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RICE PRODUCTION IN THE WANGDIPHODRANG-PUNAKHA VALLEY OF BHUTAN

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ABSTRACT

A farm survey was conducted in the Wangdiphodrang-Punakha Valley of Bhutan to document current methods of rice production, provide a basis for measuring the impact of the national rice program, and identify research priorities.

The dominant crops in the valley were rice in summer, and wheat, mustard, and buckwheat in winter. Local rice is broadly classified as *maap* (red rice) or *kaap* (white rice). Kaap accounted for 61% of the rice area at low elevations (less than 1,500 m); maap, 36%; and modern rice (MPR and IR36), 3%. Maap accounted for 92% of the rice area at high elevations; kaap covered the remaining 8%.

At low elevations, the average yield of maap rice (1.5 t/acre [3.7 t/ha]) was slightly higher than that of kaap (1.4 t/acre [3.5 t/ha]), but the difference was not significant. Both kaap and maap rices yielded 1.3 t/acre (3.2 t/ha) at high elevations. The most important determinant of rice yield was land quality. On the best quality land, average rice yields were 1.5 t/acre (3.7 t/ha); on medium-quality land, 1.3 t/acre (3.2 t/ha); and on poor land, 1.0 t/acre (2.5 t/ha).

Rice production was labor intensive: some 112 d/acre (280 d/ha)was used to grow the crop. More than 40% of the labor was used for harvesting, threshing, and associated operations. Few purchased inputs were used. The major inputs were farm household produced: owned seed, bullock power, human labor (mainly women), and compost.

The value of farm-produced and -used inputs (e.g., straw and compost) influenced net returns to rice production. Net returns to owned land were 325 Nu/ha (US$ = 12.8 Nu) when the value of farm-produced inputs was ignored, and 525 Nu/ha when these inputs were valued at their shadow market prices.

Technology that would reduce labor constraints (e.g., mechanical threshers, improved weed control, direct seeding) appears to be attractive to rice farmers, and its development should receive research attention. Agronomic research to ensure the long-term stability of more intensive rice-based systems (fertility management, identification and assessment of insect and disease damage, development of response strategies) should continue to be encouraged. Increased rice production could lead to increased marketing surpluses, implying that rice prices and market development may become a more pressing issue for the government.

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RICE PRODUCTION IN THE WANGDIPHODRANG-PUNAKHA VALLEY OF BHUTAN

Bhutan's reliance on imported cereal grains is increasing. In recent years, rice imports have reached 13,000 t/yr—more than 20% of annual consumption—compared with virtually no imports two decades ago. The government wishes to reduce its dependency on foreign sources for this staple food and, in 1982, established the Centre for Agricultural Research and Development (CARD) within the Department of Agriculture. CARD conducts research on rice and rice-based cropping systems. Its rice research capability was strengthened in 1984 when links were established with the International Rice Research Institute (IRRI) under the International Development Research Centre-funded IRRI-Bhutan Rice Farming Systems Project.

CARD research has demonstrated the potential of modern rice varieties in the mid-altitude irrigated ricelands. In on-farm tests in 1987, improved varieties IR36 and IR64 yielded as much as 1.9 t/acre (4.7 t/ha) compared with 1.6 t/acre (4.0 t/ha) for traditional varieties (RGOB-DOA 1988). IR36 was distributed to selected farmers for on-farm demonstrations in 1986-87, and during 1988 the Ministry of Agriculture distributed these varieties more widely.

RICE IN BHUTAN

Almost all rice in Bhutan is grown in irrigated or bunded rainfed fields. Very little is cultivated as upland rice. The total rice area is estimated to be 86,000-90,000 acres (35,000-37,000 ha)[3]. National yields average 0.8-0.9 t/acre (2.0-2.2 t/ha). Increased production must come from increased productivity, as there is little additional land for expanding rice cultivation.

Rice is grown in three distinct elevation zones: the southern rice-growing belt at 130-600 m elevation (37,000 acres [15,000 ha]); the mid-altitude valleys and foothills of the Himalayan ranges at 600-1,800 m elevation (37,000 acres [15,000 ha]); and the area at high altitudes, above 1,800 m (12,000 acres [5,000 ha]). The mid-altitude zone is further divided into humid (>1,000 mm annual rainfall) and arid (<1,000 mm) areas. Rice yields in the mid-altitude zone are about 1.2 t/acre (3 t/ha) or higher, yields in the southern zone are reported to be as low as 0.4 t/acre (1 t/ha). The low yields in the southern zone are attributed to soil constraints and to greater pest incidence.

CARD research has focused on the low- and mid-altitude rice zones. The headquarters are located in Wangdiphodrang (hereafter referred to as Wangdi), at 1,340 m altitude in the dry zone. The rice-based cropping systems in the Wangdi-Punakha Valley are the focus of this study.

THE STUDY AREA

Wangdi and Punakha and the far eastern portion of Thimphu Dzongkhags (districts) lie in the Chang Chu Valley and its tributaries in the Inner Himalayan Ranges of Bhutan (Figs. 1 and 2). More than 19,200 persons, some 3,200 households, are thought to live in the valley (IFAD 1987). The lowest point in the valley is about 1,200 m above sea level; the highest, 4,825 m. The altitude range for cultivation and habitation is 1,200-2,500 m, with most cultivation—possibly 80%—below 1,800 m.

The Wangdi-Punakha Valley is one of the largest contiguous rice areas in Bhutan. With about 12% of the rice area, it accounts for about 18% of national rice production. It is close to Thimphu, the capital and the largest urban center. Rice is the most important crop in the valley in terms of area, production, and employment, and as a food staple and a cash and barter crop. Wetland rice occupies more than 10,000 acres (4,000 ha), more than 80% of the cultivable area of the valley (IFAD 1987).

The Wangdi-Punakha Valley system is characterized by warm summers, cool winters, and monomodal monsoon-related rainfall (Fig. 3). Annual rainfall is 650-750 mm; about 75% of it falls during the May-September monsoon season. Thus, there are two distinct cropping seasons, summer (June-October/November) and winter (November-May/June). All rice grown in the valley is irrigated. Rice dominates land use in summer; wheat, mustard, buckwheat, and vegetables are important winter crops (DA 1986, Dorji 1986).

We conducted a farm-level study in October-November 1987 to document current methods of rice production, to provide a basis for measuring the impact of the national rice program, and to identify research priorities.

DATA COLLECTION

Preliminaries

The participating researchers spent five days at the study site talking to farmers and Department of Agriculture staff to become familiar with rice production practices before designing the questionnaire or considering sampling procedures.

