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ABSTRACT

Agriculture is the most important sector of Nepal's economy and within this sector, rice is the most important cereal. A field survey in the southern Kosi zone, one of Nepal's major rice-producing areas, examined the comparative profitability of modern (MV) and local (LV) rice production and the distribution of earnings from rice between farm operators and laborers.

Interviews with 166 rice farmers were augmented with information from the rice service industry. Tenant farmers rarely grew MV; among the owner-operators sampled, those with access to irrigation and production credit tended to be the adopters of MV technology. A production function analysis showed that the productivity of rainfed LV did not differ significantly due to tenure status, and that the productivity of both MV and LV was higher in irrigated than in rainfed fields. Farmers used more labor to grow MV than LV and within varietal groups, more labor was used to grow irrigated than rainfed rice. Owners growing irrigated MV used more hired labor than owners growing rainfed MV or tenants producing LV.

Gross margins were higher for owners than for tenants. Within the subset of owners, MV produced slightly higher benefits than LV in irrigated fields but lower benefits in rainfed fields. A hypothetical budget analysis indicated that a tenant would gain less growing MV than LV in rainfed fields.

Hired labor earns 20-25% of an owner-operator's and 13% of a tenant's rice crop and more from irrigated than from rainfed rice irrespective of variety. Current inputs earn 7-14% of the output -- higher for MV than for LV.

Owner-operators in the southern Kosi zone with irrigation appear to be benefiting from the introduction of MV, but tenants have not and generally do not grow them. Land reform will probably not lead to farmer tenants growing MV. Other factors strongly associated with the adoption of MV are access to irrigation and production credit. Although tenants have not directly benefited from the MV, they and landless laborers have indirectly benefited through increased employment on farms growing those varieties.

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RICE PRODUCTION IN THE TARAI OF KOSI ZONE, NEPAL

Agriculture provided Nepal's economy with more than 60% of its Gross Domestic Product, more than 80% of the country's export earnings, and employment for nearly 90% of its labor force in the late seventies (CBS 1977). This sector continues to play an important role in creating employment, earning foreign exchange, and meeting Nepal's domestic food requirements.

In the current Agricultural Development Plan it is proposed that the alternative agricultural options be evaluated in relation to farm and national profitability and the distribution of the predicted benefits among various social groups. Considerable emphasis is being placed on developing and extending the use of modern varieties of rice, wheat, and maize. This paper focuses on rice, the most important cereal in Nepal.

The welfare implications of the new rice technology have been the subject of considerable debate (FAO 1972, IRRI 1978, Farmer 1979), which has tended to focus on the logic that the technology associated with the spread of modern varieties is labor saving compared to existing methods of rice production. This shift in input use, it is argued, reduces the returns to labor -- which often is the less advantaged rural dwellers, the landless laborers, and tenant farmers -- and increases the returns to other factors of production such as land and capital items often owned by relatively privileged persons. Some empirical studies support this view (Griffin 1974, Sinaga and Sinaga 1978, Collier 1979), others do not (Ranade and Herdt 1978, Critchfield 1979).

The distribution of benefits derived from technological advances are the outcome of complex interactions between the characteristics of the technology, the rural institutions, and economic policies prevailing in the area, which in turn affect the distribution of resources and prices in both input and product markets (Kikuchi and Hayami 1980, Sisler and Colman 1979). Thus, it is hazardous to extrapolate the findings of research on this issue from other countries to Nepal -- or from one agroecological zone of Nepal to another. For this reason, the impact of modern rice varieties (MV) on the income and employment of farmers and laborers was examined in the southern Kosi zone as one ecological zone of Nepal. The area was chosen because it is an important rice-exporting area and a target zone within Nepal for land reform and for the extension of modern farming methods.

DATA SOURCES AND FARM CHARACTERISTICS

The southern Kosi zone is on the northern fringe of the Gangetic plain in the Tarai of southeastern Nepal. Crops and livestock are closely integrated in prevailing farming systems. Modern rice varieties were introduced in the late sixties and now occupy some 24% of the rice land (HMG Nepal 1977). IR8 is the dominant MV in the area. Typical rice-based cropping patterns on wetland fields are MV and wheat (Mexican RR21), jute (early) and MV, and MV (early) and local[2] rice variety (LV) (late) (Mathema and Van der Veen 1978). Jute, maize, mustard, and pulses are the dominant crops on dryland fields.

A field survey from November 1978 to February 1979 provided information on resource use and productivity of MV and LV. Data were primarily collected from two classes of respondents:

- Institutions (banks, cooperatives, Agricultural Inputs Corporation, Department of Agriculture, Rice-Exporting Company, etc.) and private agencies (rice merchants, machinery dealers, etc.) to obtain background information on the distribution of MV and associated inputs; and
- Rice farmers. 166 farmers were interviewed to obtain information on their rice-based cropping systems.[3] A portion of the survey sought detailed information on the farmer's largest rice plot, following the concept of the *intensive data parcel* (De Datta et al. 1978).

Some characteristics of the households surveyed are listed in Table 1. The farmers sampled were from two distinct ethnic groups -- those indigenous to the Tarai and those who migrated from adjoining hills since the 1950s following the suppression of malaria. More of those who had migrated owned the land they farmed than was the case with the indigenous inhabitants (χ^2=4.99**). Discussion with those familiar with the area suggested two important reasons for this apparent anomaly:

- Before the suppression of malaria the Tarai people tended to live on the higher ground and there were fewer people in the Anopheles-infected area. Thus, these large wetland areas -- which are now the better rice lands -- tended to be vacant lands.

