Wheat and Rice in the Mid-Hills of Nepal:

A Benchmark Report on Farm Resources and Production Practices in Kavre District

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CIMMYT (www.cimmyt.mx or www.cimmyt.cgiar.org) is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center works with agricultural research institutions worldwide to improve the productivity, profitability, and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of 16 similar centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR comprises over 55 partner countries, international and regional organizations, and private foundations. It is co-sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP). Financial support for CIMMYT's research agenda also comes from many other sources, including foundations, development banks, and public and private agencies.

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Abstract: This benchmark survey involved a random sample of 54 farmers from the Naldung area, grouped by altitude class, ethnicity, land type, and several farm-level categories to characterize sample variability for production practices and yield. The study identified soil fertility, crop establishment, and weed and pest management as key factors for maintaining high rice and wheat yields in the mid-hills of Nepal. Results are available in the form of an easily accessible database, and will allow researchers and policy-makers to track changes in farmers' resources, production practices, and system productivity.

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We are deeply indebted as well to all the technical staff—agricultural officers, junior technicians, and junior technician assistants—who, through their long hours of field work, helped compile a virtual "Mt. Everest" of data. Technical staff also visited farmers at the time of the survey, administered field questionnaires, and collected crop cuts from intensive data plots at the time of harvest. The drivers of NARC, Khumaltar, deserve special recognition for safely and efficiently transporting all survey participants to and from the study area.

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Executive Summary

This paper presents benchmark data collected in the first year of a long-term study of farmers' resources and production practices in the rice-wheat system research site of Naldung, Kavre District in the mid-hills of Nepal. The monitoring project has two objectives: the first is to quantify current farm resources, management practices, land and resource quality, and system productivity; the second is to describe changes in these variables over time.

Methods

A random sample of 54 farmers was selected from six villages in the Naldung area comprising three altitude classes. The sample included 9 farmers from each village, or a total of 18 farmers from each altitude class. During both rice and wheat seasons, a multidisciplinary team from the National Agricultural Research Center (NARC) in Khumaltar surveyed selected farmers and visited the largest rice-wheat field from each farm. These fields were used as intensive data plots (IDPs) from which soil samples were taken and crop cut measures gathered for yield estimates. In addition to altitude class, the samples were grouped by ethnicity (*Bhramin/ Chhetri*, *Newar* or *Tamang*), land type (*Danda* and *Tar*), and several farm-level categories to characterize sample variability for production practices and yield levels.

Farmers' Resources

Farmers' resources—including land use/type, labor and power resources, and livestock—were quantified. Farms in the study area are small on average (1.1 ha) and all are owner-operated. Forty-four percent of the land is cropped to wheat in winter, with the remainder cropped to oil seeds, potatoes, pulses, and vegetables. Rice is the major summer crop grown during the wet monsoon period on the bunded *khet* land. Maize is grown on the unbunded, sloping *bari* land. Family size was large, with an average of 7.7 members and four workers per family. Farm mechanization was minimal, with most fields being plowed and planked by bullocks. Farmers owned on average four large animals per farm.

Wheat and Rice Production Practices

Wheat and rice production practices (seeding date, seed variety, input use, water and pest management, etc.) were recorded. All wheat was sown by broadcasting, with seed rates averaging 138 kg/ha, higher than recommended levels. The most popular wheat variety was RR21, an old improved variety with rust and blight susceptibility. Nearly 83% of farmers are using improved varieties. Wheat planting dates ranged from 22 October to 22 December, with only 40% of fields planted during the optimal period of mid-November. Low plant population was a problem on 30% of fields, and was typically associated with poor seed quality. Almost all wheat fields received nitrogen (N) and phosphorus (P) fertilizer and 50% of farmers used farmyard manure (FYM) on every crop. On average, 59 kg N and 34 kg P_2O_5 /ha were applied for wheat, well below recommended application rates (100 kg/ha and 60-80 kg/ha, respectively). Farmers used 7 t/ha FYM prior to planting. Manure was applied to every crop on 50% of the fields and every year on 28% of the fields.

All rice fields were transplanted. The median seedbed establishment date was 7 June, and 36 day-old seedlings were transplanted with a median date of 15 July. The majority of the fields had fair to good plant stand. Eight rice varieties (all improved) were reported. Himali, Khumal-4, and Taichung were the most popular varieties, covering more than 75% of fields. Land preparation consisted of 3-4 plowings and plankings by bullock. Fertilizer doses were similar to those for wheat (55 kg/N ha and 38 kg P/ha), also well below recommended levels. Drought or water stress was not found to be a problem in rice. Half the survey fields had received FYM prior to the rice season. Pests were relatively minor. No chemical pest control was used on wheat or rice. The average date of rice harvest was 7 November, with a range of 15 October to 30 November. All rice harvesting and threshing was done manually.

Estimated Yields and Factors Affecting Yields

Paddy rice yields obtained by survey farmers were higher (3,529 kg ha^{-1}) than the statistics for Kavre District (2,100 kg ha^{-1}) or farmers' estimate (3,291 kg ha^{-1}). In general, higher average yields were recorded at lower altitudes. Nitrogen and phosphorus rates and plant stand were all related to higher yield.

Average wheat yield was 1,964 kg ha^{-1} and ranged from 1,120 kg ha^{-1} to 2,820 kg ha^{-1}. Yield differed by farmer categories. Higher yields were recorded on *Tar* land, among large holders, and among lower altitude farmers, where most *Tar* land is found. Nitrogen (both basal and topdress) and phosphorus application rates were also related to higher wheat yield. Plant stand and disease, particularly rust and blight, were important constraints to wheat yields, particularly in RR21. Other improved varieties had higher yields than RR21.

Total rice and wheat yields averaged 5,490 kg ha^{-1}, with a maximum yield of 8,672 kg ha^{-1}. These yield levels are sub-optimal, and likely related to low input levels. Rice and wheat yields were not correlated with each other, indicating that the factors affecting rice and wheat yields are different. In most cases, different parameters had significantly different effects on total rice or wheat production, and very few parameters were important for both rice and wheat production. Rice yields varied mostly by altitude and ethnic group, while wheat yields were affected by altitude, ethnic group, land holding and land type.

The 114 kg N and 80 kg P_2O_5 applied on average to rice and wheat are well below levels needed to obtain higher yields in either crop. Increased levels of these two major nutrients as well as greater potassium (K) use will be needed to prevent soil nutrient depletion. Farmyard manure, generally of poor quality in the study area, is also essential for sustainable yields. Farmers in higher altitudes applied more FYM in their crops, most likely because of the greater proximity of their fields to the household. More FYM was used on wheat than on rice. Wheat is planted in the winter (dry) season, when FYM is drier and thus easier to transport to the fields. Finally, poor land preparation and seed quality caused poor crop establishment and plant population. Future research should emphasize balanced nutrient management, improvement of FYM quality, and the improvement of implements for land preparation and seed quality.

Conclusions

Soil fertility, crop establishment, and weed and pest management are all important for high, sustainable rice and wheat yields. This benchmark survey will be the basis for describing changes in farmers' resources, production practices, and system productivity in the years to come. It will also provide a valuable, easily accessible database that can be used by researchers and policy makers alike in their efforts to improve the productivity and sustainability of the rice-wheat system in the mid-hills of Nepal.

Wheat and Rice in the Mid-Hills of Nepal: A Benchmark Report on Farm Resources and Production Practices in Kavre District

Introduction

The Nepal Agricultural Research Council (NARC) has begun a program of collaborative research with the international agriculture research centers, represented by the International Maize and Wheat Improvement Center (CIMMYT, by its Spanish acronym), the International Rice Research Institute (IRRI), and the national agriculture research systems of India, Bangladesh, and Pakistan. The goal is to improve the productivity and long-term sustainability of rice-wheat cropping systems in Nepal. This collaboration is implemented through an ecoregional initiative, called the Rice-Wheat Consortium (RWC),[1] of the Consultative Group on International Agricultural Research (CGIAR).

Rice-wheat systems research in Naldung, Kavre District, Nepal, began in 1992 with a diagnostic survey of farm resources and production practices. Subsequently, monitoring of farm households was initiated during the 1993-94 wheat season and is on-going.

The rice-wheat cropping system is essential to food security in the hills of Nepal. Rice, maize, and wheat constitute the preferred staple foods for the region. Yet recent diagnostic field surveys based on farmer interviews and qualitative assessment have documented stagnant or declining yield trends in the rice-wheat system. This decline has been attributed to several factors, most notably:

- Soil health decline due to erosion, continuous cropping, and the mining of soil nutrients.
- Insect pests, disease, and weed build up on crops.
- Low input use, labor scarcity, and harvesting and storage losses.
- Poor crop establishment and late planting of wheat due to 1) incompatibility of rice and wheat varieties in the cropping system, and 2) lack of tillage equipment and/or draft power to reduce the turn-around time between rice and wheat crops.

However, in the hill farming system context, these production constraints have yet to be verified by quantitative assessment in farmers' fields. After much discussion, RWC members concluded that long-term monitoring of farm households would enable researchers to effectively track changes in farmers' practices, resource availability and use, and any other quantifiable variables affecting total system productivity. For this purpose, a household monitoring survey including intensive data plot (IDP) monitoring was initiated in 1993. As data accumulate in future cycles of monitoring, researchers will aim to separate changes in yields from changes in factor productivity, dividing the latter into favorable effects of technological change and unfavorable effects of resource degradation (Hobbs et al. 1996). Continuous monitoring of the same households and IDPs in specific fields over successive years will help us to understand and distinguish between separate effects on productivity in farm input-output relationships, technological change, and resource degradation. This task will be particularly challenging given the extreme variability among farming households in physiography, land type, input use, and socioeconomic measures.

Objectives

The objectives of the study are to: 1) establish a baseline measure of farmers' management practices, farm resources, and yield levels against which future changes in these variables can be measured; and 2) document changes in these variables over time to better evaluate their implications for the sustainability of rice-wheat systems.

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[1] The Rice Wheat Consortium (RWC) was formed in 1994 to address the problems of rice-wheat systems in the Indo-Gangetic floodplain and Himalayan mid-hills. It is a partnership between national program scientists from Bangladesh, India, Nepal and Pakistan, four international centers of the CGIAR (IRRI, CIMMYT, IWMI and ICRISAT) and several institutes of scientific excellence (Cornell, IACR Rothamsted, and IAC Wageningen). The goal of the RWC is to identify sustainable solutions for increasing food production in the region.