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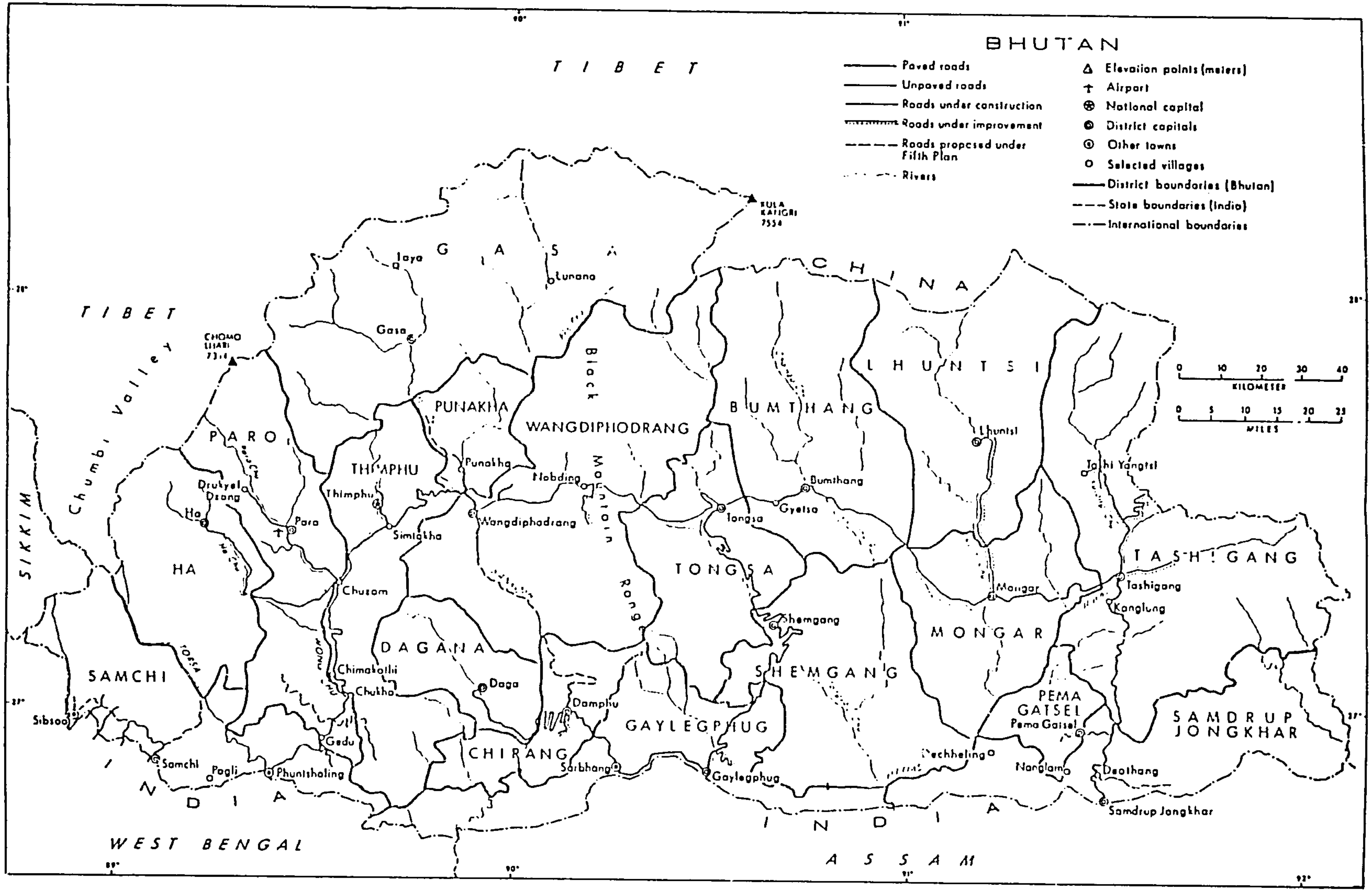
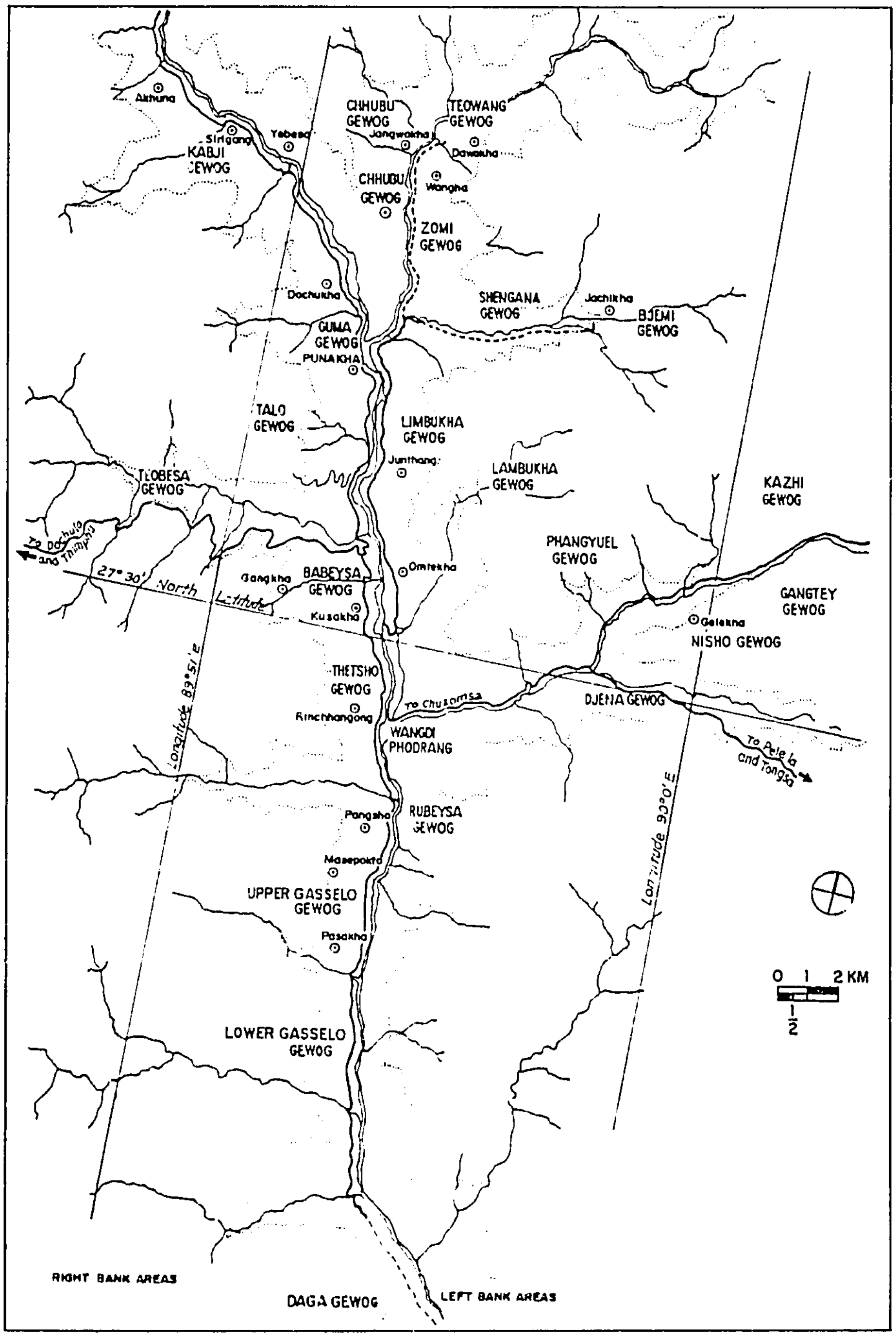
[3] Data are presented on a per-acre, rather than per-hectare, basis (1 acre = 0.4047 hectare). Acre is the unit of measure officially used in Bhutan, and the unit the primary audience of this report most readily understands. Because rice areas are small, errors of scale are reduced if data are reported on a per-acre basis. (Per-hectare equivalents are reported in brackets following some per-acre amounts.) Also, economic data are reported in Bhutanese Nu (*ngultrum*). The US$ equivalent in 1987 was 12.8 Nu.



1. **Administrative districts of Bhutan (Source: Royal Government of Bhutan Fifth Plan Document, 1981-87).**



2. Villages in the Wangdi-Punakha Valley, Bhutan.

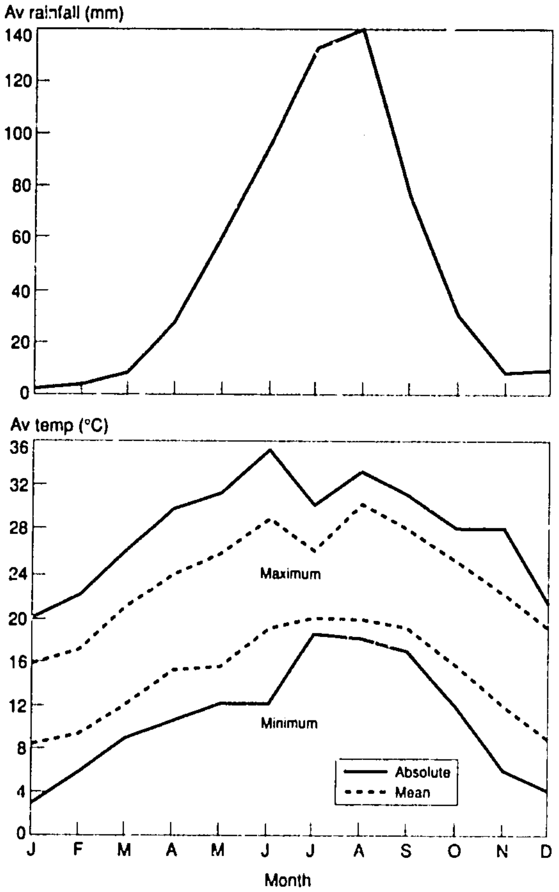
The input of CARD research scientists was of great value during this phase of the study.

This preliminary survey aided us when developing and sharpening our hypotheses and provided the framework for questionnaire design—which went through two cycles of testing before being finalized.

Sampling methods

Rice-growing areas in the valley were stratified into low-elevation villages (less than 1,500 m) and high-elevation villages (more than 1,500 m). The limit of local white (*kaap*) rice was about 1,500 m, and that is thought to represent the cut-off elevation for modern rices such as IR36 and IR64, although cold-tolerant modern rices such as Japanese No. 11 are adapted to higher elevations. Recommendations for rice culture (varieties and management) are expected to differ between the low and high strata.

Villages were grouped into low- and high-elevation strata with the assistance of Punakha and Wangdi District Agricultural Officers (DAOs). Time constraints limited the survey to 20 villages. Ten villages were randomly selected from each stratum (see Appendix). The cut-off point between low- and



3. Average monthly rainfall and temperature in Wangdi, Bhutan, 1985-86.

Table 1. Distribution of family members of farm households by gender and age group, Wangdi-Punakha Valley, 1986-87.

Age group	Percentage^a		
	Males	Females	All years
Children			
≤ 4	6	4	9
5-14	12	10	22
Subtotal	18	14	33
Adults			
15-59	29	28	57
≥ 60	7	5	12
Subtotal	36	33	69
Total	54	46	100

[a] Totals may not be exact, due to rounding.

high-elevation villages was at best approximate, as most villages farm land extending to higher and lower elevations than the village proper. Village names and their actual altitudes are listed in Appendix Table 1.

Based on the DAOs' records, farms within the study villages were classified into small (<1.50 acres [0.61 ha]), medium (1.51-3.00 acres [0.61-1.21 ha]), and large (>3.01 acres [1.22 ha]). Medium-size farms are typical of households in the valley. Two farm households from each size category within each village were randomly selected. This stratification was at the request of the Department of Agriculture, which is particularly interested in farm size-household productivity relationships.

Survey procedures

With the approval of the Dzongdha (District Administrator), selected villages were contacted and arrangements made to interview. The survey team (an agricultural economist-supervisor and two enumerators) visited one village per day. Two questionnaires were used:

- a questionnaire to collect village-level data and other information not likely to vary appreciably between farms (e.g., prices), and data on factors that individuals often estimate imprecisely, but where group estimates may provide indicative values for planning (e.g., labor inputs)
- a questionnaire to collect information on each farm household in the sample: its resource base, crop management, and crop yields

Specific information elicited was based on the largest contiguous parcel of riceland farmed by each household (the intensive data parcel). Time constraints precluded eliciting information on each parcel of riceland (modal parcels per household = 6), and rice crop management often differs field by field. It is preferable to collect data for a specific parcel, and not expect a respondent to generalize over the farm as a whole.

Questionnaires were completed with 60 farmers in 10 low-elevation villages and 58 farmers in 10 high-elevation villages.

Data accuracy

Because Bhutanese farmers do not maintain records of their farming activities, the information collected reflects respondents' abilities to recall the information requested, their willingness to share it, and the enumerators' skills in eliciting it. This is a general problem with single-visit surveys.