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[2]The term *local* is used in preference to *traditional*. Most of the local rices grown in eastern Tarai are improved varieties introduced from India.

[3]Background surveys of value included HMG Nepal (1971) and ILO (1976). Area sampling was used to identify 14 panchayats (villages). Within these sample panchayats, stratified random sampling was used to ensure that a minimum of 2 samples were drawn from each of three strata (owners whose main rice crop was a modern variety, owners whose main rice crop was a local variety, and a tenant farmer).

- Government-sponsored resettlement schemes provided the migrants with tenured land in the Tarai, often in the less-populated tracts.

Family size was similar between tenure groups. The owner-farmers had a larger full-time family labor force than the tenant-farmers. Owners, however, farmed larger holdings and as a result, tenants had significantly more labor per hectare than owners. Owners had a significantly higher proportion of their farms irrigated, and a significantly higher cropping intensity, than did tenants.

Table 1. Structure of rice-producing farm households, southern Kosi zone, Nepal, 1979.

	Av value		t-test[a]
	Owner	Tenant	
Origin of respondents (%)			
Tarai	29	41	
Hills	71	59	
Family size (no.)			
All members	8.8	8.4	.57 ns
Full-time farming	4.5	3.8	3.02**
Part-time farming	.8	1.1	.91 ns
Formal schooling of operator (years)	6.5	1.0	6.54**
Farm size (ha)	2.6	1.4	2.59**
No. of parcels	2.8	1.6	6.17**
Man-land ratio[b]	1.6	2.7	2.68**
Portion of farm irrigated (%)	61	21	5.59**
Multiple cropping index	1.6	1.3	3.02**
Livestock density (animals/ha)	3.9	3.1	1.04 ns
Sample size	134	32	-

[a]To test for differences between mean values of owners and tenants. **Significant at 1% level, ns = not significant. [b]Ratio of full-time family labor force to total farm size. Source: Data collected by authors.

CHARACTERISTICS OF PRODUCERS OF MODERN AND LOCAL RICES

During the pretest of the survey it became apparent that although essentially all farmers had some areas planted to LV and half the owner-operators grew MV, it was rare to find a tenant growing MV. Thus, we purposely sought out such rice producers. The percentage of tenants growing MV in the sample (3 in number) was not indicative of their proportion in practice. It is instructive, therefore, to examine the factors, and their relative importance, that appear to be associated with the adoption of MV in the area. To distinguish between the MV adopters and non-adopters in terms of their underlying characteristics or discriminatory variables, we used discriminant analysis (Fisher 1936).[4]

The logic and procedures of discriminant analysis are reported elsewhere (e.g. Klecka 1975, Tatsuoka 1970, Tintner 1952). The discriminant function takes the form:

$$D_j = d_1 Z_{ij} + d_2 Z_{2j} + \ldots + d_n Z_{nj}$$

where

D_j = is the discriminant score estimated for observation j;

Z_{ij} = is the level of the ith discriminant variable (i = 1, ...,n), for observation j, coded in standard form;

d_i = are the standardized coefficients of the linear discriminant function.

The d_i's are estimated such that the squared difference between the mean D-score for the one group and the mean D-score for the other group is as large as possible in relation to the variation of the D-scores within groups.

The nonstandardized and standardized discriminant coefficients are listed in Table 2. The discriminant function is significant at the 1% level and correctly classified 80% of the observations.[5] Four underlying characteristics were found to significantly differentiate between adopters and non-adopters -- tenure, irrigation, use of formal sources of production credit, and the farmer's education. Other factors -- farm size, livestock density, and the family labor force -- were judged to be insignificant. The relative importance of the significant factors when discriminating between adopters and non-adopters is gleaned from

[4]Adoption is obviously not a zero-one effect in the sense that farmers often grow MV in some fields and LV in others. Thus, the proportion of the farm grow to MV is frequently used as the dependent variable i regression models. This approach proved to be of limited value in the present case so discriminant analysis was used. The unit of analysis for adoptio non-adoption was the farmer's intensive data parcel.

[5]The statistical theory of discriminant analysis assumes that the discriminating variables have a multivariate normal distribution, which is clearly not the case for the tenure and irrigation dummy variables, for example. However, as pointed out by Klecka (1975) and Morrison (1969), the technique is, in practice, very robust and these assumptions need not be strongly adhered to.

the standardized discriminant coefficients reported in Table 2. Whether the farmer was an owner, had irrigation, and used production credit was found to dominate when distinguishing between adopters and non-adopters. The farmer's formal education, however, has a small standardized (or weighting) coefficient, and from an empirical viewpoint appears to have a smaller impact on the farmer's adoption of MV than the tenure, irrigation, or credit variables per se.

In summary, within the group of owners, those with access to the complementary inputs to MV -- irrigation and access to production credit -- also tended to be the adopters of the *modern* rice technology. As reported elsewhere (IRRI 1975, 1978), the so-called seed-fertilizer technology was more commonly adopted in the favorable, irrigated environments. Although tenure is less frequently identified as a factor significantly influencing the adoption of MV, the results of our study are consistent with others reported for the Indian subcontinent (Khan 1975, Mandal and Ghosh 1976, Schluter 1971).