One major interest in rice-wheat system research is to identify current constraints to the sustainability of a cropping system that is under threat due to widespread resource degradation. Rice and wheat are two of the three most important cereal grains in Nepal, and their production must keep pace with population increases, if Nepal is to remain self sufficient in cereal grain production. This task assumes greater urgency in the hill environment of Nepal, where continuing resource degradation threatens to offset any improvements brought about by new technological innovations, many of which are difficult to extend to hill environments. In addition, agriculture is a major source of employment and income for rural communities and the poor and this needs to be considered in any technical innovation to the system.

In areas with ready access to market centers, substitution of more profitable cash crops (i.e., vegetables) in response to market pressures can effectively displace cereal crops. While diversification into high value crops is a desirable objective and can improve farmer incomes, substitution of such crops will mean less land for cereal production. One objective is to increase rice and wheat yield per unit area so that farmers will be able to meet their own cereal needs on fewer hectares, freeing up land for the cultivation of high value crops. Thus, greater rice-wheat system productivity can help achieve the twin goals of improved food security and greater flexibility for crop diversification.

Sustainable increases in rice and wheat yields must come in part through greater efficiency in the use of agricultural inputs. Put in economic terms, we must enhance total factor productivity (TFP)[2] – a measure of agricultural output per unit of input –if we wish to ensure the sustainability of the rice-wheat system. Data were collected in this study on costs and returns of the various stages of crop production so that TFP can be roughly estimated. Long-term monitoring of farm households and intensive data plots will also help us understand trends in the following factors:

- Resource degradation – processes and causes of such degradation, as well as short, medium, and long-term impact scenarios. Data include labile soil carbon, soil organic matter, and biotic factors above and below ground.
- Technological innovations currently used and their effect on TFP.
- Socioeconomic change, the effect of market forces, and other relevant social, economic, and political factors.

Location and General Characteristics of the Study Area

The Naldung Rice-Wheat Research Site is located 34 km east of the Kathmandu Valley, in the Kavre District of the Central Development Region of Nepal (85° 24' - 85° 59 ' latitude and 27° 20' - 27° 45' longitude) (Fig. 1).[3] It is one of three sites in Nepal involved in a program of collaborative research under the Rice-Wheat Consortium for the Indo-Gangetic Plains. The goal of this research is to improve the productivity and sustainability of rice-wheat cropping in the region. The first two sites represent the subtropical eco-zone of the *Terai.* One is located in Rupandehi and Kapilvastu Districts and is centered around the National Wheat Research Program in Bhairahawa; the other is situated in Bara and Parsa Districts and coordinated by the Parwanipur Rice Research Station near Birganj. The third research site, located in Naldung, Kavre District, represents Nepal's mid-hill eco-zone (Hobbs et al. 1996). It is this site that is the focus of this paper. The Arniko highway, connecting Kathmandu to the Tibetan border, bisects Kavre District, making parts of the area easily accessible from the capital. The research area extends from the eastern slope of the ridge at Nagarkot to the Indrawati River below at Sipaghat. Ranging from valley bottom to mid-hills (650 to 2,150 masl), the Naldung area represents diverse agro-ecological conditions and major cultivated land types of the Mahabharat middle mountain range in Nepal.

Six villages, grouped into three altitude domains, constitute the main locations for rice-wheat research at the Naldung site. Though all six villages lie within

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[2] Total factor productivity (TFP) is defined as "the ratio of total output value (i.e. grain and harvested biomass or forage) to the total cost of all inputs used to produce the crop, including labor, animal work, fossil fuels, organic and inorganic nutrient applications, pesticides, irrigation water, and seed." (Cassman and Pingali 1995).

[3] Refer to Harrington et.al. (1992) for a more detailed description of this site.

the mid-hill ecozone, for the purposes of this study they are classified as "high," "middle" or "low altitude." Naldung and Chitte (1,400 masl) form the high altitude group, Singhe and Nayagaun (1,100 masl) the midaltitude group, and Sipaghat and Mahadevsthan (650-750 masl), in the river valley, constitute the low altitude group. Together, these sites comprise lowland (121 ha), upland (222 ha), *kharbari* (uncultivated private lands) (65 ha), pasture (34 ha), and forested land types (33 ha). Lands cultivated in the valley include both plains and terraced land. Streams are the sole source of irrigation for the 343 hectares of cultivated land; 8.4% are fully or partially irrigated lowland, 26.2% rainfed lowland, and 65.4% upland.

There are two major land types in the mid-hills of Nepal. One consists of level, bunded terraces and valley bottom lands where rice and wheat are grown, locally referred to as *Khets*. The other dominant land type is the unbunded, sloping *Bari* land, where maize and millets are grown. Crops such as oil seeds, pulses, potatoes, and vegetables can substitute for wheat or maize on this land and, in some cases, two rice crops are grown per year on *Khet* land.

The region's climate is variable, ranging from sub-tropical in the valley at Mahadevsthan and Sipaghat to warm humid temperate in the hills at Naldung and Chitte. More than 87% of the 1,300 mm annual rainfall occurs during the monsoon season (based on ten years of climatic data collected from Nagarkot, Panchkhal, and Khumaltar; Harrington et al. 1992). The southeastern monsoon that brings the bulk of rain to Nepal begins in mid-May and ends in mid-September. There is substantial variability in terms of location, amount, and intensity of rainfall in the dry period from October to April (Fig. 2). Rainfall during this period is critical for the growth of the wheat crop. Temperatures are strongly influenced by both the altitude and aspect of the mountainous terrain: the mean monthly temperatures in the mid-hill site are 10 and 15° C lower than the valley bottom sites in summer and winter, respectively. Frost is also common at high altitude. South-facing slopes are warmer by 3-4° C than north-facing slopes. This climatic variability has a strong influence on farming systems in the area.

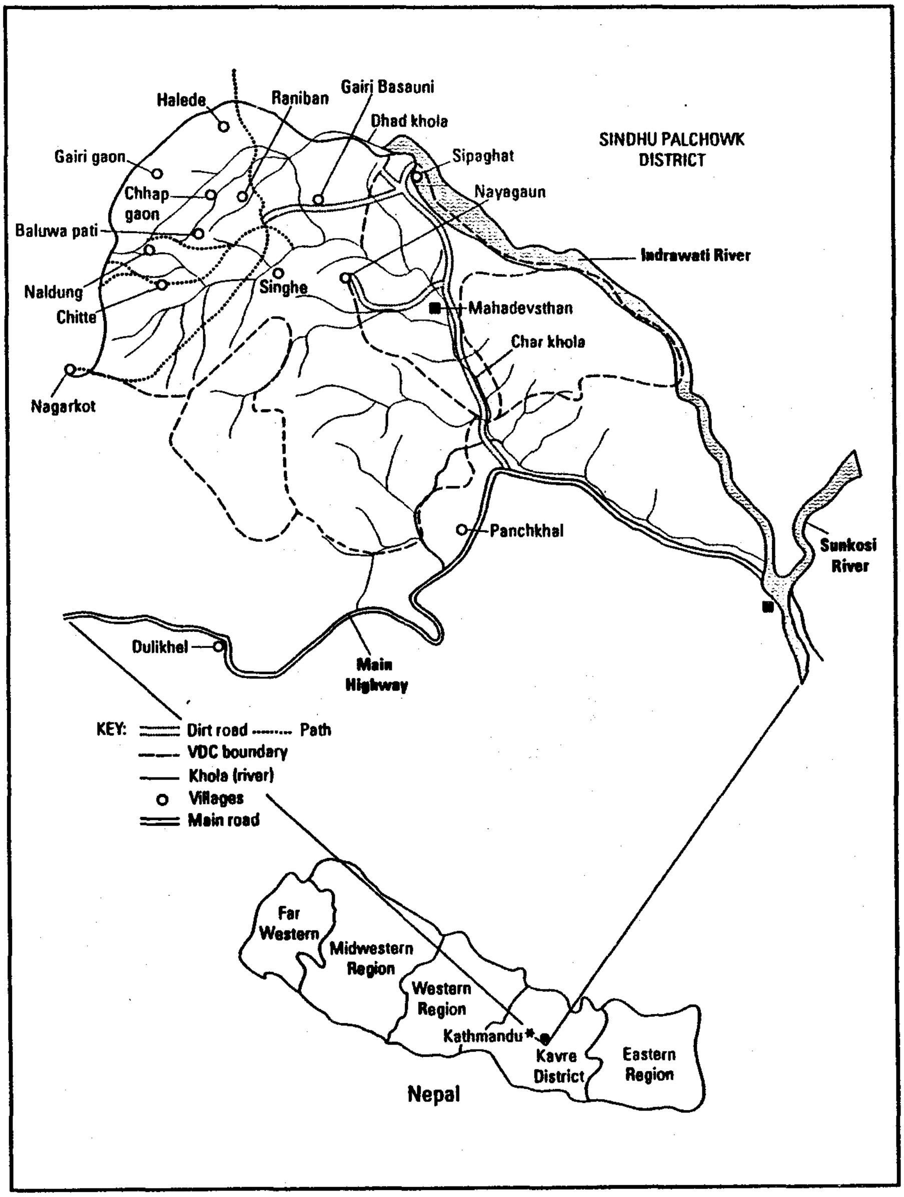

Figure 1. Location of the Kavre District study area.

Review of Constraints Highlighted by the Diagnostic Survey at Naldung

Prior to actually administering of the baseline survey and subsequent monitoring, a team of experts from NARC and CIMMYT carried out a detailed diagnostic survey. A participatory research approach, as well as numerous informal contacts, was used to identify socioeconomic and biophysical factors important for the assessment of input use, productivity, and constraints to rice and wheat production. The outcome of the diagnostic survey was the identification of variables to be used in questionnaires for the baseline and monitoring surveys.