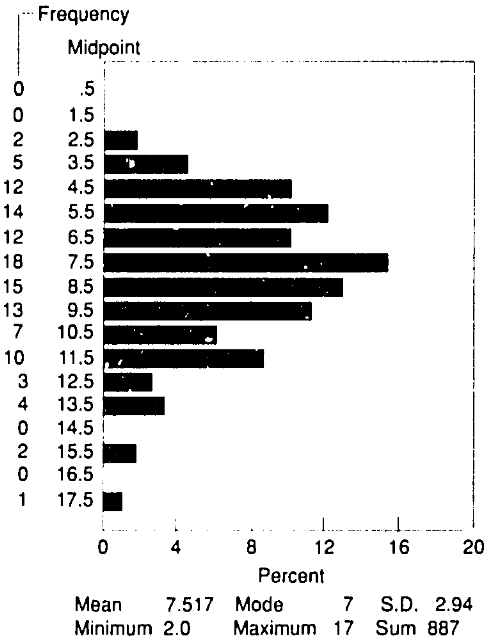
Another problem is that farmers do not know several factors of central importance to the study—such as land area and weights—quantitatively. For example, the unit of land, a *langdo*, approximates the area of land that a pair of bullocks can plow in a day. Its size differs between wetlands (about 0.25 acres [0.10 ha]) and drylands (about 0.33 acres [0.13 ha]). The volume measure for grain, a *dre*, is about 1.24 kg rough rice, 1.56 kg wheat, or 1.42 kg mustard. One *chewo* (basket) of farmyard manure weighs from 20 to 25 kg, depending on moisture content. It would be desirable to measure fields and to take crop cuts, particularly of rice, but that was not possible for this study, given time and resource constraints.

HOUSEHOLD PROFILE

Demographic characteristics

The head of household in a Wangdi-Punakha Valley family is usually female. When a young man marries, he joins the house of his wife's mother, who presides over the household. It is also common for land to be inherited through the wife's family, from mother to daughter. This social arrangement may be associated with the traditional migration of males into monkhood (DA 1983).

The modal household in the sample consisted of seven to eight people. Distribution of household sizes did not differ between elevations (Fig. 4). In a typical household, 22% were children of school age, 9% younger children, 57% adult males and females within the working age group, and 12% elderly (Table 1). The proportion of males (54%) was higher than females (46%), but the difference is not significant (Z = 1.23^{ns}).



4. Frequency distribution of household size (total sample, low- and high-elevation villages), Wangdi-Punakha Valley, 1986-87.

Land resources

Land use. Cultivated land has five major uses in the valley: wet (irrigated) crop land, dry (nonirrigated) crop land, kitchen (vegetable) gardens, orchards, and fallow. In addition, some land is pasture or forest. The distribution of cultivated land was estimated as irrigated, 81%; dryland, 13%; kitchen gardens, 2%; orchards, 1%; and fallow, 3% (IFAD 1987).

The proportion of wetland to total farm size was 90% or higher among the low-elevation villages surveyed (Table 2). The proportion of wetland in the high-elevation villages surveyed was 78% or less. Not all households had access to each class of land. Kitchen gardens and orchards were more common in the low-elevation villages and on small farms. Dryland was more common in the high-elevation villages.

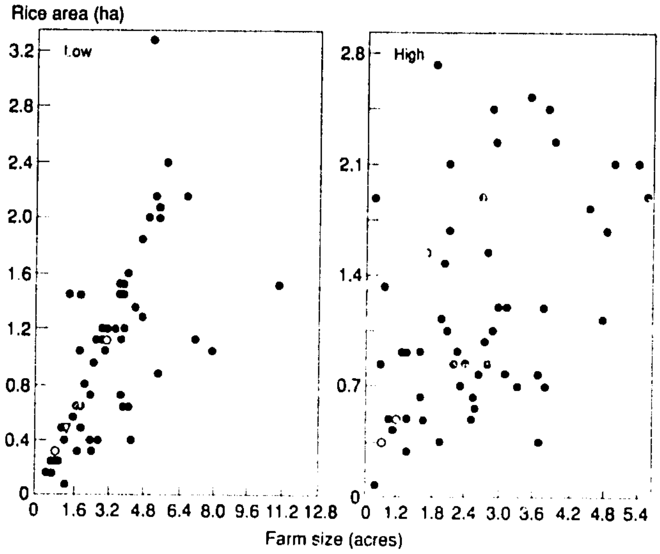
Riceland. The basis for sampling farms was operational holding, not area of wetland rice. However, as total farm size increased, the proportion of riceland tended to decrease (Fig. 5). Among the low-elevation villages, a 1% increase in farm size was associated with a 0.88% increase in riceland. Among the high-elevation farms, a 1% increase in farm size was associated with a 0.68% increase in riceland. That is, the increase in rice area was less than the increase in farm size. If the focus of a study is rice production:farm size relationships, then it may be advantageous to sample on the basis of farm rice area rather than on size of operational holding.

Tabular and statistical analysis in general did not reveal any systematic trends between rice-related variables and farm

Table 2. Farm size and land use by rice-based farming households, Wangdi-Punakha Valley, 1986-87.

Land use	Farm size[a]					
	Small		Medium		Large	
	%	Acres (no.)	%	Acres (no.)	%	Acres (no.)
Low altitude						
Wetland	100	0.99	100	2.01	100	4.16
Dryland	7	0.42	20	0.52	18	0.31
Kitchen garden	73	0.09	68	0.11	41	0.20
Orchard	20	0.04	0	-	32	0.27
Fallow	0	-	12	0.78	9	0.91
Operational holding[b]	-	1.00	-	2.23	-	4.54
Wetland as % of total	99		90		92	
High altitude						
Wetland	100	0.83	100	1.76	100	3.10
Dryland	36	0.43	27	0.40	28	1.50
Kitchen garden	56	0.10	53	0.20	40	0.25
Orchard	0	-	11	0.14	15	1.70
Fallow	8	0.33	9	0.69	17	2.17
Operational holding[b]	-	1.11		2.25	-	4.64
Wetland as % of total	75		78		67	

[a] Percent (%) refers to the proportion of respondents who operated that land class.
[b] Operational holding was calculated as total area divided by sample size, for each category.



5. Relationship between total rice area and total farm size, low- and high-elevation villages, Wangdi-Punakha Valley, 1986-87.

Table 3. Distribution of rice area by land quality and elevation, Wangdi-Punakha Valley,1986-87.

Elevation	Rice area (%)		
	Rap (high quality)	Ding (medium quality)	Tha (low quality)
Low	53	38	9
High	32	47	21

$\chi^2 = 20.55^{**}$.

size. The results of this survey are reported mostly as means of low- and high-elevation samples.

Riceland quality. Three types of land quality for wetlands are used as bases for land taxation. They are *rap* (high-), *ding* (medium-), and *tha* (low-) quality land. The distribution of wetland by land quality is summarized in Table 3. The proportion of good land was larger in the low-elevation sample; the proportion of poor land was larger in the high-elevation sample. No systematic relationships were found between riceland quality and farm size or total rice area.

Tenure

All households owned at least some of the land they farmed. However, a large proportion reported that they rented a portion of the riceland they cultivated (Table 4). The percentage of farmers who rented land and the percentage of riceland rented were lower among the larger farms..

Table 4. Rental of riceland by elevation and farm size, Wangdi-Punakha Valley, 1986-87.

Riceland rental	Percentage					
	Low elevation			High elevation		
	Small	Medium	Large	Small	Medium	Large
Households renting riceland	54	58	25	38	64	38
Rice area rented	20	16	12	21	30	12

A number of tenancy arrangements were reported. The most common were 50:50 (12 of 20 villages) and 60:40 (6 of 20 villages) shares of output between tenant and owner. One village reported in-kind rentals of 124, 62, and 50 kg rough rice/acre (100, 50, 40 dre/langdo) for good land, medium-quality, and poor land, respectively. No village reported cash rentals.

Rentals were based on the rice crop; the tenant retained all output from a second, or winter, crop.

Livestock

The links between a household and its crops and livestock are intricate. What is important to this study is that livestock are the source of power and compost for rice; the rice crop is the source of straw and bran for livestock feed, particularly during feed-scarce winter months.

An overview of livestock ownership is shown in Table 5. Most households owned a pair of working bullocks, young cattle (bullocks and heifers), pigs, and chickens. Milking cows (cows in milk and in calf) were more frequently owned by the larger farms. A higher proportion of high-elevation farms owned horses. (Horses are often used as pack animals, particularly in high-elevation areas remote from roads.) Among households that owned animals, the number of animals did not differ appreciably with farm size. A typical livestock-owning household may have had a pair of oxen, two milking cows, three to four young cattle, three horses, three to four pigs, and a few chickens.

RICE-BASED CROPPING PATTERNS

Dominant crops

The dominant crops were rice in summer, and wheat, mustard, and buckwheat in winter. Vegetables (e.g., winter cabbage, cauliflower, spring potato, tomato, summer tomato, beans, and potato) were increasing in importance but data on these crops were not collected. The high-value crops merit a sharply focused survey in their own right.

Local rice varieties are broadly classified as *maap* (red rice) and *kaap* (white rice). In the low-elevation villages, 61% of the rice area was planted to kaap rice, 36% to maap (the remaining 3% was planted to modern rices, such as MPR and IR36). In the high-elevation villages, maap rice accounted for 92% of the rice planted, kaap rice for 8%.

Maap rice, favored for its eating quality, was frequently retained for household consumption. It also commanded a premium price in the market. Both rices are japonica types, medium to tall, long-duration, and low-temperature tolerant in the seedbed. They are prone to lodging.

Wheat was the dominant winter crop, both irrigated and as a rainfed crop following rice. Sonalika, an older and rust-susceptible improved variety, dominated. Wheat is not a staple food in the valley or more generally in Bhutan, but is widely used for beverages and as cattle feed.