Table 2. Estimated coefficients of the discriminant function for adopters and non-adopters of modern varieties, southern Kosi zone, Nepal, 1978.[a]

Variable	Canonical discriminant coefficient: Unstandardized	Canonical discriminant coefficient: Standardized	F-ratio[b]
Irrigation (dummy)	-1.38	-.57	75.92**
Education (years)	[c]	-.02	30.04**
Credit (dummy)	1.37	-.57	73.41**
Tenure (dummy)	-.78	-.28	36.71**
Farm size (ha)	.02	.11	.24[ns]
Livestock (no./ha)	.05	-.20	1.85[ns]
Farm labor (no. of persons)	-.05	-.09	5.16[ns]
Family size (no. of members)	.03	.13	1.67[ns]
Constant	2.06	-	

$\chi^2 = 97.12$**

"Grouped" cases correctly classified = 80%.

Group centroids: non-adopters = .79
adopters = -1.04

[a]The discriminant function was estimated using SPSS, see Klecka (1975). [b]**Significant at 1% level, ns = not significant. [c]Implies less than .01.

Table 3. Mean rice yields reported by farmers in the southern Kosi zone, Nepal, 1978 monsoon.[a]

Category	Variety	Mean yield (kg/ha)	Sample size	Significant difference
I. Combined	modern	2678	75	x
	local	1850	94	y
II. Owners				
Irrigated	modern	2805	60	a
	local	1995	22	bc
Rainfed	modern	2070	12	b
	local	1814	40	bc
III. Tenants				
Irrigated	modern[b]	(2577)	(3)	
	local		nil	
Rainfed	modern		nil	
	local	1721	29	c

[a]In a column means followed by the same letter are not significantly different at the 1% level. The combined results (I) compare the means of local (LV) and modern (MV) varieties, irrespective of tenure or irrigation status. [b]The sample of 3 tenants growing MV with irrigation was derived from purposeful sampling and is too small to allow meaningful comparison with other strata. Thus, although the data are reported for comparative purposes, they are not included in the statistical analysis, and therefore enclosed in parentheses.

YIELDS, RESOURCE USE, AND INCOME GAINS FROM MODERN RICE VARIETIES

The mean yields reported by farmers for MV were significantly higher than for LV (Table 3). However, as shown in the same table, these averages mask important differences -- and similarities -- within and between rice production systems. For example, owners growing MV reported significantly higher yields when the crop was irrigated (2.8 t/ha) than when rainfed (2.1 t/ha). Although the differences were not significant the same trend was observed between irrigated and rainfed production of LV. Within the subsets of rainfed LV, mean yields obtained by owners (1.8 t/ha), and tenants (1.7 t/ha) were not significantly different. The three tenants who grew MV with irrigation (pumpsets) reported an average yield of 2.6 t/ha. No tenants growing rainfed MV or irrigated LV were included in the sample.

Labor use in modern and local rice production

The total labor input to grow MV was significantly higher than for LV (Table 4). The higher labor input was achieved by hiring more labor instead of making the farm-household themselves work more

days. Indeed, the use of family labor was significantly lower for MV than for LV. A comparison of the influence of tenure on labor for LV production showed that although total labor inputs were higher on an owner's than on a tenant's crop, it was not significantly so. However, owners were hiring significantly more labor whereas tenants used higher levels of family labor to grow their LV.

Table 4. Reported total labor input, by category, for three rice production systems, southern Kosi zone, Nepal, 1978 crop season.[a]

Labor input (days/ha)	Owner		Tenant,
	MV	LV	LV
Family	25a	39b	53c
Hired	102a	62b	36c
Total	127a	101b	89b

[a]In a column, figures followed by the same letter are not significantly different at the 5% level. MV = modern varieties, LV = local varieties.

Labor use, by operation and production category, is shown in Table 5. The mean total labor input for land preparation ranged from a low of 31 labor days/ha to a high of 37 labor days/ha, but did not differ significantly between production systems. The proportion of family labor used in this process was lowest for the owner producing MV and highest for the tenant producing LV. Similarly no significant difference in total labor input for crop establishment (largely transplanting) was observed. However, a larger proportion of the labor used to establish MV was provided by hired labor than was the case with LV.

In the case of preharvest crop management -- largely weeding -- labor inputs were highest for MV, whether irrigated or rainfed, than for LV. Within the set of LV, the irrigated subset was weeded more intensively than those varieties grown in rainfed paddies. As with land preparation, a larger proportion of the labor used to weed MV was supplied by hired labor than by family labor. The benefit of, or need for extra weeding, particularly when fertilizer is applied, for MV, if its yield potential is to be achieved, is recognized by farmers. This observation is consistent with the findings of agronomists that MV in general are less competitive with weeds in their early growth stages than LV (Moody 1979).

Harvesting and threshing labor (50 labor days/ha) was significantly higher for irrigated MV (about 33 days/ha) than for the other production systems. Within LV, labor inputs for these operations were similar regardless of tenure. The quantity of labor used to harvest and process the crop was positively related to the crop yield and inversely related to bullocks used to thresh the crop by trampling the straw, as a substitute for hand threshing. The relationship estimated between harvest/postharvest labor (HL) in labor days, yield (Y) in kilograms per hectare, and animals used for threshing (A) in bullock days was:

$$\text{LV:} \quad HL = 7.235\ Y^{.583}\ A^{-.176} \qquad \bar{R}^2 = .38,\ F = 28^{**}$$

$$\text{MV:} \quad HL = 11.811\ Y^{.481}\ A^{-.281} \qquad \bar{R}^2 = .43,\ F = 26^{**}$$

with all partial regression coefficients significant at the 1% level.