Three diagnostic surveys in both rice and wheat cropping seasons were initiated in 1992 and 1993 at the Naldung site in Kavre (Ali et al. 1993a, 1993b; Harrington et al. 1993). The major cropping patterns on *Khet* land are numerous, including rice-wheat, rice-rice-wheat, rice-wheat-maize, rice-maize-fallow, rice-rice-potato, rice-potato-maize, rice-potato-tomato, and rice-fallow. Triple cropping patterns and patterns including potato and/or tomato are concentrated in the river valley, which has reliable irrigation. The major cropping patterns on *Bari* land are maize followed by a relay crop of millet, soybean, groundnut or upland rice. The diagnostic surveys highlighted the following constraints to greater productivity of the rice-wheat cropping system:

Poor crop establishment of wheat
- Poor plant population.
- Poor plant growth.
- Delayed planting due to long turn-around time between crops.
- Inadequate land preparation.
- Poor seed quality.

Incompatibility of rice and wheat varieties in the system
- Long-duration rice varieties mature late and thus limit the turn-around time available for land preparation for wheat.
- Late-planted wheat and long duration wheat varieties may be damaged by rainfall during harvesting, since farmers lack grain-drying provisions.

Lack of tillage equipment and seeding machinery
- The use of animal or manual power sources, together with traditional implements, increases the time needed for land preparation, resulting in soil moisture depletion and delayed planting.
- Seed broadcasting in the absence of seeding equipment leads to poor plant stand establishment.

Poor seed quality and care
- Farmers lack both an appreciation for and understanding of how to produce high quality seed.
- Absence of seed storing facilities, especially for wheat during the wet monsoon season, affects seed germination.
- Seed recycling and continued use of seed saved by farmers without introduction of new seed stock causes degeneration of germplasm.

Soil-related problems
- Reduced use of organic and inorganic fertilizers results in lower yield potential.
- Unbalanced use of fertilizers in both rice (early and normal varieties) and wheat will eventually lead to mining of soil nutrients.

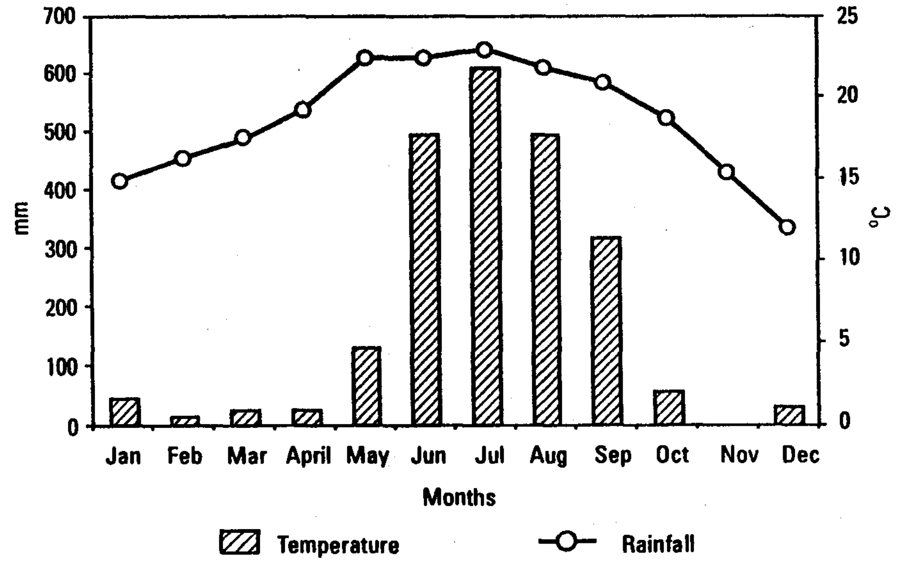

Figure 2. Monthly average rainfall and temperature at the Naldung site

Methodology

Selection of the Study Area

The 'Naldung Rice-Wheat Project' site is located east of Kathmandu in the mid-hills of Kavre District, lying in the Central Development Region of the Kingdom of Nepal. The site was chosen because of the following characteristics: 1) easy accessibility at various altitude classes, with both the high and low altitude sites bordered by roads; 2) significant socio-cultural and economic diversity among the study sites; 3) the presence of improved infrastructure in the study area (roads providing market accessibility, availability of agricultural inputs, etc.); and 4) a central location and proximity to both NARC headquarters and the CIMMYT office in Kathmandu.

Preparation of Questionnaires

The questionnaires addressed key issues raised in the diagnostic survey. These questionnaires had two components:

1. Comprehensive information at the farm level (including land holdings, livestock holdings, ownership of draft power, machinery and/or implements, input use, source of inputs, etc.). Farmers were also interviewed for their opinions on both the causes and nature of recent trends in their management and agricultural systems. This included changes in input use and farm resources over the previous five years.

2. Selective information gathered from a single intensive data plot (IDP) per farm. A representative rice-wheat plot measuring approximately one *ropani* (500 sq. m.) was selected on each farm for continuous monitoring throughout the study period. During farmer interviews in both rice and wheat season, important agronomic practices, input use, outputs, and constraints such as pests and adverse climatic conditions (floods, droughts), etc., were recorded. This information was complemented by crop cut data for grain yields. Data were also collected on labor hours for each activity and the costs of labor and inputs used so that cost and returns could be calculated.

Determination of Sample Sizes and Stratification

The study site was divided into three natural strata based on altitude differences (Table 1). Two villages were chosen randomly from each altitude class or strata. Within each village, nine farmers were chosen at random from a list of village members provided by the village head. For each farmer, a *Khet* field planted to rice and wheat of approximately one *ropani* was selected for intensive data collection. This classification system helped to facilitate sampling and reduce overall variance. For simplicity, these strata are subsequently referred to as altitude classes.

For quantitative factors such as quantity of inputs used, grain yields, etc., the sample size (N=54) is adequate at the altitude class level, and in certain cases even allows us to further stratify the sample by other criteria such as irrigation status. It can be shown that for a 90% confidence interval (up to 10% relative error of estimate) and 20% coefficient of variability for yield – both reasonable given farmers' conditions – a sample size of 16 is adequate for statistical analysis of continuous variables such as yield.

On the other hand, the sample size is not adequate for statistical inference at the strata level for attribute data.[4] Such analysis would require a sample size of several hundred for each domain of study, quite beyond the scope of this project. There are nevertheless several benefits to collecting attribute data in this study. First of all, such data, collected through participatory rural appraisal or key informant surveys, can provide a valuable descriptive assessment of the area. Second, changes in farmers' attribute variables *can* be subjected to statistical analysis for long-term trends – a major objective of this study in future years of data collection. Finally, those attributes with possible significant effects on yield levels (e.g., applying farmyard manure) can be used as explanatory variables in linear models.

Table 1. Altitude classes and sample sizes

Altitude class	Villages	Sampled farmers
High	Naldung	8
	Chitte	10
Middle	Singe	9
	Nayagaun	9
Low	Mahadevsthan	9
	Sipaghat	9

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[4] Attribute, or categorical data, as opposed to continuous data, are data which are collapsed into numerical categories for the sake of analysis (i.e. for pest damage scores: 0 = none, 1 = slight, 2 = moderate, etc.)

Data Collection

As mentioned above, field data were collected at both the farm level and the intensive data plot (IDP) level. At the IDP level, data were gathered at flowering and at harvest for both rice and wheat crops. In future cycles of monitoring, data will also be gathered on any alternate crops planted by farmers, such as mustard, potato, lentil, etc. There were four types of data collection:

1. *Whole farm data.* Data at the farm level were collected with a semi-structured questionnaire through interviews with the household head or a knowledgeable member of the farm family. Subject matter specialists conducted the interviews, during which the overall farm inventory and farming method of the family were assessed. This was performed at the beginning of the study and will be repeated at 4-5 year intervals from the date of the benchmark survey.

2. *IDP soil samples.* Soil samples from IDPs were taken under the supervision of soil scientists. The samples were analyzed in the Soil Science Division, NARC, Kumaltar, for organic matter, nitrogen, phosphorous, potassium, and pH. As above, samples will be taken again every 4-5 years from the date of the benchmark survey to study changes in soil nutrient status over time.

3. *IDP visits.* A member of the farming family, advised of the visit beforehand, accompanied a field assistant from the survey team to the IDP. There they were joined by the interviewer. During his discussion with the farmer, the interviewer filled out a structured questionnaire. He also observed the plot directly for any discernible constraints to plot productivity and/or other crop conditions. Economic data (labor hours and prices) were also collected for cost and return analysis.

4. *IDP crop cuts.* Field assistants obtained crop cuts with the help of the farmer. At harvest time (estimated in advance), the field assistant selected 3 random samples of 1 m^2 each with the help of a quadrant. Crop cuts were bulked separately for each IDP and carried with a bag to the research farm to be dried, threshed, and weighed for grain yield. Other characteristics, such as plant stand (number of productive tillers/m^2), number of grains/spike, 1000-grain weight, and grain moisture, were also measured for each IDP. Yields were calculated at 12% seed moisture content.

Processing of Data

Each questionnaire was subject to "real-time" checking by the field supervisors just after data collection. After collecting survey information for 2-3 plots, interviewers gathered in the camp to code the data. A coding sheet was provided to each person for this purpose. Any inconsistency in farmers' responses was corrected by re-contacting and re-questioning the farmer. The data were also processed for individual cases to assure uniformity in units of measurement. The interviewers were instructed beforehand to take notes on all local units of measurement and conversion methods (e.g., how many *ropani* of land area were broadcast with a given *pathi* of wheat seed). Data were then entered into an SPSS statistics package and re-coded into standard metric units.

Statistical Analysis

In this report, most results are presented in the form of descriptive statistics with the aid of tables and graphs. Statistical tests of significance for quantitative data (fertilizer use, etc.) were performed wherever appropriate. Comparisons were made for different categories of important variables such as altitude classes, land type, etc. As already mentioned, no useful statistical inference can be made for the attribute data themselves (e.g. comparisons of proportions) due to the inadequacy of the sample size.

Presentations of the results and discussions have been made at three levels:

1. Summary statistics by altitude domain, as well as descriptions of farm characteristics, agro-ecology, crop productivity, and constraints to production within each domain.
2. Productivity of rice and wheat as influenced by various factors, and their statistical and economic significance.
3. A multivariate analysis of production factors and their interactions.

In statistical inferences, a 90% confidence level and 0.10 level of significance have been chosen as acceptable. With the given sample size, this allows for a relative error of estimate not to exceed 15%, as will be shown. These are the accepted levels among outreach researchers in this country.