Table 5. Livestock ownership by farm size and elevation, Wangdi-Punakha Valley.

Item[a]	Low elevation			High elevation		
	Small farms	Medium farms	Large farms	Small farms	Medium farms	Large farms[b]
			Livestock ownership (%)			
Draft cattle (pair)	92	95	100	81	100	100
Milking cows	16	66	74	63	50	85
Dry cows	0	24	22	56	8	5
Young cattle	58	81	100	100	88	90
Horses	23	29	48	100	88	100
Pigs	67	90	100	81	92	90
Chickens	57	86	96	81	92	90
			Livestock numbers			
Draft cattle (pair)	1	1	2	1	1	2
Milking cows	2	2	2	2	2	2
Dry cows	0	2	2	1	2	2
Young cattle	3	4	3	2	3	4
Horses	3	3	2	3	3	4
Pigs	3	3	4	2	2	3
Chickens	4	5	6	4	3	5

[a] Milking cows include cows in milk and in calf. Dry cows are cows that are not in milk.

[b] Four high-elevation large farmers without bullocks were recently resettled farmers, each with only 1 acre or less of rice.

Mustard was grown at all elevations (in 18 of the 20 villages surveyed). In Bhutan, mustard refers to brassica oil crops in general. The principal species is a local cultivar of *Brassica campestris* (Riley 1988). Buckwheat (*Fagopyrum esculentum*), the third most widely grown winter crop, was not found in the low-elevation villages. At high elevations, it was grown primarily for animal feed, although small quantities were used as a food supplement and for making beverages.

Dominant cropping patterns

Four rice-based cropping patterns dominated (Table 6). Rice - wheat and rice - fallow accounted for nearly 70% of wetland use. Rice - mustard and rice - buckwheat accounted for an additional 17% of land use, with mustard more widely grown at the low elevations, buckwheat at the high elevations. Other crops grown on small areas included barley, chili, maize, potato, and winter vegetables. The multiple cropping index of the wetlands was high, on the order of 1.7. Nearly half of the winter fallow land was used to raise the dry-bed rice nursery.

Table 6. Dominant rice-based cropping patterns in Wangdi-Punakha Valley, 1986-87.

Cropping pattern	Percentage[a]		
	Low elevation	High elevation	Low and high elevations
Rice - wheat	37	44	40
Rice - fallow	29	30	29
Rice - mustard	12	8	10
Rice - buckwheat	5	9	7
Rice - other crops[b]	17	9	14
Total	100	100	100

[a] Farmers who planted their rice area to a following winter crop.

[b] Other crops included barley, maize, and winter vegetables.

The cumulative frequency distributions of rice and wheat planting and harvesting dates are summarized in Figure 6. Rice was seeded into a dry seedbed between mid-March and late April—well before the wheat crop was harvested. Seedbed establishment began earlier in the high-elevation villages because cold temperature slows the growth of rice seedlings.

Most transplanting took place in early June to mid-July, a shorter time span than for rice seedbed establishment. More than half the rice was harvested in November.

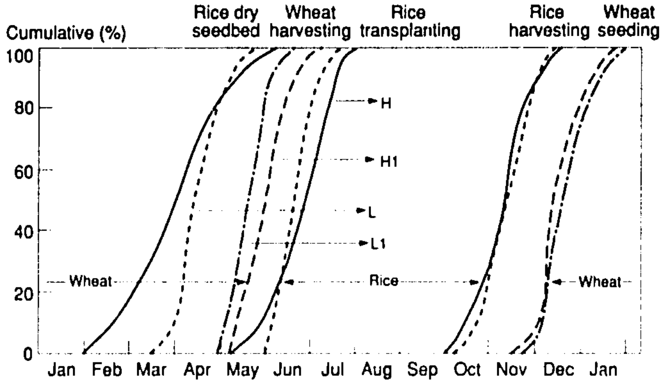
Duration of the rice crop in the field (the time between transplanting and harvesting) is related to elevation, transplanting date, variety, and seedling age. The least-squares estimated regression was

$$\begin{array}{l} D = 227.21 + 0.001E - 19.93D + 9.53V - 0.12A \\ \qquad\qquad (0.23^{ns}) \quad (7.43^{**}) \quad (2.38^{**}) \quad (1.52^{*}) \\ \bar{R}^2 = 0.42;\ F(4{,}93) = 18.63^{**}\ (t\text{-values in parentheses}) \end{array}$$

where D = duration, E = elevation, T = transplanting date, V = variety (0 for kaap, 1 for maap), and A = seedling age.

Mean field duration of maap rice was about 146 d; kaap rice was 136 d. Field duration was significantly shorter for late-planted rice (20 d less for each month's delay in transplanting) and when older seedlings were transplanted. When other factors were accounted for, duration appeared to be independent of elevation.

About 90% of wheat seeding took place from late November to early January. In the low-elevation villages, most wheat was harvested during 4 wk between early May and early June. In the high-elevation villages, most wheat was harvested between late May and late June. Average duration of wheat was 145 d for the low-elevation villages and 159 d for the high-elevation villages. Duration of wheat was related to planting date:



6. Cumulative frequency distribution of planting and harvest dates of rice and wheat in rice - wheat cropping patterns, low- and high-elevation villages, Wangdi-Punakha Valley, 1986-87. *n* = 60 for low-elevation (L) villages, 55 for high-elevation (H) villages.

$$D = 159.57 - \underset{(5.85^{**})}{17.16\,P} + \underset{(3.88^{**})}{0.02A}$$

$\bar{R}^2 = 0.44$; $F(2,74) = 30.51^{**}$ (t-values in parentheses)

where D = duration, P = planting date, and A = altitude.

Wheat crop duration was significantly shorter with late sowing and significantly longer at high altitudes.

Turnaround time (the period between harvest of one crop and sowing of the next) was about 1 mo from rice to wheat and from wheat to rice. We were not able to identify any significant relationship between turnaround time and farm characteristics.

RICE PRODUCTION SYSTEMS

The data summary describes rice production systems from seedbed preparation to harvest. Nonlabor inputs are based on the individual farmer sample; labor inputs are based on the village sample.

Seedbed

A traditional dry-bed method was used to raise rice seedlings. The average seedbed area was 14-15% of the area to be transplanted. Seedbeds were plowed an average of 3 times (range 2-5 times) on both low- and high-elevation farms. The first plowing followed rice harvest, with subsequent plowings between February and April. Ninety percent of the low- and 83% of the high-elevation farmers reported that they irrigated the seedbed land in February or March to soften the ground before a second plowing. Most farmers harrowed and leveled their seedbeds before broadcast seeding.

Average seeding rate was 11-14 kg seed to grow a seedbed sufficient to transplant 1 acre (Table 7). That was considerably lower than CARD's recommendation of 20-30 kg/acre.

Almost all farmers (97%) applied compost (a mixture of farmyard manure, decomposed straw bedding, and leaves) to their seedbeds, at about 0.5 t/seedbed for 1 acre of transplanted rice. Few farmers applied inorganic fertilizer. Among the 19% of the low- and 5% of the high-elevation farmers who did, average rate of urea (46-0-0) was 2-3 kg/0.15 acre of seedbed. One farmer reported applying sulphala (15-15-15) to the seedbed.

A higher proportion of the low- (91%) than the high- (78%) elevation respondents reported weeding their rice seedbeds. Among those who weeded, the average number of weedings was two at the high elevation and one at the low elevation (range, one to three weedings).

Crop establishment

Land preparation. Land preparation for rice normally began in mid-May (later if the area was occupied by wheat). Primary land preparation was done with a traditional wooden plow drawn by two bullocks. Fields were often irrigated before plowing to make the job less difficult. After the first or second plowing, clods were crushed with a wooden mallet or spade.

Table 7. Nonlabor inputs to rice seedbed to produce rice seedlings for 1 acre, Wangdi-Punakha Valley, 1986-87.

Input		Unit[a]	Low elevation	High elevation	Difference	Low and high elevations
Land		acres	0.13	0.15	0.02	0.14
Irrigation	Users	%	90	83	7	86
		no.	1	1	0	1
Plowings	Users	%	100	93	7	97
		no.	3	3	0	3
Harrowing	(once)	%	91	100	9	96
Compost	Users	%	97	98	1	97
		t/sb	0.4	0.5	0.1	0.4
Seed	Kaap	kg/sb	14	-	-	14
	Maap	kg/sb	11	14	3	13
Fertilizer						
Urea	Users	%	19	5	14	13
	Rate	kg/sb	2.8	2.3	0.5	2.7
Sulphala	Users	%	0	2	2	-
	Rate	kg/sb	0	2	2	-
Weeding	Users	%	91	78	13	85
		no.	1	2	1	2

[a] sb = seedbed area.

The field was again irrigated and puddle-plowed before a final harrowing to level it for transplanting. The mean number of plowings was 2.4 (range 1-3) on low-elevation farms and 2.2 (range 1-4) on high-elevation farms (Table 8).

Transplanting. All but one of the low-elevation respondents reported random-transplanting at 1-2 seedlings/hill. Mean seedling age at transplanting was 69 ± 2 d for maap and 62 ± 2 d for kaap at low elevations, and 73 ± 3 d for both maap and kaap rices at high elevations.

Crop management

Nonlabor inputs are also summarized in Table 8.

Fertility management. Nearly all farmers (98%) applied compost at 4-5 t/acre (about 50 baskets/langdo). However, if wheat was the previous crop (which occurred on about 40% of the rice area), then compost was not applied to the rice crop because it had been applied to the wheat. Few farmers applied inorganic fertilizer. Among the 17% of the low-elevation farmers who did, the mean application rate of urea was quite high, a little less than 1 bag/acre (21 kg N/acre or 50 kg N/ha). The 12% of high-elevation farmers who applied urea used 0.6 bag/acre (14 kg N/acre or 35 kg N/ha). A few farmers applied sulphala (15-15-15)—1 at the low elevation and 4 at the high elevation.