Total labor inputs for harvest and postharvest operations are expected to be higher for MV because of higher yields. However, that did not account for the substantially higher levels of hired labor with the MV. The probable reason for the dominance of hired labor for these operations is that MV tend to mature in the wet season when unfavorable weather results in a high risk of grain spoilage and crop loss unless the rice is harvested and threshed rapidly. Completing harvest and postharvest operations in a short period once the MV crop is mature requires more labor than the family can provide from its own resources. Thus, the use of hired labor at harvest time can be expected to increase when farmers switch from LV to MV. The problem does not occur to the same extent with LV because they are photoperiod sensitive and mature in the dry season.

In summary, in the eastern Tarai of Kosi zone, more labor is used to grow MV than LV and, within varieties, more labor is used to grow an irrigated than a rainfed crop. Furthermore, a greater proportion of hired labor is used to grow MV than to grow LV. The higher labor input tends to be concentrated in weeding and harvesting where the timeliness of operation is an important determinant of the eventual yield of the crop.

The family labor figures reported in this study probably understate the owner-operator's time committed particularly to MV rice production. The reason for this implied bias is the survey's inadvertent focus on field operations and failure to capture the time allocated by farmers in the planning and management of their crops and in the supervision of hired laborers. As demonstrated by Smith and Gascon (1979) management and supervision functions become comparatively more important with MV where the timeliness of operations is more critical, and where in general, more labor is hired to enable completion of these tasks in as timely a manner as possible.

Power inputs

The major nonhuman power for rice production in the Kosi zone are bullocks for land preparation and threshing. The mean number of bullock-pair days per hectare ranged from a low of 34 for the tenant farmer to a high of 40 for the owner-farmer growing rainfed MV. The weighted average of 36 days/ha did not differ between production systems; more than 84% of bullock time was allocated to land prepara-

Table 5. Labor inputs (labor days/ha), by operation and rice production category, southern Kosi zone, Nepal, 1978 rice crop.[a]

Task	Owner				Tenant	
	Irrigated		Rainfed		Rainfed	Irrigated[b]
	MV (n = 60)	LV (n = 22)	MV (n = 12)	LV (n = 40)	LV (n = 29)	MV (n = 3)
Land preparation						
Family	12	16	16	18	26	(13)
Hired	21	17	21	16	5	(21)
Total	33a	33a	37a	34a	31a	(34)
Crop establishment						
Family	4	7	2	10	9	(5)
Hired	23	19	23	13	12	(12)
Total	27a	26a	25a	23a	21a	(27)
Preharvest						
Family	4	4	6	3	2	(14)
Hired	14	10	12	6	3	(0)
Total	18a	14ab	18a	9bc	5c	(14)
Harvest/postharvest						
Family	4	8	7	11	15	(25)
Hired	46	27	27	21	18	(5)
Total	50a	35b	34b	32b	33b	(30)
Total labor inputs						
Family	24	35	31	42	52	(67)
Hired	104	73	83	56	38	(38)
Total	128ab	108bc	114ab	98cd	90d	(105)

[a]In column means followed by the same letter are not significantly different at the 5% level. MV = modern varieties, LV = local varieties. [b]Due to the small sample size of this stratum, the data are included only for information and are, therefore, enclosed in parentheses. See Footnote b, Table 3.

tion.[6] Hired bullocks accounted for less than 10% of bullock use.

Irrigation

Of 166 farmers interviewed, 84 reported they irrigated their rice crop: 28 used pumps and 56 used surface supplies to supplement rainfall. Most of the pumps were 5- to 7-hp diesel, 10-cm pumps. The surface supplies varied from small diversions from local streams to the Chatra Canal, a government irrigation scheme. There was general agreement among farmers that in winter it was more profitable to irrigate wheat than the monsoon-season rice crop. The direct cost of irrigation water varied widely between sources. In the case of local diversions there was no specific water rate, but for the Chatra Canal, farmers were charged Rs64/ha per crop. Pumps were owned, or rented for Rs10-11/hour.[7] The weighted average irrigation cost across supply sources (Rs62 for MV and Rs12/ha for LV) was used in the budget analysis reported later.

Other inputs

The other important managed inputs for rice in Nepal's eastern Tarai were seed and fertilizer. Herbicides were not used for weed control, and only one farmer reported use of insecticides. Farmers reported lower seeding rates for their irrigated rice (61 kg/ha) than for the rainfed

[6]Tractors are used extensively for wheat but less so for rice cultivation in the zone. Of the 166 farmers sampled, only 5 reported the use of tractors, and then in combination with bullocks, for land preparation. The users of tractors for primary tillage of rice lands fell into each stratum. In this analysis tractor inputs were converted to equivalent bullock days.

[7]At the time of the study (December 1978-January 1979) 12 Nepalese rupees (Rs) = US$1.

rice (66-68 kg/ha) but the differences were not significant (Table 6). Tenant farmers claimed they did not use inorganic fertilizer on their rice crop; owner-farmers applied minimal amounts to LV (mainly in the seedbed) and an average of 89 kg/ha of inorganic fertilizer (mainly ammonium sulfate) to their irrigated MV rice crop and 47 kg/ha to their rainfed MV rice crop.

Compost from farmyard manure was used in all rice production systems. The quantities applied were significantly higher for MV than for LV. The compost levels reported do not, however, provide an accurate estimate of the nutrients applied because the unit of measurement for compost -- *doku*, which is about 15-20 kg -- is an imprecise volume measure, and the nutrient content of compost varies widely between sources.

Table 6. Average levels of seed and fertilizer inputs (kg/ha) reported by farmers, southern Kosi zone, Nepal, 1978 rice crop.[a]

Input	Owner				Tenant, rainfed,
	Irrigated		Rainfed		
	MV	LV	MV	LV	LV
	(n = 60)	(n = 22)	(n = 12)	(n = 40)	(n = 29)
Seed	61a	61a	68a	66a	67a
Fertilizer	89a	0c	47b	5c	0c
Compost	3246a	996b	2850a	1790b	1195b

[a]In a column means followed by the same letter are not significantly different at the 5% level. MV = modern varieties, LV = local varieties.

