditional upland rice which has different seasonal labor demands than swamp rice [Spencer and Byerlee, 1976]. In the Bolilands labor inputs of households with mechanical cultivation are slightly less in the slack period since this is the time of mechanized land preparation.

The introduction of improved technologies has a significant impact on the use of household labor by sex. In the IADP project male adults increase their labor inputs by at least 50 percent when they join the project. In the first year of participation in the project when most land development is undertaken male adults worked over 2,000 hours per year. In contrast, female labor input is not significantly changed by participation in the IADP project.

In the Bolilands, the effect of mechanical technology on labor use by sex is quite different. The mean hours of work per adult male decreases slightly as mechanical cultivation is subsituted for hand cultivation (but the difference is not statistically significant even at the 30 percent level). However, the hours worked increases significantly for female adults so that in households using primarily mechanical cultivation, females work 50 percent more than in households using primarily hand cultivation. Also, at the peak season, women in households using mechanical cultivation work the same number of hours in farm activities as men.

The key to these differential effects of varying technologies on male and female labor inputs lies in the sex-specific nature of some farm activities in Sierra Leone. In the Bolilands mechanization almost completely eliminates the land preparation usually undertaken by men but increases

farm size so that there is an increase in the demand for labor for planting and harvesting where women traditionally play an important role. In the IADP area, the substantial land development required in the early years of the project places the burden of the work primarily on men.[8]

This analysis of total work hours for adults shows that the number of hours worked for both men and women nearly always exceeds the 1,000 hours per year noted by Cleave [1974] in a review of several African surveys. In most cases too, this labor input exceeds 1,200 hours per year stated by Brandt [1974] as the maximum number of hours worked by male adults in rural households of tropical Africa.

Finally, in this paper we have not examined buying and selling of labor, although this is clearly an important activity in both project areas. However, it should be noted that in the Bolilands area the wage rate for men and women was almost identical, while in the IADP area, as in most other areas of Sierra Leone, the daily wage rate for men was about one-third higher than women.[9] This observation supports our earlier findings with respect to the relatively important role of women in the Bolilands compared to the IADP area. It is also of interest to note that there is considerable hiring of labor at harvest in both areas, although household members work less at this time than in the peak planting season. With cash in hand at harvest time and an available supply of labor, some farmers are apparently willing to hire labor and reduce their own labor inputs.

Conclusions

Examination of the impact of two technological packages representing biological-chemical technology and mechanical technology in rice production in Sierra Leone has illustrated some of the interrelationships

between improved technology and labor use. In a situation of a high land-labor ratio, mechanical technology can overcome peak season labor constraints and increase the acreage cultivated. Under these conditions mechanization is not labor displacing, since the increased acreage resulting from mechanization requires added labor for planting and harvesting.

Private returns to family labor are substantially increased by mechanization, but because of a large subsidy for the use of tractors the economic returns are low. The biological-chemical technology increases returns to land, but because of a large increase in labor requirements the returns to labor are below that for traditional swamp rice cultivation. These results have significant implications for policy in Sierra Leone. Under present costs and factor endowments both technologies have low economic returns. Other technologies which have higher returns to peak season labor such as improved seed and fertilizer for upland rice should be given greater emphasis [Spencer, 1975].

Analysis of total family labor inputs in the various systems demonstrated that peak season labor demand is indeed a constraint to increased production since farm families are working at capacity during this period. Moreover, there is relatively little underutilized labor among our sample of farmers even if 2,000 hours per year are taken as an upper bound for labor use. Finally, our results suggest some important interrelationships between use of improved technology and division of labor by sex. Biological-chemical technologies increased the male labor input but did not affect female labor inputs while mechanical technology increased female labor inputs but male labor slightly declined.

Finally the analysis presented in this paper demonstrates the need for detailed information to evaluate the impact of new agricultural technologies on the demand and supply of labor. Under the conditions we have examined in this paper it is clear that the use of labor in the peak season

should be a priority consideration in the development of technological packages for small farmers.

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Footnotes

Dunstan S.C. Spencer is currently Visiting Associate Professor of Agricultural Economics, Michigan State University, on leave from his position as Senior Lecturer, Njala University College, Sierra Leone. Derek Byerlee is Assistant Professor of Agricultural Economics, Michigan State University and formerly Research Fellow, Njala University College, Sierra Leone. This research was financed under a U.S. Agency for International Development Contract (AID/csd 3625) with Michigan State University subcontracted to Njala University College.

[1]There is also some variation in biological technology in the Boliland area with respect to the planting procedures--broadcasting or transplanting--and use of fertilizer.

[2]Weeding is not an important activity in swamp rice production in either or the two study areas.

[3]Equation estimated directly through non-linear maximum likelihood regression approach following Ramsey and Zarembka [1971]. R^2 for the estimation was .73. This function was chosen because unlike the Cobb-Douglas function it allows the elasticity of substitution to range from 0 to infinity and can thus better reflect the extent to which factors can be substituted for one another.

[4]The function fitted was, $Ya = 7.40 + \underset{[.07]}{.15}\ Fa + \underset{[.006]}{.014}\ La$ where Ya is yield per acre (bushels), Fa is fertilizer per acre (pounds), and La is labor per acre (hours). Standard errors are bracketed and the R^2 is .50. A variable representing method of ploughing (hand or mechanical) had no significant effect. However, mechanical farms use 60 pounds of fertilizer per acre compared to 37 pounds per acre on hand cultivation.

[5]In fact, part of this difference is the result of higher inputs of fertilizer on mechanical farms. If hand cultivation fields use the same level of fertilizer, returns per man hour are 22 cents.

[6]It is estimated that current subsidy levels are 67 percent for fertilizer and 85 percent for mechanical services.

[7]Yields of improved rice in the area are below the potential for the area partly because farmers did not follow recommended practices especially in the second year of participation when the level of extension advice was reduced, cultural practices were poor and the rate of fertilizer was reduced. Also labor inputs are high partly because farmers are still engaging in land improvement even in the second year of the project.

[8]We should raise a note of caution that the two areas compared here include two different ethnic groups. Work is now underway to examine the role of women in different production systems and ethnic groups in Sierra Leone.

[9]Based on 551 observations in IADP and 407 observations in the Bolilands an analysis of variance showed significant seasonal differences in wage rates in both areas at the 1 percent level and significant sex differences in the IADP area only.