Pest management. Potamogeton sp. was identified as a major weed problem by nearly two-thirds of the low- and one-third of the high-elevation farmers (Table 9). Other important weeds identified were *Echinochloa* sp. and *Scirpus supinus*. CARD agronomists identified a number of *Cyperus* spp., *Cynodon dactylon*, and *Paspalum distichum* as important weeds, at least on the research station (Pradhan and Chettri 1987).

All respondents weeded at least once. Curiously, a far higher proportion of high-elevation farmers (81%) than low-elevation farmers (8%) reported weeding rice a second time. Possibly, rice forms a closed canopy more slowly at higher, cooler altitudes, and thus is less competitive with weeds during early growth. None of the farmers applied herbicides.

The insect pests most widely recognized by farmers were planthoppers and stem borers, more by the low- than the high-elevation farmers. The specific planthoppers and stem borers occurring in the valley could not be determined. The farmers described many other insects in their rice crops, but they did not have local names. It is not known whether these insects reduce rice yields or are natural enemies of rice pests.

In Bhutan, insecticide application is the responsibility of the Department of Agriculture. Thirteen percent of the farmers reported that their riceland was sprayed by the Gewog (block) Agricultural Assistant (AA). The names of insects that prompted application of insecticide were not recorded by the AA, and the farmers did not know what insecticides the AA applied.

Table 9. Farmers' perceptions of pests limiting rice yields, Wangdi-Punakha Valley, 1986-87.

Item	Respondents (%)[a]	
	Low elevation	High elevation
Weeds causing most trouble in ricefields		
Sochum (*Potamogeton* sp.)	63	37
Enchodhum (*Echinochloa* sp.)	15	0
Jam (*Scirpus supinus*)	13	13
Insects causing most trouble in ricefields		
Jochum (planthoppers)	41	36
Bub (stem borers)	29	10
Unidentified insects	39	35
Do diseases reduce rice yields?		
Yes	3	17
No	53	40
Don't know	44	43

[a] Percentage of respondents reporting each pest problem.

Table 8. Nonlabor inputs to rice production, Wangdi-Punakha Valley, 1986-87.

Input	Qualifier	Unit	Low elevation	High elevation	Difference	Combined
Cultivation						
Plowings		no.	2.4	2.2	0.2	2.3
Harrowings		no.	1.0	1.0	0	1.0
Fertilizer						
Compost[a]	Users	%	97	98	1	98
	Rate	t/acre	5.2	5.1	0.1	5.1
Urea	Users	%	17	12	5	14
	Rate	kg/acre	45	31	14	39
Sulphala	Users	%	2	7	5	4
	Rate	kg/acre	60	15	45	24
Pest management						
Weeding	Once	%	100	100	0	100
	Twice	%	8	81	73	45
Insecticide	Users	%	12	14	2	13

[a] Assume a basket of compost weighs 25 kg; rate would be about 4 t/acre had a conversion ratio of 20 kg/ basket been used.

Farmers could not identify specific diseases of rice, and few knew whether diseases existed. This probably reflects low incidence in the local rices grown. It would be useful to document the insect, disease, and weed pests that occur in the valley.

Harvesting and threshing

Farmers harvested their rice crop by sickle, often when it was sufficiently mature to thresh without further field drying. Half of the rice crop was threshed within 3 wk of harvest. Kaap rice in particular was threshed in the field because it is prone to shattering. Nearly 75% of the farmers threshed rice by treading bundles of stalks, an extremely time-consuming method (Table 10). The Department of Agriculture had introduced drum pedal threshers, which were sold to farmers for cash or through a rural credit scheme. More large (35%) than small (21%) or medium (14%) farms used threshers.

Labor inputs

Labor inputs for rice were collected at the village level, because 1) it would have taken too long had labor data been elicited on a respondent-by-respondent basis; 2) precise labor data are difficult to collect in a single-visit survey; and 3) group estimates of typical labor inputs were felt to provide an acceptable measure for the purposes of this survey.

Labor inputs to rice production are summarized in Table 11. A striking feature is the high labor input used to grow an acre of rice. The 110 or more days per acre are in sharp contrast to the 30-40 labor days used to grow an acre of irrigated rice in the Philippines, but are consistent with labor inputs reported in similar environments in Nepal (e.g., Paudyal 1980).

A second feature is the large and specialized input of women. Women provided all the labor for carting compost and for transplanting, and shared equally with men (if they did not provide most of the labor) in weeding, harvesting, and threshing. Only cultivation was exclusively a man's job. Overall, women probably provided two-thirds or more of the labor to grow rice in the valley.

Labor inputs by major operations are summarized in Figure 7. Harvesting and threshing were the most time-consuming activities, accounting for more than 25% of the total labor input. The labor used to harvest kaap and maap rice was similar. However, farmers consistently reported that kaap shatters more easily than maap rice, making it easier to thresh; mean threshing days/acre were 14 for kaap and 19 for maap.

Table 10. Farmers using different rice threshing methods by farm size, high and low elevation strata combined, Wangdi-Punakha Valley, 1986-87.

Threshing method	Farmers (%)			
	Small farms	Medium farms	Large farms	All groups
Foot	75	84	63	74
Pedal thresher	21	14	35	24
Power thresher	4	0	2	2
Combined	0	2	-	-

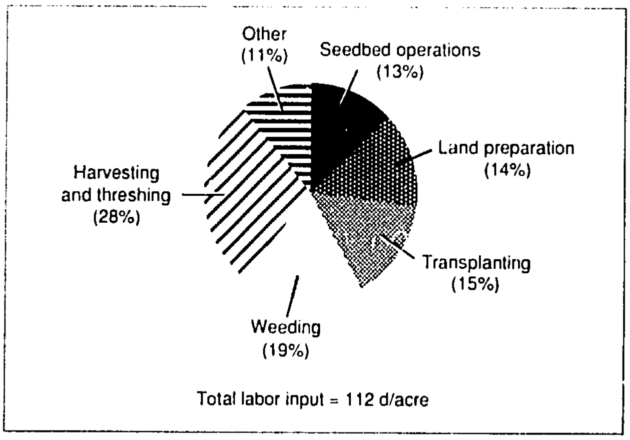
$\chi^2 = 6.18^*$ for foot versus mechanical threshing by farm size.

Weeding accounted for the second largest labor input. Estimates for weeding labor varied extremely, and respondents stressed that requirements differed from field to field, depending on the weed population and field-water status. Head loading of compost also had a highly variable labor input, depending on the distance and the elevation difference between the homestead and the ricefield.

Table 11. Labor inputs by gender, to grow 1 acre of rice, Wangdi-Punakha Valley, 1986-87.

Activity[a]	Labor input (d/acre)			
	Women	Men	Both	Total
Seedbed (0.15 acre)				
Cultivation (plowing, harrowing)	-	3	-	3
Leveling, digging, seeding	-	-	1	1
Compost production, carting, and spreading	1	-	-	1
Weeding	10	-	-	10
Subtotal	11	3	1	15
Ricefield (1 acre)				
Cultivation and land preparation	-	9	7	16
Compost production, carting, and spreading	3	-	-	3
Transplanting	17	-	-	17
Weeding	-	-	21	21
Irrigation/crop care	-	-	9	9
Harvesting and stacking	-	-	15	15
Threshing, winnowing, and bagging	-	-	16	16
Subtotal	20	9	68	97
Total	31	12	69	112
Labor days by gender (%)	28	11	61	-

[a] Labor for carting compost was not recorded; therefore, the figure was estimated, on the basis that 3 persons can cart and spread compost on 0.6 acres in 1 d. Transplanting includes pulling and bundling of seedlings, carting from seedbed to field, and transplanting.



7. Distribution of labor inputs by farm operation for rice production, Wangdi-Punakha Valley, 1986-87.

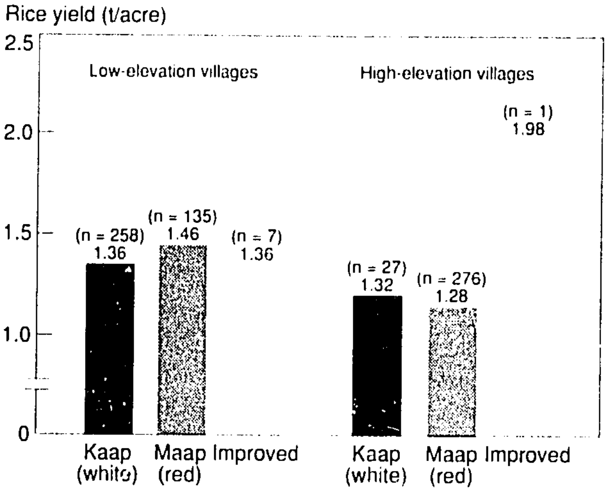
Labor shortages at peak periods undoubtedly influence farming practices. For example, the spread of transplanting dates may be an important mechanism to even out the demand for labor and draft power during this busy period. Staggering transplanting dates, combined with choice of variety (kaap matures about 10 d earlier than maap), also extends the harvesting period, possibly reflecting the management of a labor constraint then. (Delaying rice harvest also delays wheat seeding, which in turn reduces wheat yields.) Also, it has been widely reported that much of the rice crop is overmature at harvest, which results in high shattering and field losses (DA 1983, IFAD 1987). Delayed harvest may reflect a labor constraint. It also may reflect that foot threshing is easiest when the grain is fully ripe.

This survey did not address how farmers manage labor constraints, but the issue should be examined carefully. Informal observations suggest that labor constraints have important impacts on yields of the total crop pattern over time. A systems perspective should be used to identify the interactions and compromises involved in a farm household's management of its scarce labor supplies. These perceptions are needed to focus and evaluate research designed to study ways to increase labor productivity.