Gross margins of rice production systems

Cost and returns analysis for the five production systems are listed in Table 7. The full-cost values represent the case where farm resources (labor, bullocks, compost) were valued at the current rate for hiring the service of buying the input, whereas the cash-cost basis represents the cost of services and inputs actually purchased by farmers.

The value of rice accruing to the farmer and the straw produced are the principal components of gross revenue of the rice crop. Modern varieties have a higher grain yield, but lower price and a lower-valued straw than the LV. The cost of labor (family and hired) accounts for 40-50% of costs on a full-cost basis; seed accounts for 10-14%, and bullock power 16-24%. Fertilizer inputs are substantial for irrigated MV (nearly 25% of production costs), but less than 15% of the costs for the other rice production systems.

The gross margins are clearly higher for the owner than for the tenant, principally because the tenant must share his crop with a landlord. Within the subset of owners producing rice, MV are calculated to provide a higher net benefit than LV in irrigated environments. However, in rainfed conditions, LV appear of comparable or higher profitability than the MV. Furthermore, the benefit-cost ratio is judged to be higher for LV than for MV in irrigated and rainfed fields.

In summary, the budget analysis reported in Table 7 suggests that although MV are probably more profitable than LV in irrigated fields, the reverse is true in rainfed fields. This modest increase (or decrease, in rainfed conditions) in profit is a result of a lower unit value of grain and straw coupled with higher levels of input costs of the MV compared to LV.

HYPOTHETICAL ANALYSIS OF TENANTS GROWING MODERN VARIETIES

An impression of MV versus LV rice production, in irrigated and rainfed field, is given in Table 8. In this hypothetical example, the tenant is assumed to use half the level of inorganic fertilizer used by the owner. Labor inputs are not reduced (the extra labor used to grow MV is hired), but yields are reduced 10% below that reported by owners in similar environments.

The net increment in revenue realized where the tenant changes varieties is less than the proportional increase in yield because of the lower price received for the MV, the increased proportion of the crop paid to hired harvest labor, and the reduced value of the straw. The main increases in cash costs are for labor and inorganic fertilizer. The bottom line shows that given present technology, the net change in profit for a tenant switching to MV is probably negative if the crop is rainfed, whether judged on a cash-cost or a full-cost basis. Where the tenant has access to low-cost irrigation, however, it may be marginally profitable for him to change to MV.

The estimates of the changes in benefits and costs resulting from the tenant adopting MV are clearly speculative for two important reasons.

- The numbers, at best, are first approximations to the input-output relationships that would occur in practice if the *new* production systems were adopted.

- Implicit to the argument is the assumption that the tenant alone decides which variety to grow and how to manage the crop. This assumption, while consistent with the conventional wisdom for landlord-tenant relationships in the eastern Tarai, was not, unfortunately, explored during the course of the study. The implied freedom of choice of the share tenant does not normally gain wide support in modern writings on landlord-tenant relationships (e.g. Hayami and Kikuchi 1981, Chapter 2).

Recognizing these caveats, the analysis suggests that with present tenural arrangements, MV grown as a rainfed crop is less profitable, or at least no

more profitable, than LV for tenant farmers in the southern Kosi zone. Specifically, without a sharing arrangement for cash costs, or a change in the shares of output (given existing technology) or a change in technology itself, which will probably involve access to irrigation, there appears to be little incentive for tenants to adopt MV in this zone of Nepal.

DISTRIBUTION OF EARNINGS FROM RICE

One way to contrast the distribution of benefits between MV and LV, irrigated or rainfed, is to compare the shares of output accruing to different factors which must be paid out of the crop proceeds. Following Ranade and Herdt (1978) the shares of output were computed as:

1. payment to landlord -- value of output given as land rent less costs borne by the landlord;
2. payment to hired labor -- sum of all operations of wage rates times the number of days worked, plus value of output given to harvesters;
3. payment to family labor -- value, imputed at wage rates of hired labor, of family labor who worked in producing the crop;

Table 7. Estimated gross margins (Rs/ha) for five rice production systems, southern Kosi zone, Nepal, 1978 rice crop.[a]

	Owner				Tenant, rainfed, LV
	Irrigated		Rainfed		
	(n = 60)	(n = 22)	(n = 12)	(n = 40)	(n = 29)
Value of output					
Rough rice (kg/ha)	2805	1995	2070	1814	1721
Harvester's share[b]	323	192	205	149	117
Landlord's share[c]	-	-	-	-	753
Net yield (kg/ha)	2482	1803	1865	1665	851
Net value of grain[d]	2954	2218	2219	2048	1047
Straw yield (kg/ha)[e]	2805	2993	2070	2721	2582
Value of straw	200	329	200	299	234
Gross value of rice crop (Rs/ha)	3154	2547	2419	2347	1331
Input costs (Rs/ha)					
Labor: family[f]	168	245	217	294	364
: hired[f]	406	322	392	245	140
Bullock: owned[g]	245	238	280	259	231
: hired[g]	0	14	0	14	7
Seed[h]	153	122	170	132	134
Fertilizer: inorganic	182	0	96	10	0
: compost	195	60	171	107	72
Pump set cost[i]	62	12	-	-	-
Interest on cash costs[j]	64	39	52	32	22
Total cash cost	867	509	690	433	303
Total full cost	1475	1052	1378	1093	970
Gross margin (Rs/ha)					
Full-cost basis	1679	1495	1041	1254	361
Cash-cost basis	2287	2038	1730	1914	1028
B-C ratio; cash costs	3.63	5.00	3.51	5.42	4.39