Results for Whole Farm Data

Results were analyzed primarily through comparisons by altitude class,[5] since as discussed above, these best represent the distinct agro-ecological strata in the region. Criteria used to characterize farmer socioeconomic status include ethnic group[6] (*Bhramin/Chhetri, Newar, Tamang*), average land holding (small, large), land type[7] (*Khet, Bari*), family size, and several other variables. Since land type was strongly correlated with altitude class, we also present a brief analysis of farm level data compared by land type.

General Comparisons by Altitude Class

High altitude farmers differed from middle and low altitude farmers in several respects. The primary difference was ethnic group: all high altitude farmers were *Tamang*, while middle and low altitude farmers were predominantly *Bhramin* and *Chhetri*, with a minority of *Newar*. Thus all comparisons by altitude class should be considered as comparisons by ethnic group as well.

Middle and low altitude (mostly *Bhramin* and *Chhetri*) farmers had larger, more fragmented land holdings than high altitude *Tamang* farmers. They also tended to have a larger *Khet* (bunded) area for planting wheat, and generally better land and soil quality. Land was classified as either *Danda* ("hillside land") or *Tar*[8] (relatively flat, river valley land). At high and middle altitudes, most lands were *Danda*, while at low altitudes, almost all lands were *Tar*. Thus low altitude *Bhramin/Chhetri* farmers possessed more *Tar Khet* (flat rice terraces) with more fertile, medium-type soils than middle and high altitude farmers. High altitude *Tamang* farmers had larger families, more farm workers per hectare, and more large animals per hectare (Table 2).

Table 2. Characteristics of farms by altitude class[a]

Variable	High	Middle	Low	All
Number of farms	18	18	18	54
Number of farms by ethnic group				
Bhramin/Chhetri	0	18	16	34 (63%)
Newar	1	0	2	3 (5%)
Tamang	17	0	0	17 (32%)
Farm size				
Average (ha)	0.75	1.25	1.25	1.10
Small (≤1 ha) (%)	72	33	39	48
Large (>1 ha) (%)	28	67	61	52
Land type[3]				
Khet (ha)	0.30	0.75	0.55	0.57
Bari (ha)	0.50	0.50	0.70	0.55
Soil type				
Light (%)	33	24	11	23
Medium (%)	67	76	89	77
Number of parcels	3.8	4.2	4.2	4.0
Average family size	8.3	7.0	7.9	7.7
Number of farm workers	3.8	3.6	4.2	3.9
Number of farm workers/ha	5.1	2.9	3.4	3.5
Number of large animals	4.2	4.2	3.8	4.1
Number of large animals/ha	5.6	3.4	3.0	3.7

[a] Such comparisons closely approximate those for ethnic group, where high altitude represents Tamang farmers, and middle and low altitude represent *Bhramin/Chhetri* farmers.

General Comparisons by Land Type

As already described, there was a significant relationship between land type and altitude class. High altitude farms possessed more *Danda Khet* while low altitude farms possessed more *Tar Khet*. Continuous rice-wheat cropping patterns were more common in *Khet* land, irrespective of land type (*Danda* or *Tar*). *Bari* land was used for other upland crops, especially oil seed, potato and vegetables in winter, and maize, soybean and finger millet in the rainy seasons

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[5] High altitude = 1,400 to 1,900 masl, midaltitude = 800 to 1,100 masl, and low altitude = 400 to 700 masl.

[6] Here, ethnic group is defined as the social group to which one belongs. In Nepali society, this group is typically defined by either caste and/ or ethnic origin.

[7] Land type: *Khet* = bunded land, where rice and wheat are grown; *Bari* = unbunded field for upland crops (Note: bunding—the creating of raised borders around fields—is done to help impound water for rice production).

[8] *Danda Khet* = bunded, terraced hillside land; *Tar khet* = bunded flat valley land.

(data not shown). Farmers who grew wheat on *Tar Khet* were more likely to plant it late (Table 3) because of poor drainage and wet soils that delayed land preparation.

Farmers' Resources

Farmers' resources, including land, labor, livestock and machinery, were counted during the survey. In addition, researchers attempted to elicit farmers' qualitative estimates of trends in resource levels and resource quality.

Land use and type – Farmers' landholdings were generally small (average 1.1 ha), and highly fragmented. On average, farmers possessed four separate parcels, in some cases separated by great distances (Table 2). For ease of water management, these parcels were often further sub-divided into individual plots. Farm area varied by farmer categories: middle and low altitude farmers and *Bhramin/Chhetri* farmers appeared to have larger holdings than high altitude and *Tamang* farmers (Table 4).

Almost all *Khet* land was cropped to wheat during winter, while *Bari* land was mostly left fallow or planted to other crops such as sweet potato, mustard, vegetables, and buckwheat. Most low altitude fields were irrigated year-round (13 of 18 farms). The proportion of wheat and other crops was similar in all altitude classes, though the average coverage area for wheat was slightly greater at lower altitudes due to larger holdings and larger *Khet* area.

The average land holding of high altitude farmers was very small (0.75 ha), as was *Khet* area (0.35 ha) for such farmers (Table 5). *Bari* and *Khet* land were evenly divided at high altitudes. At middle altitudes, *Khet* area was somewhat greater than *Bari* area, while at low altitudes, the converse was true (Table 5).

Table 3. Characteristics of farms by land type: *Danda Khet* and *Tar Khet*[a]

Variable	Danda Khet	Tar Khet	All[b]
Number of farms	33	21	54
Farm size			
Small (≤ 1 ha) (%)	68	32	100 (25)
Large (> 1 ha) (%)	55	45	100 (29)
Wheat planting date			
On time (before 7 December) (%)	36	64	100 (31)
Late (after 7 December) (%)	22	78	100 (23)
Altitude			
High (%)	94	6	100 (18)
Middle (%)	72	28	100 (18)
Low (%)	28	72	100 (18)

[a] *Danda* refers to higher well-drained areas; *Tar* refers to low-lying poorly-drained areas.

[b] Number in parentheses indicates number of farmers.

Table 4. Farmers' land resources and land use by altitude class

Variable	High	Middle	Low	All
Number of farmers	18	18	18	54
Proportion of farms irrigated				
Some (%)	72	44	28	48
Mostly (%)	28	56	72	52
Soil texture on intensive data plots				
Light (%)	22	50	44	39
Medium (%)	78	44	28	50
Heavy (%)	0	6	28	11
Land type on intensive data plots				
Danda (%)	94	72	6	57
Tar (%)	6	28	94	43
Farm area in				
Wheat (%)	38	48	43	44
Other crop[a] (%)	62	52	57	66

[a] *Bari* land is used for other crops after rice (sweet potato, vegetable, etc.) or is left fallow.

Table 5. Farmers' land resources: some comparisons

Variable	Average farm size (ha)	Average Bari[a] land (ha)	Average Khet land (ha)
All farms	1.1	0.55	0.57
Altitude			
High	0.75	0.35	0.35
Middle	1.25	0.50	0.75
Low	1.25	0.75	0.55

[a] *Bari* = unbunded land; *Khet* = bunded land.

Labor and power – Family size in the study area was fairly large, with approximately eight individuals per family, including pre-school children, students, farm workers, off-farm workers and elderly (Table 6). Of these, four were typically considered farm workers. There was little difference in family size between altitude classes. As a result, high altitude farmers had more farm workers per hectare due to the small size of their farms (Table 6). While no quantitative data yet exists on labor scarcity, informal interviews with farmers suggested an increasing trend in the occurrence and severity of labor shortages. When questioned directly, no farmers reported problems with labor scarcity. At the same time, many farmers reported worsening labor bottlenecks during peak labor periods (i.e., during rice transplanting and wheat and rice harvesting). The differences in these responses may merely be semantic—interviewees may consider labor scarcity to be a permanent, rather than a seasonal condition. This issue needs clarification.

While almost all farmers owned dairy buffaloes (data not shown), only 45% owned bullocks for plowing. On the other hand, all farmers reported using bullocks for plowing and land preparation. This suggests that more than half of surveyed farmers rent bullocks for these tasks. Currently, farm mechanization is almost nonexistent in the study area. Manual power was also common for land preparation, especially on smaller terraces and for slicing the terrace walls. The latter practice is performed to control weeds and pests, as well as to provide fresh soil for the terraces. Harvesting and threshing were done manually (data not shown).

As already alluded to, small-scale farmers had a far greater number of farm workers available per hectare, since the number of farm workers they possessed was comparable to large farms (Table 7). On the other hand, large-scale farmers were twice as likely to own bullocks as small-scale farmers (60 vs 30%).

Results from Intensive Data Plots

Soil texture was determined by farmer response and through direct observation by survey enumerators. More than half the selected intensive data plots had medium soil texture type, a third had light soil, and a very few were heavy. Most high altitude soils (typically *Danda* soil) were of medium texture, while all heavy soils were found at lower altitudes (Table 8).

Table 6. Labor and power resources by altitude class

Variable	High	Middle	Low	All
Number of family members	8.3	7.0	7.9	7.7
Pre-school age children	2.7	1.9	0.9	2.7
Students	1.6	2.1	2.4	2.2
Farm workers	4.3	4.0	4.3	4.2
Elderly	0.3	0.1	0.9	0.5
Off-farm workers	0.3	-	0.4	0.35
Farm workers/ha	6.3	3.2	3.5	3.8
Percentage of farmers owning bullock(s)	45	45	45	45

Table 7. Labor and power resources by farm size

Variable	Large (≥ 1 ha)	Small (< 1 ha)	All
Average number of farm workers	4.5	4.2	4.3
Number of farm workers/ha	2.9	7.8	3.8
Percentage of farmers owning bullock(s)	60	30	45

Table 8. Characteristics of intensive data plots by altitude class

Variable	High	Middle	Low	All
Number of farms	18	18	18	54
Soil Texture				
Light (%)	22	44	28	32
Medium (%)	78	50	44	57
Heavy (%)	0	6	28	11
FYM history				
Never use (%)	6	22	39	22
Every year (%)	55	56	39	50
Every crop (%)	39	22	22	28
Proportion irrigated				
Some (%)	72	44	28	48
Most (%)	28	56	72	52
Number of irrigations	6	2	2	2

[a] Number in parentheses indicates number of farmers.

High altitude farms tended to apply more farmyard manure. More than half such farms applied FYM every year, and approximately one-third applied FYM on every crop.[9] By comparison, close to half of the intensive data fields on low altitude farms never received FYM. Such variation in FYM use may relate to the distance between the FYM source and the farmer's field. At higher altitudes, all fields were near to the house, making the transport and application of FYM easier, while at lower altitude, many fields were far from the house and the source of FYM. High altitude farms also had more animals per hectare and therefore more manure (Table 2).