Rice yields

There was not an appreciable difference between average farmer-reported yields at low and high elevations. Farmers estimated average rice yields at the plot level (Fig. 8). Kaap rice averaged 1.4 t/acre (3.4 t/ha), and maap rice 1.5 t/acre (3.7 t/ha) at the low elevation. At the high elevation, mean yields were 1.3 t/acre (3.2 t/ha) for both kaap and maap rices.

Yield determinants. Rice yields result from many environmental and management factors in complex interaction. One important determinant of yield may be land quality. Consistent with that expectation, farmers reported significantly higher yields on the good than on the medium-quality land, which in turn were significantly higher than on the poor land (Table 12).



8. Estimate, based on farmer recall, of rice yields by variety type in low- and high-elevation villages, Wangdi-Punakha Valley, 1986-87.

Table 12 also illustrates a second important point: the yield performance of modern rices should not be assessed against yield averages for local varieties, but rather in terms of yield of local rices grown on the same soil type. Thus, if modern rice varieties are grown on good land, and if experiments are located on good land—as seems to be the case—then they may be competing with yields of local varieties, which are already on the order of 1.5 t/acre (3.7 t/ha).

We attempted to relate rice yields to site- and management-related variables using production function analysis. This was unsuccessful: the only consistently significant variable was land quality.

Rice disposition

Rice. Rice consumed by the household represented 74% or more of production, more in the high- than in the low- elevation villages (Table 13). Another 4% (high elevation) and 9% (low elevation) of production were used for beverages.

Some 12-14% of the rice produced was marketed—sold for cash or used to trade for goods such as meat and butter. While in the low-elevation villages the amount bartered was only a little more than the amount sold, barter was considerably more important in the high-elevation villages.

Rice marketed (i.e., cash sales and barter) was regressed against total rice production and family size to provide a sense of the relationship between production and off-farm disposal. The estimated equation in logarithms was

$$\begin{aligned} M &= -0.55 + 1.12Q - 0.14F \\ &\qquad\quad (9.64)^{**}\ (.62)^{ns} \\ F\,(2,\,68) &= 46.83^{**}\ \bar{R}^2 = 0.57 \end{aligned}$$

where M = rice marketed, Q = total production, and F = family size.

As total rice production increased, the quantity marketed increased faster (Fig. 9). Specifically, a 1% increase in rice production was associated with a 1.12% increase in off-farm disposition; a 1% increase in household size was associated

Table 12. Rice yields by land quality, low and high elevation landscape positions, Wangdi-Punakha Valley, 1986-87.

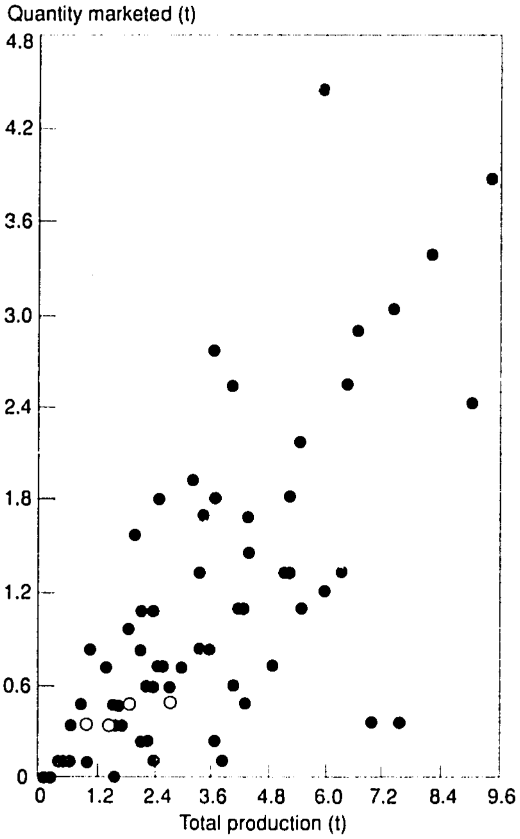
Item	Plots (no.)	Yield (t/acre)[a] *Rap* land	*Ding* land	*Tha* land
Low elevation				
Kaap (white)	238	1.53 a	1.29 b	1.00 c
Maap (red)	135	1.62 a	1.33 bc	1.05 c
Combined	381	1.57 a	1.30 b	1.01 c
High elevation				
Kaap (white)	27	1.61 a	1.26 a	1.25 a
Maap (red)	276	1.49 a	1.25 b	0.99 c
Combined	304	1.50 a	1.25 b	1.01 c

[a] Within rows, yields followed by the same letter are not significantly different at the 5% level based on DMRT.

Table 13. Disposition of rough rice, low- and high-elevation samples, Wangdi-Punakha Valley, 1986-87.

Disposition	Rice quantity (%) [a]					
	Low elevation			High elevation		
	Kaap	Maap	Combined	Kaap	Maap	Combined
Consumed	76	72	74	89	81	83
Made into beverages	7	13	9	2	4	4
Sold	7	5	6	1	2	2
Bartered	8	9	8	7	11	10
Other	2	1	2	0	2	1

[a] Percentages may not add up to 100 due to rounding.



9. Relationship between quantity of rice marketed and total production, low- and high-elevation villages, Wangdi-Punakha Valley, 1986-87.

with a 0.14% decrease in marketed rice. The difference with family size was not significant. (Family size was not well estimated. It is likely that rice consumption differs with gender and age, but we did not have adequate data to weight rice consumption accordingly.) This analysis does suggest that increases in rice supplies resulting from the adoption of modern rice technology by Wangdi-Punakha rice-farming families would have a substantial market impact, by increasing market supply rather than increasing home consumption.

Rice straw. Rice straw was the major source of livestock feed, particularly in winter when feed is scarce due to the combination of low temperature and low rainfall. Two-thirds of the low-elevation and half of the high-elevation respondents reported they produced sufficient rice straw to feed their livestock. For those farmers, the trade-off between more grain but less straw with modern varieties versus less grain but more straw with traditional varieties may not have been a major issue. However, for the one-third of the farmers at low elevation and half the farmers at high elevation who reported that straw supplies were scarce, there may indeed have been an important trade-off between rice grain and rice straw.

Factors associated with a household's perception of the scarcity of rice straw were evaluated via probit analysis. The probability of straw scarcity was related to farm size and density of large animals (cattle and cows/acre of riceland) by:

$$\begin{array}{l} \text{Prob}(S=1) = 1.46 - \underset{(0.23^{**})}{0.78F} + \underset{(0.005^{*})}{0.01A} \\ \text{log likelihood ratio} = -69.86,\ df = 98 \end{array}$$

(bracketed numbers are standard errors of the estimates)

where S = straw scarcity, F = farm size, and A = animal density.

The probability that a household would be short of straw for winter livestock feed decreased as farm size increased, and increased as livestock density/acre of riceland increased.

Rice bran. Although it was not considered in conducting the survey, rice bran is a major diet item for pigs, and most households own pigs. In winter, when other feed sources are scarce, a mixture of bran and rice husks often is boiled and fed to the pigs.

COSTS AND RETURNS OF RICE PRODUCTION

Valuing rice inputs and outputs

The prices of inputs and outputs of rice production in the Wangdi-Punakha Valley are summarized in Table 14. The prices of items that are traded, and thus have market values, are comparatively easy to obtain. However, assigning a value to compost and rice straw is more difficult, because they are not normally bought and sold. From the farmer's viewpoint, the value of rice straw or compost is unlikely to be zero. What is difficult is to determine the value to impute to these nontraded inputs to provide a "shadow" price for accounting purposes. Prices paid by government research farms for these goods were adjusted and used as a proxy for their in-use value.

Costs of and returns to rice production

To compare current and proposed rice technology, it is desirable to calculate the costs and returns of rice production from the farmer's viewpoint, even though very little rice is sold and few purchased inputs are used. Returns to rice production can be estimated in at least two ways:

- Calculate labor returns per kilogram of rice (because virtually no purchased inputs are used).
- Calculate the financial costs and returns by using market prices for traded inputs, such as labor, bullock power, and seed, and imputed values for home-produced and -consumed inputs, such as rice straw and compost.

Labor returns. The labor returns to traditional rice production are summarized in Table 15. The labor return to rice production (12.5 kg/d) was 1.4 times the in-kind wage (9 kg/d). Labor returned nearly 7 kg milled rice/d, in addition to the value of the straw.

A limitation of this calculation is that the share of output attributed to other factors of production (such as animal power, compost, and land) is ignored. This will become a severe limitation when the returns to new technology, which uses higher levels of purchased inputs, are assessed.

Financial analysis. Table 16 presents a financial picture of the benefits of rice production by comparing the costs and returns of rice production. Two budgets are presented. Scenario 1 assumes that the value of straw and compost is zero. In Scenario 2, opportunity costs are assigned to these nonmarketed factors. The analysis is in terms of kaap rice, because it is more usually sold and is lower priced. Kaap rice has similar yields to maap rice, so it provides a conservative

Table 14. Typical costs of rice inputs and outputs, Wangdi-Punakha Valley, October-November 1987.