[a]MV = modern varieties, LV = local varieties. A dash (-) indicates not applicable. [b]The harvesting/threshing share averaged 12.5% of the crop. However (see Table 5), the farm family contributes from 10 to 50% of the harvest labor. Thus, the harvester's share is that reported paid to the harvesters; the family contribution to harvesting is reflected in the cost of family labor. [c]Fifty percent of the cleaned rice after harvesters' share is deducted. [d]IR8 was priced at Rs1.19/kg, LV at Rs1.23/kg. These are on-farm prices, not posted or official prices. US$1 = 12 Nepalese rupees (approx). [e]Based on a grain-total harvest (grain + straw) ratio of 50% for IR8 and 40% for LV. Japonica-type straw used widely as livestock feed and valued at Rs11/quintal; IR8 straw sold at Rs200/ha for strawboard manufacture. [f]Labor valued at Rs7/day (wages plus meals). [g]Valuing a pair of bullocks at Rs7/day. [h]For seed, IR8 = Rs2.50/kg; LV = Rs2.00/kg. [i]See section Irrigation. [j]2% per month for 4 months on cash costs.

4. payment to current inputs -- covers expenses for fertilizer and other agrochemicals, rent of bullocks, etc;

5. payment to institutions -- landowners are assessed land taxes, and as applicable, irrigation dues by Government; and

6. operator's residual -- the value of output less payments made to participants (1-5), above. Payments to capital and the operator's profit were not discriminated due to a lack of information on the value of the farmer's capital equipment and its use on other crops. Thus, the operator's residual, as calculated, approximates a return to the farmer's management and capital.

Table 8. Hypothetical changes in costs and returns if a tenant grew modern rice varieties in irrigated and rainfed conditions.[a]

	Tenant Rainfed LV[b]	Hypothetical change Irrigated, MV	Hypothetical change Rainfed, MV
Value of output			
Rough rice (kg/ha)[c]	1721	+804	+142
Harvesters' share	117	+101	+ 18
Landlords' share[d]	753	+352	+ 62
Net yield (kg/ha)	851	+351	+ 62
Net value of grain[e]	1047	+383	+ 40
Straw yield	2582	- 57	-719
Value of straw[f]	234	- 34	- 34
Gross value of rice crop (Rs/ha)	1331	+349	+ 6
Input costs (Rs/ha)			
Labor: family[g]	364	0	0
: hired	140	+ 70	+105
Bullock: owned[h]	231	+ 14	+ 70
: hired	7	- 7	- 7
Seed	134	+ 19	+ 16
Fertilizer: inorganic[i]	0	+ 91	+ 48
: compost	72	+123	+ 99
Pump set cost	0	+ 62	0
Interest on cash costs	22	+ 19	13
Total cash cost	303	+254	+175
Total full cost	970	+391	+344
Gross margin (Rs/ha)			
Full-cost basis	361	- 42	-338
Cash cost basis	1028	+ 95	-169

[a]MV = modern varieties, LV = local varieties. [b]Source: see Table 7. [c]Tenants' yields reduced 10% below owners' for same production system. [d]50% of the cleaned rice after harvesters' share (12.5%) is deducted. [e]MV priced at Rs1.19/kg (see Table 7, footnote c). [f]As in Table 7, assuming straw of MV is sold for Rs200/ha. [g]Assuming no change in family labor use, increase in labor is hired. [h]Bullock inputs taken as difference between owner, MV; and tenant, LV. [i]Assumes tenants use half the level of fertilizer used by owners but same levels of compost.

The distribution of the total rice yields to various claimants on the crop for the five production systems are listed in Table 9. In the table, the opportunity cost of farm labor and animal power are imputed at the cost of hiring these services. The landlord's share of his tenants' crop is nearly 44% of the yield (50% net of harvesters' shares). However, the landlord pays the land taxes and his residual after meeting these costs is 42% of the crop. Because owner-operaters do not share their crop with landlords, this component is retained as part of the operator's residual. The owner's residual, irrespective of production system, is in the order of 50-55% of the crop, the tenants', less than 20%.

Hired laborers earn about 20-25% of the landlord's, and 13% of a tenant's crop. In quantity terms, this amounts to 0.5 to 0.6 t of the owner's MV crop, and 0.3 to 0.4 t of his LV crop. For both MV and LV, hired labor earns more from the irrigated than from the rainfed rice crop. Hired laborers earn less of the tenant's crop (0.2 t) largely because tenants use a higher proportion of family resources. Current inputs (seed, fertilizer, hired power) earn in the order of 7-14% of the output and are higher for MV than LV. Taxes and levies account for less than 3% of the output.

PRODUCTIVITY DIFFERENCES BETWEEN PRODUCTION SYSTEMS

The preceding analysis has shown differences (and similarities) in profit levels between the five systems studied. However, because input levels, combinations, and technologies differ between the systems, the analysis has not clearly identified whether there are differences in resource productivity between owners and tenants, or between irrigated and rainfed systems of rice culture.

To provide some insights to the productivity question, linear output functions were estimated for MV and LV;

$$y = b_0 + b_1x_1 + b_2x_2 + b_3D + e$$

where

y is the total output of the intensive data parcel (IDP), in quintals;

x_1 is the area of the IDP, in hectares;

x_2 is, in the case of MV, the quantity of inorganic fertilizer applied to the IDP, in quintals;

x_2 is, in the case of LV, the quantity of compost applied to the IDP, in quintals;

D is a credit dummy (D = 0, no credit; = 1, received credit);

e is a random variable; and

b_i (i = 1, ..., 3) are the regression parameters to be estimated.