Low altitude farms had a higher frequency of irrigation and greater proportion of irrigated land than middle and high altitude farms. Survey data shows that 72% of fields in lower altitudes were mostly irrigated; this figure drops to 28% for high altitude fields (Table 7).

Similar patterns in soil chemistry were observed for the three altitude classes. All soils were acidic in reaction (average pH: 4.52; range: 3.9 - 6.5) and low in organic matter, total nitrogen and available P_2O_5. Available K_2O, by contrast, was relatively high. Some variability in soil fertility was observed. Organic matter and total nitrogen content were slightly higher at low altitudes, while available P_2O_5 and K_2O were more abundant in high altitude fields (Table 9).

Wheat and Rice Production Practices and Yields

In addition to describing cropping systems and farmers' resources, the monitoring survey seeks to document current farming practices and crop yields. Production practices and yields for wheat and rice are described below.

Wheat Production Practices and Yields

Land preparation and crop establishment – On average, two to three bullock plowings were done in preparation for wheat planting, with closer to three plowings among high altitude farmers (data not shown). Very few farmers reported preparing their fields by hand (a common practice within the Kathmandu valley where religion does not allow use of bullocks to plow). All wheat was sown by broadcasting. Farmers used a seed rate of 138 kg/ha (range 64 to192 kg/ha), slightly higher than the recommended rate of 120 kg/ha. Seed rate tended to be higher at middle and low altitudes (Table 10). This most likely represents an effort by lower altitude farmers to compensate for poorer seed quality, probably resulting from higher temperatures and greater humidity during storage at low altitude.

Wheat planting dates ranged from 22 October to 22 December (median date 30 November) (Fig. 3). In high altitude farms, there was an even distribution of late, medium, and early planting dates, while at midaltitude more farmers planted their wheat crop late (Table 10).

Wheat varieties [10] and seed source – About 60% of the farmers planted RR21, an older improved variety

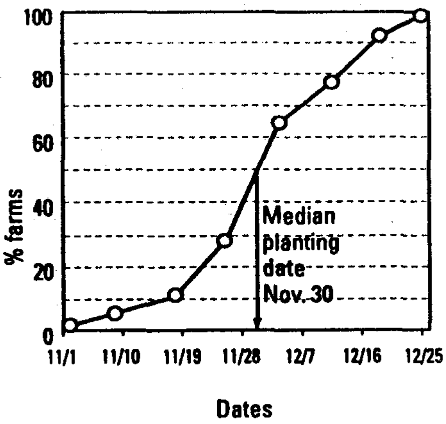

Figure 3. Cumulative wheat planting date

Table 9. Soil analysis of intensive data plots by altitude class

Variable	High	Middle	Low	Mean	Range	Remarks
Soil sample size	18	18	18			
pH	4.4	4.7	4.5	4.52	3.9 - 6.5	Acidic
Organic matter (%)	2.0	1.5	2.1	1.9	0.8 - 3.6	Low
Total nitrogen (%)	0.09	0.07	0.11	0.08	0.04 - 0.16	Low
Available P_2O_5 (kg/ha)	24.3	16.6	19.5	20.6	5.9 - 30.1	Moderate
Available K_2O (kg/ha)	307	291	245	281	106 - 592	High

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[9] The survey design did not allow for a distinction between FYM application to specific fields versus application to the farm as a whole. Thus while many farms apply FYM every year, they may do so only to a rotating group of fields, such that a given field may not receive FYM each year. However, this does not affect the average yearly application rate per field, since this is expressed as total FYM per holding size.

[10] Lerma 64 was the first improved variety introduced by CIMMYT. It was a taller variety than those released later, but remains popular with some farmers in the hills of Nepal. RR21 was introduced as an improved variety in the 1970's, and is still popular today due to its bold, white grain type. Annapurna and NL539 were introduced in the 1990's.

(Fig. 4). Most of the wheat grown in fields where farmers did not know the name of the variety appeared to be RR21 as well. All farmers in the study reported using improved varieties (Table 10). However, most farmers used either seed from their own farms or borrowed seed from neighbors.

Soil fertility management – Farmers in the study area applied both organic and inorganic fertilizers to wheat. Almost all farmers used inorganic sources of nitrogen (N) and phosphate (P_2O_5). These were typically given in the form of DAP (an N-P fertilizer) and/or urea (an N fertilizer) as basal fertilizers, and urea as a topdress applied 30-35 days after planting (Table 11). Almost all farmers applied N as basal fertilizer, and nearly 42% applied additional N as topdressing. The average N dose was 59 kg/ha (range 0-120 kg/ha) with greater dosages at lower altitudes (Table 11). This rate is higher than most mid-hill farming areas in Nepal, and most likely reflects the area's proximity to Kathmandu and better road infrastructure. The mean P_2O_5 rate was 34 kg/ha (with a range of 0-90 kg/ha), higher than might be expected. Organic fertilizer in the form of farmyard manure—a combination of animal manure, animal urine and plant materials used for animal bedding—was applied at least once per year (usually before wheat planting) on 80% of fields. FYM was typically applied before or after first plowing, and was often left unincorporated for long periods of time. Farmers are aware that valuable nutrients may be lost when FYM is left on fields in this manner, yet they appear to accept these losses as inevitable given local labor scarcity. Almost all high and midaltitude farmers used FYM in their fields, while only 50% of low altitude farmers did so. As mentioned earlier, this is probably because low altitude fields are

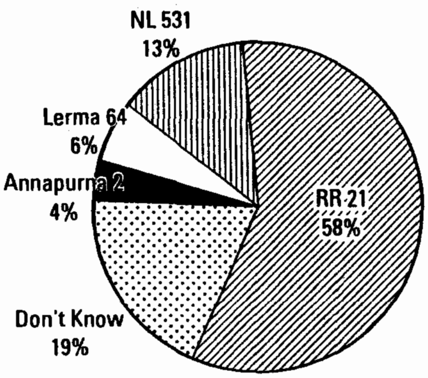

Figure 4. Wheat varieties grown by farmers

Table 10. Crop management practices in wheat by altitude class

Variable	High	Middle	Low	All
Number of farmers	18	18	18	54
Planting date				
Early (%)	33	28	22	28
Median (%)	33	28	50	37
Late (%)	33	44	28	35
Average	16 Nov	21 Nov	27 Nov	22 Nov
Variety				
RR21 (%)	44	83	50	59
NL539 (%)	-	-	39	13
Lerma 64 (%)	6	11	-	6
Annapurna-2 (%)	-	-	11	4
Don't know (%)	50	6	-	18
Variety: Old vs. New				
Old (%)	50	94	50	65
New (%)	-	-	50	17
Don't know (%)	50	6	-	18
Seed rate				
Mean (kg/ha)	121	140	152	138
Range (kg/ha)	64 - 192	96 - 188	72 - 188	64 - 192

Table 11. Soil fertility management in wheat by altitude class

Variable	High	Middle	Low	All
Number of farmers	18	18	18	54
Nitrogen use				
Farmers using N fertilizer (%)	100	100	100	100
Basal N use (%)	83	100	100	96
Topdress N use (%)	17	50	62	42
Total N use (kg/ha)	47	60	70	59
Phosphate use				
Basal P use: (%)	78	100	100	92
Mean (kg/ha)	29	36	38	34
Range (kg/ha)	0 - 90	18 - 67	12 - 72	0 – 90
FYM use				
Never use (%)	6	11	44	22
Every crop (%)	56	66	32	52
Every year (%)	38	23	23	28
FYM use (t/ha)	6	6	2	5

farther from farmers' homes. No farmers in the study area reported using potash fertilizer. Soil tests for this element reveal that soil K levels are presently high, counseling against any K supplementation by farmers at this time. Nevertheless, continued mining of soil K could result in deficiencies in the future.

Plant population – Low plant population was identified as a constraint to wheat production during the 1992 diagnostic survey. This was verified by visual observations in the field during the monitoring survey. It was found that only 19% of the fields had good plant stands, 51% were fair, and the remaining 30% had poor plant stand (Table 12). Midaltitude fields had comparatively better plant population than both high and low altitude fields. Interestingly, midaltitude fields also had less weed problems, which may be related to better plant stands.

Pests – Only 15% of the wheat fields observed were scored with a severe weed infestation, and one-third were moderately infested (Table 12). Fields at high and low altitudes had more weeds than at middle altitudes. Rust was a major wheat disease in the study area. Nearly 25% of fields were infected either moderately or severely, and only 25% of the fields were disease-free (Table 12). Significantly, RR21—the variety planted by the majority of farmers—was also the most susceptible to rust. One future goal therefore should be to help farmers switch to more recent varieties that have greater resistance to rust. Although 56% of farms had some insect infestation, actual damage was minimal. Insects were thus not a major problem for wheat.

Wheat harvest and yields – Wheat was harvested between 10 April and 5 May. Harvesting is done manually with a sickle, usually by women. The wheat is then carried to the household for threshing or to a threshing floor in the field. The most common technique in the area for threshing wheat is to beat it with wooden sticks. An alternative technique is to beat a bundle of wheat against a stone. No farmers in the survey used a mechanical thresher or animal for wheat threshing.