Input or output	Qualifier	Value	Unit[a]	Comment
Output market prices				
Rice	Kaap			Rice is rarely sold as unmilled rice
	High	7.2	Nu/kg	High price in July to September
	Low	5.8	Nu/kg	Low price in November to January
	Maap			
	High	8.6	Nu/kg	High price in July to September
	Low	7.0	Nu/kg	Low price in November to January
Rough rice				
	Kaap	3.2	Nu/kg	Rough rice normally exchanged at 5 dre or Nu 20 for a day's labor
Threshing				
	Pedal thresher	40	Nu/d	10 dre rough rice for machine without operator
		60	Nu/d	For machine and operator
	Power thresher	12.5	%	5 dre rough rice for each 40 dre threshed
Rice milling		6	%	1 dre of rice for each 40 dre of milled rice
		55.0	%	Milling recovery for local rice varieties
Labor				
	Cash/kind	20.0	Nu/d	Both men and women are usually paid Nu 20/d cash or 5 dre rough rice/d. Three meals are normally provided, and often snacks during transplanting season. By transplanting time, when rough rice is more expensive, in-kind payment of rough rice may fall to 3-4 dre/d.
	Meals	15.0	Nu/d	
	Total	35.0	Nu/d	
Cultivation				
	Bullocks (2)	40	Nu/d	Nu 40/d (10 dre rough rice) or 2 d of labor paid to owner for a pair of bullocks for plowing or harrowing.
	Plowman	20	Nu/d	If plowman is hired, an extra Nu 20/d (or 5 dre rough rice) is paid.
	Total	60	Nu/d	
Imputed prices				
	Compost	100	Nu/t	Compost is not sold in the market, although it may be exchanged. The CARD research farm at Wangdi buys compost at Nu 150 for a 1.5-t trailer load; Nu 50 is deducted for transport, etc.
	Rice straw	300	Nu/t	Grain-to-straw ratio = 1:1.8. Rice straw is rarely sold. The livestock farm at Wangchutaba in Thimphu Valley buys rice straw. Straw is priced low at harvest (Nu 250-300/t); it doubles in price by the feed-scarce period at the end of winter.
	Transport cost	1.2	Nu/kg	Rice is normally sold in Thimphu. Typical fare from the valley to the city is Nu 18 each way, plus Nu 13 for a 40-kg sack of rice.

[a] Nu 12.8 = US$1.

Table 15. Labor returns to rice production, Wangdi-Punakha Valley, 1986-87.

Item	Level	Unit	Comment or source
Output			
Grain	1.4	t/acre	Table 12
Straw	2.5	t/acre	Table 16
Labor input	112	d/acre	Table 11
Output/labor day			
Rough rice	12.5	kg/d	
Milled rice	6.9	kg/d	55% milling recovery
Rough rice wage rate	8.7	kg/d	5 dre/d (plus 2 dre/d as food equivalent)

and defensible estimate of the gross margin of traditional rice production.

Benefits. Gross returns are summarized in Table 16 Marketing costs (Nu 1.2/kg) are deducted from the sale price to derive a farmer-effective price of milled rice of Nu 5.3/kg. Rough rice is converted to milled rice and in-kind milling charges are deducted to derive the farmer-effective yield of milled rice. Gross returns varied from Nu 3,143 to Nu 3,893/acre, depending on the value assigned to rice straw.

Variable costs. Variable costs include the costs of growing both the rice seedbed and the rice crop. Costs for inorganic fertilizer applied to the seedbed and for insecticides are not included because of their low frequency and level of use. The variable cost of producing an acre of rice is Nu 2,818 (US$220)-Nu 3,368 (US$263) when all household resources are valued at their market or opportunity prices.

Net returns. Net returns, the difference between gross revenue and variable costs for owned and tenanted riceland, are given in Table 16. The net return for owned land is about Nu 325 (US$25)/acre when the values of straw and compost are ignored, but nearly Nu 525 (US$41) when an imputed value for these factors is included.

Net returns for tenanted land are negative, more so for Scenario 1 than for Scenario 2. However, the values must be treated with caution: they do not imply that the household is taking an operating loss from rice production. The negative returns do imply that the returns to the tenants' household resources (as labor and animal power) used in rice production are less than the market (or rental) rates. But the tenant does not pay a share of the winter crop to the owner. Returns from tenant farming should be assessed in terms of land use over the cropping year, not be based on the rice crop alone.

Table 16. Costs and returns of kaap rice, Wangdi-Punakha Valley, 1987 prices.

Item	Level	Unit	Nu/acre		
			Cost/unit	Scenario	
				1	2
Gross returns					
Market price [a]	6.5	Nu/kg			
Marketing costs	1.2	Nu/kg			
Net price	5.3	Nu/kg			
Rice [b]	400	kg/acre			
Milling [a]	28	kg			
Milled rice	593	kg	5.3	3,143	3,143
Straw [a]	2.5	t/acre	300	0	750
Gross revenue		Nu/acre		3,143	3,893
Variable costs					
Labor [c]	112	days	20	2,240	2,240
Seed [d]	12	kg	4	48	48
Compost [e]	5.5	t	100	0	550
Draft power [e]	12	days	40	480	480
Capital [f]	-	Nu	-	50	50
Variable costs				2,818	3,368
Net returns					
Owned land		Nu/acre		325	525
Tenanted land [g]		Nu/acre		-1,222	-1,022

[a] Source: Table 14.

[b] Source: Table 14.

[c] Labor input, see Table 11; labor cost, see Table 14. Food costs are not included because most labor was household or exchange.

[d] Source: Table 7,14.

[e] Table 8,11,14.

[f] Charges to capital are low because a) animal power is charged at rental rate; b) most implements (plow, plank, etc.) were home produced. Minor cost for sickle, replacement steel share (tip) for plow, perhaps Nu 50/acre per yr.

[g] Output share was 50:50 for grain; tenant retained the rice straw and paid for half the seed.

We think Scenario 2 better reflects the circumstances farmers face. Inaccurate conclusions may be reached if existing and proposed technologies are compared using a Scenario 1-type analysis.

WINTER CROPS

Wheat

About 40% of the rice area was planted to wheat in winter (Table 6). Labor input to grow an acre of wheat averaged 48 d (Table 17). Wheat was seeded in November-December and harvested in late April-June. Cultivation practices are summarized in Table 18.

Plowing for wheat was done during the 4 wk following rice harvest. Most farmers plowed their wheatland twice (61% in the low elevation and 91% in the high elevation), and harrowed once. Seventy percent of the low-elevation and 30% of the high-elevation farmers harrowed a second time. The wheat seeding rate reported averaged 55 kg/acre (136 kg/ha).

Table 17. Labor input to wheat production, Wangdi-Punakha Valley, 1986-87.

Activity	Labor input[a] (d/acre)
Land preparation	
Bullock days	8
Labor days	16
Compost production, carting, and spreading,	4
Seeding	1
Irrigation	5
Weeding	9
Harvesting	13
Total[b]	48

[a] Weeding labor was not included in the total because wheat was seldom weeded.

[b] Total days may not add exactly due to rounding.

About 90% of the wheat growers applied compost, at an average rate of more than 5 t/acre (14 t/ha)—about the same as for rice. No respondents reported using inorganic fertilizer on wheat.

A higher proportion of low-elevation than high-elevation farmers irrigated their wheat, and they irrigated often—as many as three times. More high-elevation (26%) than low-elevation (2%) respondents weeded their wheat crops.

Wheat yields were regressed against site- and management-related factors:

$$Y = 413.26 - \underset{(-1.38^{*})}{132.10D} + \underset{(1.93^{*})}{155.11L} + \underset{(12.62^{**})}{6.06S} - \underset{(-1.31^{*})}{0.24A} + \underset{(0.75^{ns})}{17.87F}$$

$$F(5, 63) = 36.12^{**};\ \bar{R}^2 = 0.72$$

where Y = yield (in kg/acre), D = seeding date, L = land quality, S = seed rate, A = altitude, and F = farm size (in hectares). Wheat yields were lower when the crop was seeded late and at high altitudes and higher on good land and at high seed rates.

All but two respondents harvested their wheat crops as grain. The two who did not fed the wheat as green feed to their livestock. Average wheat yields were 0.35 t/acre (0.9 t/ha) on the low-elevation farms and 0.30 t/acre (0.7 t/ha) on the high-elevation farms, an average of 0.33 t/acre (0.8 t/ha) over the whole sample.

Other field crops

Small areas of mustard, buckwheat, potato, and barley were grown in rotation with rice (Table 6). The yield figures for these crops (Table 19) are at best indicative. Because areas were small and observations few (other than for mustard), standard errors of estimates and scaling errors may be high.

Table 18. Input use and yield of winter-grown spring wheat by elevation, Wangdi-Punakha Valley, 1986-87.[a]

Item		Unit	Elevation		Difference	Combined
			Low	High		
Plowing: first		%	100	100	0 ns	100
	second	%	61	91	30 *	74
Harrowing: first		%	93	88	5 ns	91
	second	%	30	16	14 ns	23
Compost						
	Users	%	89	95	6 ns	92
	Rate	t/acre	5.2	5.8	0.6 ns	5.5
Seed		kg/acre	54	56	2 ns	55
Irrigation: 1		%	96	81	15 ns	89
	2	%	70	40	30 *	55
	3	%	32	2	30 *	17
Weeding		%	2	26	24 *	14
Yield		t/acre	0.35	0.30	0.05 ns	0.33
		S.D.	0.15	0.17	-	0.16
Sample size		n	54	43	-	97

[a] Differences in proportions (%) were based on χ^2 tests, quantity values on *t*-tests. * = significant at the 5% level, ns = not significant.

Mustard yielded 0.19-0.25 t/acre (0.5-0.6 t/ha) over the farms surveyed, with more low-elevation (72%) than high-elevation (43%) farms growing the crop. Buckwheat yields averaged 0.5-0.7 t/acre (1.2-1.7 t/ha), barley about 0.5 t/acre (1.3 t/ha). Potato (more widely grown by high-elevation farmers) yielded an average 1.8 t/acre (4.4 t/ha). The average potato yield was low because the potato crops of 5 of 19 respondents were severely damaged by hail.

CONCLUSIONS

This survey of rice production in the Wangdi-Punakha Valley was undertaken

- to provide a base to measure the future impact of CARD's rice program,
- to document current methods of rice production, and
- to identify on-farm research priorities.