The simple linear model was chosen because alternative formulations of the model did not provide improvement over the ones reported. Other variables (e.g. seed rate, bullock inputs, etc.) were examined but not included in the analysis because the coefficients were not statistically significant. Others (e.g. labor inputs) were excluded because of their high collinearity with the size of the IDP (i.e. variable x_1).

Owners versus tenants, local varieties

Because tenants, in general, were not growing MV or irrigating their LV, the only comparison of owners' and tenants' rice production that can be reasonably made is of their rainfed LV. Production functions for rainfed LV between owners and tenants were examined using the approach suggested by Chow (1960) to test for significance between regression functions. As shown in Table 10 this involves estimating the following rice response functions for LV:

- for owners and tenants, separately; and
- for owners and tenants, pooled.

The F-ratio of 1.01 ($n_1 = 4$, $n_2 = 61$) is not statistically significant (Table 10). Therefore, there is a lack of statistical evidence from which to imply that rainfed LV have different production functions when grown by owners or tenants. That is, the tenure of the operator does not appear to influence the productivity of rainfed LV in the study area.

Irrigated versus rainfed local varieties

Because the crop response functions for farmers producing rainfed LV appear independent of tenure, all rainfed observations were pooled when testing for differences in productivity between the irrigated and rainfed subsets of local rice. A similar analysis, reported in the preceding section, resulted in a calculated Chow's F-ratio of 5.52 ($n_1 = 4$, $n_2 = 86$), which is significant at the 1% level (Table 11). Therefore, there is quantitative evidence that the resource productivity of rainfed and irrigated LV grown in the southern Kosi zone differ. However, the source of the difference, that is, whether the intercepts or the slopes of the production functions differ, is not clear.

Johnston (1972) shows how, after allowing for differences in intercepts (via the dummy, the fourth equation in Table 11), similarity in production (i.e. slope) coefficients can be examined through the construction of an F-statistic. The calculated F-ratio of 5.41 ($n_1 = 4$, $n_2 = 86$) is significant at the 1% level. Hence, there is evidence that the intercept (based on the significant dummy variable) and the slope coefficients of the production functions (based on the F-ratio) for rainfed and irrigated LV differ. Thus, by implication, the productivity of LV is higher in irrigated than in rainfed environments.

Table 9. Directly measured allocation of grain output from rice production, southern Kosi zone, Nepal, 1978.[a]

	Owner				Tenant,
	Irrigated		Rainfed		Rainfed,
	MV	LV	MV	LV	LV
Some factors contributing to distribution of earnings					
Rice yield (kg/ha)	2805	1995	2070	1814	1721
Price of rice (Rs/kg)	1.19	1.23	1.19	1.23	1.23
Labor (Rs/day)	7.00	7.00	7.00	7.00	7.00
Land taxes (Rs/ha)[b]	70.00	70.00	66.00	66.00	0
Allocation among earners (kg/ha)					
Landlord[c]	-	-	-	-	726
Labor: hired	664	450	534	348	231
: family	141	199	182	239	296
Operator's residual	1554	1148	1049	1020	308
Current inputs	387	141	250	153	133
Taxes and levies	59	57	55	54	27
Relative shares among earners (%)					
Landlord	-	-	-	-	42
Labor: hired	24	23	26	19	13
: family	5	10	9	13	17
Operator's residual	55	57	51	56	18
Current inputs	14	7	12	9	8
Taxes and levies	2	3	2	3	2

[a]MV = modern varieties, LV = local varieties. A dash (-) denotes not applicable. [b]Land taxes vary with farm size and level of irrigation development. Land tax per hectare increases with increasing farm size, is assumed to be spread over two crops, and is paid by the landlord. Irrigation costs are included in current inputs. [c]Landlord's share of crop (50% net of harvesters' share).

Table 10. Least squares estimates of production function for owners and tenants growing local rice varieties, southern Kosi zone, Nepal, 1978.[7]

	Coeff.	Owner (O)	Tenant (T)	Pooled (O+T)
Intercept	b_0	-9.2018	2.3557	-7.6807
Area	b_1	20.7518**	13.8677**	20.3655**
Compost	b_2	0.0543^{ns}	.1146**	$.0748^{ns}$
Credit	b_3	0.2688^{ns}	-2.2572^{ns}	$-.7670^{ns}$
$\bar{R}^2$		.92	.62	.91
d.f.	n_1 to n_3	36	25	65
RSS	s_1 to s_3	9,270	1,308	11,278

[7]** = significant at the 1% level, * = significant at the 5% level, ns = not significant, d.f. degrees of freedom, RSS = residual sum of squares.

Chow's test

$$\text{F-ratio} = \frac{[s_3 - (s_1 + s_2)] : [n_3 - (n_1 + n_2)]}{(s_1 + s_2) : (n_1 + n_2)}$$

$$= \frac{[11,278 - (9,270 + 1,308)] : [65 - (36 + 25)]}{(9,270 + 1,308) : (36 + 25)}$$

$$= 1.01$$

Irrigated versus rainfed, modern varieties

Some 60 owner-operators irrigated their MV, others (12) grew a rainfed MV crop (Table 12). The calculated Chow's F-ratio of 4.56 ($n_1 = 3$, $n_2 = 64$) is significant at the 1% level, implying that the response functions for irrigated and rainfed MV differ. Further, the intercept terms differ between the two equations, as do the slope coefficients (F-ratio = 4.26 ($n_1 = 3$, $n_2 = 64$), significant at the 1% level. Thus, the production functions differ in both intercept and productivity (slope) coefficients. By implication, irrigation significantly increases the productivity of MV, other things being equal.