Table 13 and Figure 5 list wheat yields at different altitude levels by crop cut. The average overall wheat yield (1,964 kg/ha; range 1,120 to 2,820 kg/ha) was about 30% higher than official government statistics for Kavre district (1498 kg/ha). Yields may be higher for two reasons. First, almost all sampled fields received at least one irrigation during the growing season, in a region where 23% of fields receive none (official district statistics). Second, the survey area has better than average infrastructure for inputs, which

Table 13. Wheat yield estimates (kg/ha) by crop cut at different altitude classes

Altitude	Average	St. Dev.	Mini-mum	Maxi-mum
High	1,509	210	1,120	1,820
Middle	2,088	266	1,558	2,469
Low	2,298	324	1,689	2,820
All	1,964	429	1,120	2,820

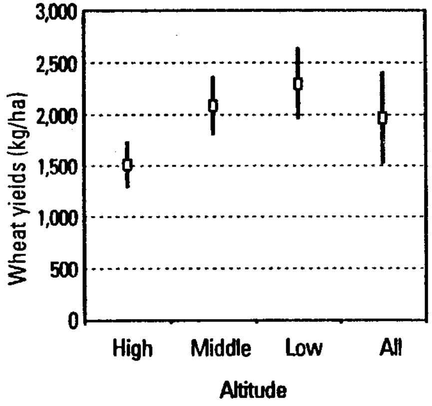

Figure. 5. Average wheat yields and standard deviations by altitude class

Table 12. Near-term productivity problems observed in wheat fields by altitude class

Variable	High	Middle	Low	All
Number of farmers	18	18	18	54
Plant stand				
Good (%)	6	39	11	18
Fair (%)	72	44	39	52
Poor (%)	23	17	50	30
Weed infestation				
Some (%)	39	83	33	52
Moderate (%)	44	17	39	33
Severe (%)	17	-	28	15
Disease in wheat				
None (%)	50	11	11	24
Some (%)	50	61	33	48
Moderate (%)	-	22	50	24
Severe (%)	-	6		4
Insect infestation				
None (%)	67	67	33	55
Some (%)	33	33	56	41
Moderate (%)	-	-	11	4
Severe (%)	-	-	-	-

may also enhance yields relative to the district average. Wheat yields increased from high to low altitude (Table 13).

Rice Production Practices and Yields

Land preparation and crop establishment – The monsoon rains typically begin by mid-June. Abundant rainfall in the first week of June encouraged farmers to establish seed beds early. The median seeding date was 7 June, with a range of 1 May to 30 June. High altitude farmers established rice seedbeds earlier than low altitude farmers (Table 14). One unit of rice seedbed area was sufficient to cover 16 to 20 units of transplanted rice area (data not shown). Farmers used about 60 kg/ha seed on average, with higher rates in low altitudes. The average seedling age was 36 days (range: 22 to 48 days). The median transplanting date was 10 July, with high altitude farmers planting earlier than middle and low altitude farms. Land preparation for rice transplanting was more intensive at low altitude (4.4 plows and planks) than middle and high altitude (2.9 and 2.7 plows and planks, respectively) (Table 14). Bullocks were the main source of tillage power. As with wheat, all land preparation and cultivation is done manually.

Rice varieties and seed source – Farmers identified 8 rice varieties in 54 sampled fields (Table 15). All of the varieties identified were medium to long duration improved varieties. Twenty-seven percent of fields were covered with Himali, a coarse grain, 22% with Khumal-4, a fine grain, and 17% with Taichung, a coarse-grained glutinous variety grown at high altitudes for flattened rice (*chiura*) (Fig. 6). The primary source of rice seed was either farmers' own stock or that of neighbors (data not shown). No farmer used rice seed from the Agricultural Inputs Corporation (AIC) or any other external sources.

Soil fertility management – Most farmers applied nitrogen fertilizer and phosphate to rice fields. This was typically applied at transplanting in the form of DAP. Urea was often applied as a topdress about a month later. The mean N application rate (including basal and topdress) was 55 kg/ha, quite comparable to that for wheat in the study area (59 kg/ha) and higher than N application rates in most mid-hill areas. There was no significant difference between altitude classes in N applied. Seventy-eight percent of farmers used phosphate fertilizer, with a mean application rate of 38 kg/ha. Farmers at lower altitudes applied

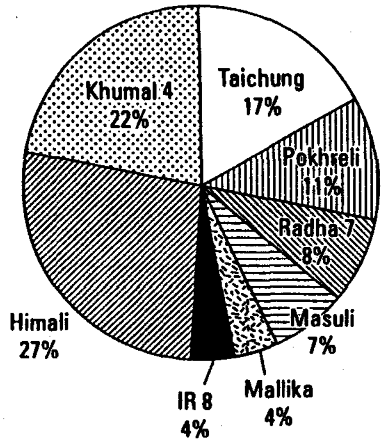

Figure 6. Rice varieties grown by farmers

Table 15. Percentage of rice varieties used by altitude class

Varieties	High	Middle	Low	All
Himali (coarse)	5	44	39	27
Khumal-4 (fine)	33	19	17	22
Taichung (coarse)	25	19	6	17
Pokhreli (fine)	17	-	16	11
Radha 7 (medium)	-	12	6	8
Mansuli (fine)	10	-	11	7
Malika (medium)	5	6	-	4
IR (coarse or fine)	5	-	5	4

Table 14. Rice production practices by altitude class

Variables	High	Middle	Low	All
Number of tillage operations (Plow and plank)	2.7	2.9	4.4	3.3
Seed rate (kg/ha)	52	50	78	60
Planting date (median)	21 May	10 June	21 June	7 June
Planting date (range)	1 May – 7 June	1 June – 20 June	1 June – 30 June	1 May – 30 June
Transplanting date (median)	7 July	15 July	15 July	10 July
Average seedling age (days)	39	34	35	36

more phosphate fertilizer to their crop than those in the high altitude class. Low altitude farmers more commonly used DAP as a basal fertilizer, whereas high altitude farmers used urea (Table 16).

On average, half of the farmers used some FYM in their rice crop, typically applied before land preparation. However, whereas almost all high altitude farmers used FYM, very few low altitude farmers did so (Table 16). Furthermore, more FYM was applied to *Bari* than *Khet* land, indicating that FYM was usually used for crops other than rice.

Pests – Most fields had fair to good plant population, indicating that plant stand is not a major problem in rice production. Most fields are transplanted by family labor and weeded twice during the growing season, both of which help to ensure good plant populations. Visual estimates suggest that plant population was better at low than high altitudes (Table 17). Half the fields had no problem with weeds while the other half had some to moderate weed infestation, suggesting that weeds are not a major constraint to rice production. Most farmers weed at least one time.

Although more prevalent than in wheat, disease and insect infestation appear to be of minor consequence to rice production (Fig. 7). Of the fields surveyed, only 31.5% showed evidence of disease. Less than half of these same fields had some degree of insect infestation, mostly from hispa, borer and leaf roller (Table 17). Additionally, farmers in the study area did not report using pesticides for rice crops. Taken together, these two findings – low insect infestation and absence of pesticide use – suggest that insect pests are not a major constraint to rice productivity in the area.

Irrigation practices – Almost all sampled fields were irrigated during the rice season. Most irrigated fields received water from small streams or seasonal and perennial water sources. Many farmers managed small surface canals for irrigation. The number of irrigations per field (data not

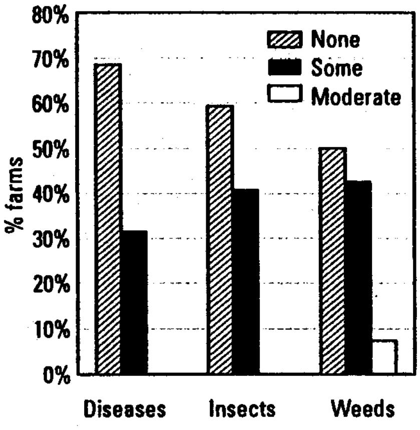

Figure 7. Percentage of rice fields affected by pests

Table 16. Soil fertility management in rice by altitude class

Variables	High	Middle	Low	All
Number of farmers	18	18	18	54
Nitrogen use				
Farmers using N fertilizer (%)	94	89	88	90
Basal N use (kg/ha)	50	43	47	47
Topdress N use (kg/ha)	9	8	8	8
Total N use (kg/ha)	59	51	55	55
Phosphate use				
Basal P use (%)	78	78	78	78
Basal P use (kg/ha)	27	35	52	38
FYM use				
This crop (%)	78	61	11	50
Every year (%)	22	39	89	50
FYM use (t/ha)	4.2	3.9	0.9	2.9

Table 17. Near-term productivity problems observed in rice fields by altitude class

Variable	High	Middle	Low	All
Plant stand				
Good (%)	22	39	50	37
Fair (%)	72	56	45	57
Poor (%)	6	5	5	6
Weed infestation				
None (%)	56	39	50	50
Some (%)	39	56	33	43
Moderate (%)	28	5	11	7
Disease				
None (%)	83	78	44	69
Some (%)	17	22	56	31
Insect infestation				
None (%)	67	50	61	59
Some (%)	33	50	39	41

shown) ranged from four to infinity (continuous water flow through the fields). Drought or water stress was not observed in rice, since streams and seasonal water sources are sufficient for the rice crops in the area.

Rice harvest and yields – Rice harvest date ranged from 15 October to 30 November (data not shown). All rice was harvested manually, usually by family labor alone. Exchange labor (*Parma*) was found only in Tamang communities and no hired or contract harvesting was recorded in the sample. Harvested rice was typically carried from the field to a threshing floor, where it was then threshed manually or by a combination of manual trampling and animal threshing. No farmers used either a tractor or a mechanical thresher.

The rice yield was estimated by crop cut in intensive data plots. The average crop cut yield was higher than the farmers' average estimate (Table 18). This difference may be explained by the special precautions taken to minimize grain losses in the crop cut. Most farmers thresh their rice by bullock trampling and must carry the rice from the field to the central threshing floor, incurring measurable losses of grain in the process. In any case, the difference between crop cut and farmer estimates was small. Similar yield estimates were obtained at all three altitude classes. The official district average in 1994 for rice yields was 2.1 t/ha, which is about 41% less than the crop cut estimate (3.5 t/ha). As already mentioned for wheat yields, higher rice yields in survey fields may relate to the better-than-average irrigation and infrastructure. While the difference between district and project area yields is interesting in its own right, it is tangential to the focus of the farmer monitoring project, which seeks to characterize changes in productivity over time rather than to evaluate absolute productivity per se.