Impact assessment

As the CARD program in the Wangdi-Punakha Valley proceeds, it would be advantageous to measure the direct and indirect effects of increased rice production. In practice, direct indicators (such as percentage of area planted to new varieties and changes in rice yields) will be the most important in measuring the program's impact. Less direct indicators (such as changes in household income, employment, food security, and other quality of life indicators) will be more difficult to measure. Also, these types of changes might not be observable within the time span in which impact will be assessed.

For these reasons, and for operational ease, we propose that impact assessment focus on direct effects, and possibly household assessment of whether their food security has improved following adoption of modern rice varieties. Confidence in impact estimates could be increased by using crop-cuts and physical measurement of plot areas to reinforce farmer recall. It is important to measure impact by riceland quality, because yields and adoption rates are likely to differ significantly among land types.

At present, modern rice varieties are not widely grown by farmers in the Wangdi-Punakha Valley. Under farmer management, traditional varieties yield about 1.5 t/acre (3.7 t/ha) on good land, 1.3 t/acre (3.2 t/ha) on medium-quality land, and 1.0 t/acre (2.5 t/ha) on poor land. These yield estimates (based on farmer recall) provide a baseline from which to measure aggregate yield gain due to the new rice technology that is recommended.

Rice production systems

The survey confirmed that farmers use labor-intensive methods of rice production. Few purchased inputs are used; soil fertility is maintained by using organic fertilizers. Pesticide use is minimal. Modern rice technology presumably will involve the use of complementary inputs, such as both new varieties and fertilizers. When the productivity gains from modern rice technology are assessed, it will be advantageous to disaggregate the sources of yield gains to their component parts.

Rice research priorities

Economic planning. Increased rice production is likely to lead to a substantial increase in the amount of rice marketed. Such supply increases may lead to rice price declines, unless the management of imported rice stocks is handled with care. The government confronts the challenge of adjusting rice imports and buffer stock releases to ensure that rice prices remain attractive to rice producers and consumers.

The nature of the indigenous rice market may change substantially if locally produced supplies of rice increase. For example, instead of farmers themselves taking most of their rice to Thimphu for sale, rice traders may become more important. It would be advantageous to monitor rice prices, market structure, and market performance to ensure that planners are informed of the changing nature of the rice market. This would enable rice policy to be directed to the needs of Bhutan.

Increasing farm household incomes in a stable and sustainable manner is unlikely to be achieved by relying on rice technology alone. Thus farmers will continue to require access to alternate high-income cash crops and livestock enterprises to increase and sustain their livelihood. The technical and financial feasibility of alternative winter and summer crops should be explored. Our judgment is that, given the concerns for income generation and self-sufficiency, research on vegetables and edible oil crops would be of higher priority than research on wheat.

Labor productivity. Rice—indeed, agricultural production in general—is based on family labor supplemented by exchange labor. Labor use (more than 100 d/acre for a rice

Table 19. Indicative yields (t/acre) of mustard, buckwheat, potato, and barley grown in sequence with rice, Wangdi-Punakha Valley, 1986-87.

Crop	Low elevation		High elevation		High and low elevations	
	Sample size	Yield (t/acre)	Sample size	Yield (t/acre)	Sample size	Yield (t/acre)
Mustard	42	0.19	26	0.25	68	0.22
Buckwheat	16	0.68	20	0.46	36	0.56
Potato	4	1.75	15	1.85	19	1.83
Barley	1	0.52	1	0.52	2	0.52

crop) is high. Even though farm size is small (usually less than 3 acres), households face severe labor constraints at peak labor demand periods, such as during riceland preparation and transplanting (June-July) and during rice harvest and wheatland preparation (November-December). One implication is that technology that aggravates existing peak demands for labor is unlikely to be adopted. Another is that, when designing research to evaluate methods to increase labor productivity, it is necessary to understand how labor shortages influence farming practices. Farmers' labor and power management strategies merit specific study. A survey using structured sets of open-ended guide questions that focus on why farmers do what they do, rather than on what farmers do, would be an appropriate research emphasis and methodology to use in addressing this issue.

CARD is conducting research to identify ways to reduce labor bottlenecks and to increase labor productivity (such as the use of rotary weeders and threshers, and direct seeding of rice). While that focus is maintained, part of its evaluation should be on the impact of changing the labor used for one operation on the labor requirements at other points in the production cycle. The role of modern short-duration varieties (such as IR36 and IR64) in spreading labor peaks also deserves special attention.

Crop management. The wide range of rice management research now being undertaken by CARD staff, both at the Wangdi station and in farmers' fields, is directed toward addressing the problems that rice farmers face. The research on fertility management, including integrated use of organic fertilizers (both composts and green manure crops) and moderate rates of inorganic fertilizer, seems particularly well directed. There may be benefit, however, in establishing trials on representative land types to examine long-term fertility and pest management of intensified rice-based systems and to evaluate the residual effects of rice and winter crops on each other. This issue may become extremely important should oilseed crops increase in importance and wheat production be intensified.

Information on pest populations (both insects and diseases, and their damage levels) now present in rice in the Wangdi-Punakha Valley should be quantified. This information is vital as a basis for interpreting any pest incidences occurring after farmers adopt new varieties and more intensive systems of crop management.

Evaluation and extension. CARD is systematically evaluating promising rice varieties and methods of crop management in farmers' fields. The Wangdi-Punakha Valley survey shows that farmers may not apply farmyard manure to a rice crop on areas where it had previously been applied to the winter wheat crop. This suggests that it is desirable

- to document the history of each field site to help interpret trial results, and
- to develop fertilizer recommendations for rice, based on land quality, fertilizer management, and type of previous winter crop.

Farmer-reported yields on good land are consistent with researcher estimates of farmers' yields in demonstration plots. It may be that trials and demonstrations have been established on better quality land. It would be advantageous to stratify sites by land quality to ensure that technology is evaluated over the range of soil conditions found in the Wangdi-Punakha Valley.

Although women play a dominant role in rice production in the valley, they seem to have been overlooked in the development and extension of technology. Better understanding of the criteria used to select rice varieties and production technologies is needed to focus extension more toward women. Extension methods should be suitable for people with low literacy.

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APPENDIX

Sampling logic

Ninety-four villages having more than 15 households each are listed for the Wangdi-Punakha Valley. Fifty-four (57%) are located in the low- and 40 (43%) in the high-altitude strata. Proportional sampling would call for selecting 11 villages from the low and 9 villages from the high strata, for a sample of 20 villages.

Nonetheless, it was decided to sample 10 villages from each stratum (Appendix Table 1), for three reasons. First, stratification of low- and high-altitude villages was arbitrary, insofar as farmlands within villages near the boundary elevation may be both above and below the cut-off point. Second, much of the more important analysis was intended to capture elevation as a continuous, as opposed to dichotomous, variable. Third, ten villages in each stratum provided the planned minimum sample of 20 respondents with each farm size at each elevation.

Sampling two households from each of the three farm size strata yielded the planned 20 samples for each cell. In practice, Department of Agriculture records and those reported by farmers did not always match (Appendix Table 2). (Underreporting of farm size for tax purposes is common.) Two high-elevation farms were excluded from the analysis. Thus, 60 households in the low elevation and 58 in the high elevation were included in the analysis of rice-based farming systems. Because the sample was a stratified one, simple averages over all observations may result in biased estimates of mean values because the number of cases in each stratum may be represented at higher or lower frequencies than they actually occur. Thus, weights must be derived from each farm size class when deriving mean values of estimates within the low- and high-elevation strata adopted in this study.

An approximate set of multipliers is presented in Appendix Table 3.

Appendix Table 1. Villages surveyed, Wangdi-Punakha Valley, 1987.

Dzongkhag (district)	Gewong (block)	Village	Altitude (m)
Low elevation			
Punakha	Bjemi	Khubji	1470
Punakha	Kabji	Wekuna	1340
Punakha	Zomi	Tana	1240
Punakha	Kabji	Tharabachaa	1330
Punakha	Tewang	Dawakha	1500
Punakha	Zomi	Zimthang	1240
Punakha	Zomi	Menagong	1240
Thimphu	Bap	Pacheykha,Motokha,Esakha	1260
Wangdiphodrang	Thetsho	Bajo	1235
Wangdiphodrang	Upper Gasello	Masepokto	1420
High elevation			
Wangdiphodrang	Nisho	Nishokha	1830
Wangdiphodrang	Bjena	Wachey Gumina	1580
Wangdiphodrang	Lower Gasello	Thapchakha, Mebesa, Gikha	1710
Wangdiphodrang	Nisho	Chebakha	1530
Punakha	Talo	Gangthramo	1900
Punakha	Shengana	Ghangkha	1755
Punakha	Talo	Norbgang	1940
Punakha	Bjemi	Datogempa	1930
Thimpu	Toebesa	Thinieygang, Mendegang	1780
Thimpu	Toebesa	Menchunang	2080

Appendix Table 2. Planned and actual distribution of sample farms, by size and elevation.[a]

Farm size	Area (acres)	Planned sample	Actual sample Low elevation	Actual sample High elevation
Small	<1.50	20	16	12
Medium	1.51-3.00	20	24	20
Large	>3.00	20	20	26
Total		60	60	58

[a] Two high-elevation farms (one medium and one large) were excluded in this analysis.

Appendix Table 3. Multipliers used to derive estimated population means for Wangdi-Punakha Valley.

Elevation	Total households[a]		Households by stratum[b]	Sampled households	Multiplier
Low	18,240	Small	10,944	16	.342
		Medium	5,472	24	.171
		Large	1,824	20	.057
High	13,760	Small	8,256	12	.258
		Medium	4,128	20	.129
		Large	1,376	26	.043

[a] Assuming 32,000 agricultural households in the valley (IFAD 1987), with 57% and 43% of villages and populations in low- and high-elevation landscapes, respectively.
[b] The proportion of households falling under each category is assumed to be 60% small, 30% medium, and 10% large. Interpolated from DA 1983.

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