In summary, the analysis of the productivity of the dominant rice production systems in the southern Kosi zone indicates that:

- the productivity of rainfed LV does not differ between tenure status;
- the productivity of LV is higher in irrigated than in rainfed conditions; and
- within the group of MV grown by owners, productivity is higher for irrigated than for rainfed fields.

These results are consistent with other analyses of rice production.[8] Specifically, rice productivity is higher in water-managed than in rainfed conditions, and tenure, per se, is not an important source of differences in rice productivity -- at least for the LV analyzed here.

CONCLUSIONS

Modern rice varieties have had the greatest impact in the Tarai of Nepal's southern Kosi zone when grown in irrigated fields. However, in rainfed fields LV appear to be as profitable as, or more profitable than, MV. Both MV and LV appear to be more productive in irrigated than in rainfed fields.

Owner-operators in the southern Kosi zone with irrigation appear to have benefited from the introduction of MV, but tenants have not, in the sense that they do not grow these varieties. Even though land reform has given farmer-tenants title to the land they till, it appears that land reform alone will not necessarily make it profitable to shift from LV to MV. Other factors are strongly associated with the adoption of MV -- access to the complementary inputs, particularly irrigation; and probably to a lesser extent, production credit. Thus, the policies of land reform, irrigation development, and input delivery systems pursued by the Nepalese Government in the Kosi zone should be conducive to an expansion in areas grown to MV.

Although tenants may not have directly benefited from the MV, they and landless laborers have indirectly benefited through increased employment in areas growing these varieties. However, because the area growing MV is reported to be less than 25% of the total area planted to rice, the aggregate impact of these varieties on employment is somewhat less than implied when considering the data purely on a per hectare basis.

The mean yield of MV on irrigated farmers' fields was less than 3 t/ha, a ton or more below yields recorded for the same varieties at the Tarahara Agricultural Station, which is in the same area (Pandey 1978). Although farm yields are certainly expected to be less than research station yields, the actual yields reported for irrigated MV are modest by most standards. Some factors probably limiting farmers' yields from MV in the southern Kosi zone are:

- lack of a MV particularly suited to the soils, climate, and pest complexes in the area;
- constraints due to water, fertilizer, and weed management; and
- constraints due to farmer's and market preferences for LV.

[8]See Ruttan and Binswanger (1978) for a review of such studies.

Table 11. Least squares regression estimates of production functions for irrigated and rainfed local rice varieties, southern Kosi zone, Nepal, 1978.[a]

	Coefficient	Irrigated (I)	Rainfed (R)	Pooled (I + R)	Pooled + dummy
Intercept	b_0	-5.3130	-7.6807	-7.4748	-6.5020
Area	b_1	23.3210**	20.3655**	21.3044**	21.1416**
Compost	b_2	$.1021^{ns}$	$.0748^{ns}$	$.0351^{ns}$	$.0415^{ns}$
Credit	b_3	2.1021^{ns}	-0.7670^{ns}	$-.2618^{ns}$	-2.0364^{ns}
Intercept dummy	b_4				6.9557**
$\bar{R}^2$		.80	.91	.95	.95
d.f.	n_1 to n_4	21	65	90	89
RSS	s_1 to s_4	3,101	11,276	17,870	17,091

[a]** = significant at the 1% level, * = significant at the 5% level, ns = not significant, d.f. = degrees of freedom, RSS = residual sum of squares.

$$\text{Johnston's test for slope variability} = \frac{[s_4 - (s_1 + s_2)] : [n_4 - (n_1 + n_2)]}{(s_1 + s_2) - (n_1 + n_2)}$$

$$= \frac{17{,}091 - [(3{,}101 + 11{,}278)] : [89 - (21 + 65)]}{(3{,}101 + 11{,}278) : (21 + 65)}$$

$$= 5.41$$

Table 12. Least squares regression estimates of production functions for irrigated and rainfed modern rice varieties grown by owners, southern Kosi zone, Nepal, 1978.[a]

	Coefficient	Irrigated (I)	Rainfed (R)	Pooled (I + R)	Pooled + dummy
Intercept	b_0	-1.1825	1.0427	.1014	-8.4858
Area	b_1	21.9238**	14.4442**	21.1480**	21.3527**
Fertilizer	b_2	.4117**	$.0226^{ns}$	$.2123^{ns}$	$.1973^{ns}$
Credit	b_3	6.1018^{ns}	4.4117^{ns}	6.4273^{ns}	3.2723**
Intercept dummy	b_4				13.3863**
$\bar{R}^2$		.80	.89	.77	.78
d.f.	n_1 to n_4	56	8	68	67
RSS	s_1 to s_4	18,997	848	25,502	23,804

[a]** = significant at the 1% level, * = significant at the 5% level, ns = not significant, d.f. = degree of freedom, RSS = residual sum of squares.

However, whether it is profitable or possible for the farmer to change varieties or to increase the use of production factors cannot be assessed with conviction from this study. Integrated on-farm experiment and survey approaches have been designed to examine and evaluate constraints faced by farmers in increasing their yields from irrigated MV (De Datta et al 1978, IRRI 1979). It would be instructive to examine the reasons for the apparent low productivity of MV in Kosi zone using this methodology.

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