Costs of Production

The costs of production for rice and wheat are presented in Table 19 and Appendix B. The average cost of production for wheat is NR 8,851/ha (US$ 130). Major expenditures include land preparation (32.4%), harvesting (16.3%), threshing and cleaning (16.3%), FYM application (14.1%), fertilizer (11.6%), and seed (9.4%). Sowing cost is not shown since it is typically a part of land preparation. Irrigation is likewise omitted, as it requires only occasional labor for the clearing of irrigation canals and channels. The net return for wheat was rather small – NR 969/ha (US$ 14). This is mostly due to low grain prices for wheat. Since wheat is grown primarily as a subsistence crop, the low grain price is not likely to discourage farmers from growing wheat in the future. Returns for wheat production can be improved by increasing wheat yields, particularly through greater use of fertilizers, and by reducing

Table 18. Rice yield estimates (kg/ha) by crop cut and farmer's estimate at different altitude classes

Methods	Average	Minimum	Maximum
Crop cut - by altitude			
High	3,447	2,321	4,760
Middle	3,267	2,411	4,640
Low	3,858	2,750	4,852
Crop cut - average	3,529	2,321	4,852
Farmer's estimate - average	3,291	1,600	5,454

Table 19. Production costs for wheat and rice

	Wheat		Rice	
	(NR)	(% of total)	(NR)	(% of total)
Costs				
Land preparation	2,865	32.4	3,720	31.9
Raising and transplanting seedlings			2,380	20.4
Seed required	828	9.4	600	5.2
Fertilizer application	1,028	11.6	1,034	8.9
FYM application	1,250	14.1	550	4.7
Weeding			1,280	11.0
Harvesting	1,440	16.3	1,040	8.9
Threshing, cleaning	1,440	16.3	1,040	8.9
Total	8,851		11,644	
Returns				
Grain yield (kg/ha)	1,964			3,529
Grain price (Rs/kg)	5			8
Gross return (Rs/ha)	9,820			28,232
Net return (Rs/ha)	969			16,588

production costs. Land preparation currently demands the lion's share of production costs. Reduced tillage technologies represent a promising means of reducing such costs.

Rice has a comparatively higher production cost at NR 11,616/ha (US$170). This greater cost owes mainly to the additional labor needed for seedbed preparation and transplanting (20.4%), as well as a greater need for weeding (11%). As in wheat, land preparation represents the greatest single expenditure, accounting for 31.9% of total production costs. The net return for rice is much higher than for wheat, at NR 16,588/ha (US$ 240). This is due to both higher grain prices and higher yields. Profits could be increased most readily by greater fertilizer use to increase yields.

The cost and return data did not include values for land, which would undoubtedly lower net returns for both crops. However, the data presented here are intended primarily for illustrative purposes. Cost and return data will continue to be collected over five years, after which point they will be used to complete a trend analysis of production costs and returns wheat and rice.

Factors Affecting Yields in the Rice-Wheat System

Factors Affecting Wheat Yields

Wheat yields were affected by several important factors (Table 20). Altitude had the greatest effect, with low altitude fields producing significantly higher yields. Seed variety also appeared to have a significant effect on wheat yields: improved varieties and RR21 produced higher grain yields than unknown seed varieties. Farm size affected wheat yields only minimally.

Wheat yields were also affected by land type. *Tar* land had higher wheat yields than *Danda* land (Fig. 8). As almost all *Tar* land was located at lower elevations, and lower altitude was positively correlated with wheat yield as well. The greater productivity of *Tar* land is most likely due to both greater organic matter and available N, and higher levels of inputs. Due to natural process of soil erosion and nutrient leaching from the hills and soil deposition in the river valley, organic matter content tends to be greater in *Tar* than *Danda* land. *Tar* land is also situated in areas with greater access to roads and, therefore, agricultural inputs. Yield was only minimally affected by farm size (Fig. 8).

Wheat yields were affected by several management practices. Type and rate of fertilizer use were significant factors (Table 21; and Fig. 9). Fields with higher yields received more nitrogen and phosphorus. Farmers gained about 10 kg of wheat grain for each kilogram of N used, which is a very good recovery rate for applied nitrogen (Fig. 10). Yet on average, farmers applied only about half the recommended dose. These results suggest that a great potential may exist for increasing wheat production in the study area through well-managed increases in N fertilizer use. Farmyard manure, on the other hand, had little affect

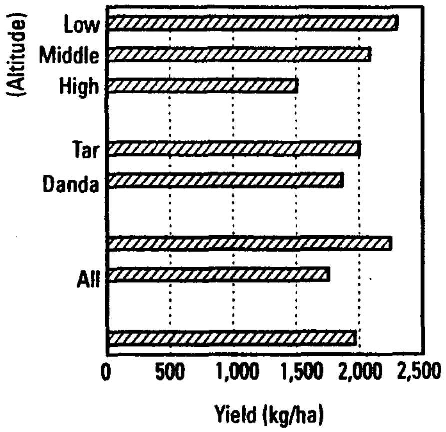

Figure 8. Factors affecting wheat yields

Table 20. Wheat yields of selected plots by farm category

Farm category	Number of farms	Average yield (kg/ha)	Significance[a]
All plots	54	1,964	
By altitude			
High	18	1,509	
Middle	18	2,084	***
Low	18	2,298	
Variety			
RR21	32	2,025	
Other improved	12	2,200	***
Don't know	10	1,480	
Farm size			
Small (< 1 ha)	26	1,874	
Large (≥ 1 ha)	28	2,047	*

[a] Statistical significance of the difference between farm categories is indicated as follows: *** 1%, ** 5%, * 10%, and ns = not significant.

on wheat yields. This may result from poor FYM quality, either intrinsically or as a result of a long exposure period before incorporation into the soil. Further research is needed on this issue.

Disease in wheat increased as fertilizer use increased, especially with N application (Table 22). Thus, higher disease and insect scores were observed with higher N rates. However, as noted earlier, higher yield was also associated with higher N rate. Interestingly, the benefits of greater N use to plant growth outweighed losses from higher pest incidence.

Factors Affecting Rice Yields

Rice yields varied by altitude, variety, and several other farm categories (Table 23, Figure 11). Low altitude farmers obtained significantly higher rice yields than farmers in other altitude classes. Although yield did vary according to the seed variety selected, this correlation was not statistically significant. *Danda khet* land types yielded less than the *Tar khet* land types. This is most likely because *Tar khet* land possesses more deposited soil materials that are rich in organic matter. There were no significant yield differences between farm sizes. Interestingly, FYM application to rice did appear to have a significant effect on yields. As noted earlier, no such pattern was found in wheat.

Rice fields were divided into low (< 3,000 kg/ha), medium (3,000 to 4,000 kg/ha), and high (> 4,000 kg/ha) yield categories. The surveyed fields showed a relatively even distribution between the three categories. Levels of fertilizer use were averaged for the three yield levels. Of these factors, nitrogen use, phosphate use, and plant stand

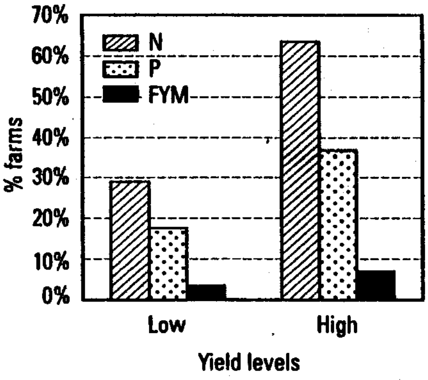

Figure 9. Factors affecting wheat yields

Table 21. Effects of fertilizer management on wheat yield

	Yield level		
Management factor	**Low** [a]	**High** [b]	**Significance** [c]
Wheat yield (kg/ha)	1,634	2,346	***
Fertilizer			
Total N (kg/ha)	46.7	73.5	***
Basal N (kg/ha)	35.3	50.7	***
Top dress N (kg/ha)	11.3	21.4	***
Total P – Basal (kg/ha)	28.9	40.6	***
FYM (t/ha)	6.3	6.8	ns

[a] low yield < 1,500 kg/ha.

[b] high yield > 1,500 kg/ha.

[c] Statistical significance of the difference between farm categories is indicated as follows: *** 1%, ** 5%, * 10%, and ns = not significant.

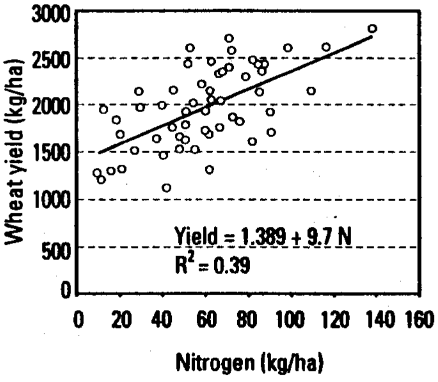

Figure 10. Nitrogen application rate and wheat yield

Table 22. Effects of nitrogen on wheat pests and grain yield

Pest	**Nitrogen rate (kg/ha)**	**Yield (kg/ha)**	**Significance** [a]
Disease			
None	46	1,625	***
Some	60	1,971	
Moderate	67	2,235	
Severe	81	2,296	
Insects			
None	48	1,858	***
Some	70	2,042	
Moderate	90	2,544	
Weeds			
None	57	1,978	ns
Some	58	1,923	
Moderate	68	1,954	

[a] Statistical significance of the difference between farm categories is indicated as follows: *** 1%, ** 5%, * 10%, and ns = not significant.

appeared to have the greatest impact (Table 24, Fig. 12). No relationship was observed between FYM rates and yield levels. However, there was a non-significant increase in yields associated with FYM use versus no FYM use (data not shown). As in wheat, one of the most notable results was the strongly significant relationship between nitrogen application rates and yield levels (Fig. 13). High-yield fields, which had 60% higher yields than low-yield fields (4,358 and 2,700 kg rice/ha, respectively), also received almost twice as much nitrogen. This suggests that current N application rates are sub-optimal for rice, and that great potential may exist to increase the region's rice yields through greater N use. However, as Figure 13 suggests, for every kg of N applied to rice crops, an increase of only 8.7 kg in grain yield is obtained. This contrasts sharply with the corresponding value for wheat, which indicates a 20.2 kg increase in wheat grain yield per kg of N applied (Fig. 10). Thus one important topic for future research is to investigate means of increasing N use efficiency in rice.

Disease, insects, and weeds were also evaluated as factors affecting rice yields. However, no significant effects were observed for any of the

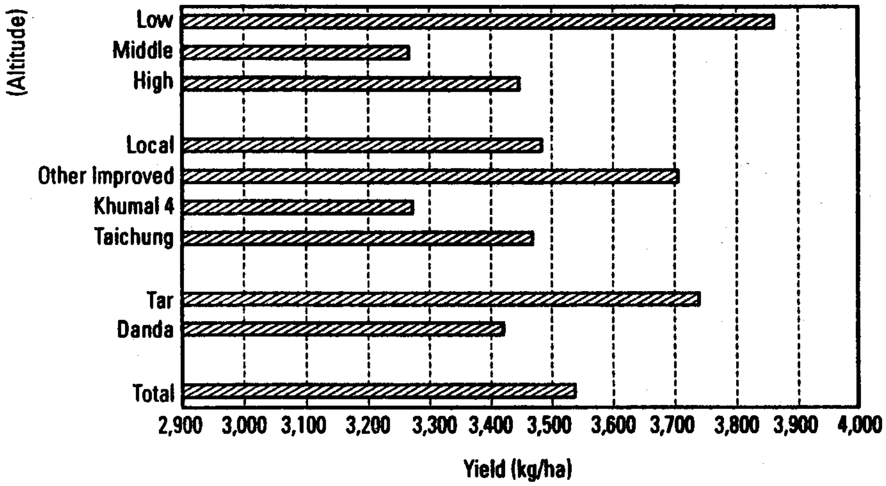

Figure 11. Factors affecting rice yields by farm category

Table 23. Rice yields of selected plots by farm category and FYM use

Factor	Number of farms	Average yield (kg/ha)	Significance [a]
All plots	53	3,529	
Altitude			
High	18	3,447	
Mid	17	3,266	**
Low	18	3,859	
Variety			
Taichung	9	3,468	
Khumal-4	11	3,171	
Other Improved Var.	25	3,672	ns
Local	8	3,642	
Land type			
Danda	33	3,420	
Tar	19	3,738	*
Farm Size			
Small	25	3,415	
Large	28	3,631	ns
FYM in this crop			
Yes	26	3,719	
No	27	3,345	**

[a] Statistical significance of the difference between farm categories is indicated as follows: *** 1%, ** 5%, * 10%, and ns = not significant.

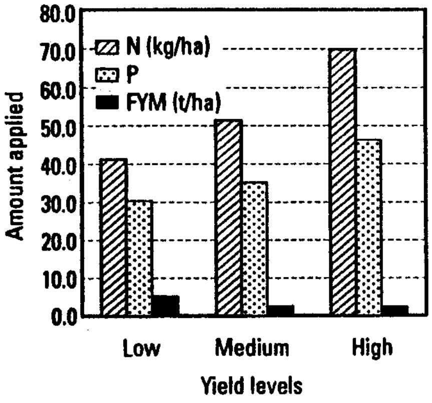

Figure 12. Factors affecting rice yields

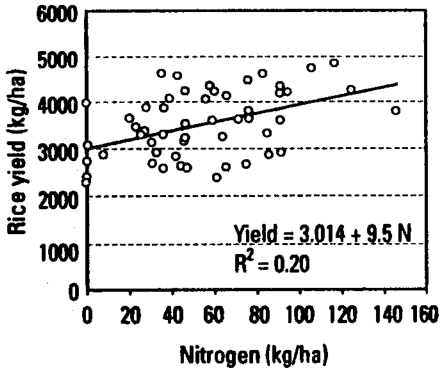

Figure 13. Nitrogen application rate and rice yield

Table 24. Effects of fertilizer management and plant stand on rice yield

Management factor	Yield level Low[a]	Median[b]	High[c]	Significance[d]
Rice yield (kg/ha)	2,700	3,487	4,358	*
Percentage of fields	30.2	37.7	32.1	ns
Fertilizer management				
Basal nitrogen (kg/ha)	34	41.5	64	**
Topdress nitrogen (kg/ha)	6.5	10.5	5.1	ns
Total nitrogen (kg/ha)	40.5	52	69	**
Phosphorus (kg/ha)	31	35	46	*
Plant stand				
Good (%)	3.7	18.5	14.8	**
Fair (%)	24.1	17.7	16.7	*
Poor (%)	1.9	1.91	-	
FYM (t/ha)	3.9	2.7	2.9	ns

[a] Low yield < 3,000 kg/ha.

[b] Median yield = 3,000-4,000 kg/ha.

[c] High yield > 4,000 kg/ha.

[d] Statistical significance of the difference between farm categories is indicated as follows: *** 1%, ** 5%, * 10%, and ns = not significant.

three variables measured (Table 25). Plant population, on the other hand, had a significant positive correlation with rice yields. This finding does not shed much light on the ultimate causes of improved rice yields, other than to suggest that factors that improve plant population are important for greater yields. Closer spacing of rice plants is one likely cause for better yields.

Table 25. Effects of disease, insects and weeds on rice yields

Insect/disease severity	Yield (kg/ha)	Significance[a]
Disease		
None	3,530	
Some	3,527	ns
Insects		
None	3,553	
Some	3,493	ns
Weeds		
None	3,523	
Some	3,516	ns
Plant population		
Good	3,792	
Fair	3,391	**
Poor	3,023	

[a] Statistical significance of the difference between farm categories is indicated as follows: *** 1%, ** 5%, * 10%, and ns = not significant.

Fertility Management for Rice and Wheat

Fertility management is a key factor affecting rice and wheat yields, especially in intensive cereal cropping systems like the rice-wheat system. Both rice and wheat are heavy consumers of soil nutrients. Therefore, in the rice-wheat double-cropping system, information on fertilizer use for both grains combined is of greater interest than information on fertilizer applied to either crop individually. Application rates for nitrogen, phosphorus, and organic manure on both crops are shown in Table 26.

Figure 14 shows fertilizer rates for both crops combined. The total application rates for nitrogen (114 kg/ha/yr) and phosphate (72 kg/ha/yr) were both much lower than levels recommended by researchers. Farmyard manure was the other major source of added nutrients in the rice-wheat system, and farmers applied more FYM to wheat than to rice. None of the farmers in the survey applied potash to either crop.

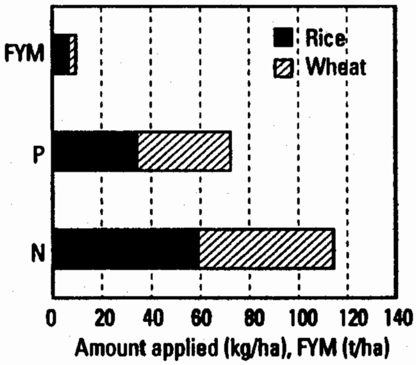

Figure 14. Fertilizer and FYM rates for rice and wheat combined, Naldung, 1993-94

Table 26. Soil fertility management for rice and wheat by altitude class

Fertilizer	High	Middle	Low	All
Nitrogen application (kg/ha)				
Rice	59	51	55	55
Wheat	47	60	70	59
Total	106	111	125	114
Phosphorus application (kg P_2O_5/ha)				
Rice	27	35	52	38
Wheat	29	36	38	34
Total	56	71	90	72
FYM application (t/ha)				
Rice	4.2	3.9	0.9	2.9
Wheat	6	6	8	7
Total	10.2	9.9	8.9	9.9

Organic manure varied considerably in terms of quantity, quality, and frequency of application. Most farmers at high altitudes applied FYM at least once a year, whereas at low altitude a greater number of farmers had never used FYM on their crops (Fig. 15). Low altitude farmers applied more chemical fertilizers than high altitude farmers, presumably because of greater access to roads and chemical fertilizers (Fig. 16).

Additional Factors Affecting Wheat and Rice Yields

Combined wheat and rice yields for 1994 had a mean value of 5,490 kg/ha (range 3,441 to 7,672 kg/ha). This average falls well short of potential yield levels for the region. Input levels are also far below the recommended use levels. The combined yields of rice and wheat in selected plots by various field parameters are presented in Table 27.

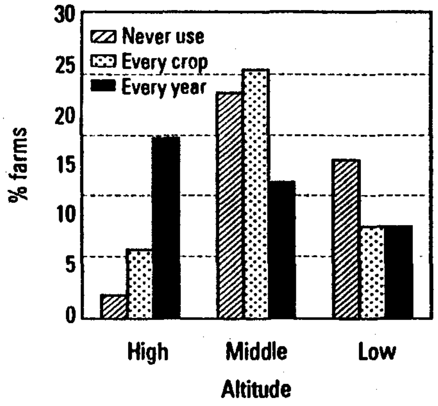

Figure 15. Frequency of FYM use in rice and wheat by altitude class

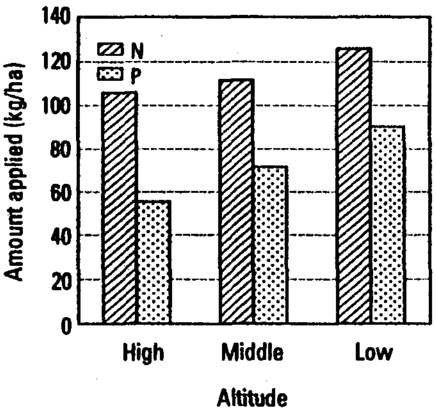

Figure 16. Combined nutrients applied to rice and wheat by altitude class

Table 27. Total rice and wheat yields for selected plots by various field parameters

Land pattern	Total yield	Sig.	Wheat yield	Sig.	Rice yield	Sig.
All fields	5,490		1,963		3,427	
By altitude						
High	4,956		1,509		3,447	
Middle	5,347	***	2,884	***	3,266	**
Low	6,157		2,297		3,859	
By ethnic group						
Bhramin/Chhetri	5,717		2,159		3,537	
Tamang	5,017	**	1,521	***	3,495	ns
Newar	5,678		2,228		3,450	
Land holding						
Small	5,227		1,873		3,415	
Large	5,678	*	2,047	ns	3,631	ns
Land type						
Danda	5,210		1,790		3,420	
Tar	6,007	***	2,262	***	3,738	ns

Statistical significance of the difference between farm categories is indicated as follows: *** 1%, ** 5%, * 10%, and ns = not significant.

Figure 17 shows the relationship between total nitrogen applied in rice and wheat combined and total grain yield. As with rice and wheat yields viewed separately, the N application rate for rice and wheat combined appears to be significantly sub-optimal. This strongly suggests that yields could be increased substantially in the study area through greater use of applied nitrogen.

Several parameters were significantly correlated with total wheat and rice production (Fig. 18). Wheat yields varied by altitude, ethnic group, land holding size and land type. It is difficult to interpret the correlation between yield levels and ethnic group, since this variable is so closely tied to both altitude and land type. Both of these latter variables have a more intuitive connection to productivity. Among these same parameters, rice yields were affected only by altitude.

Rice and wheat yields showed no correlation with one another (Fig. 19). This indicates that the factors affecting rice and wheat yields may be different, and that a soil that is productive for rice may not necessarily be productive for wheat.

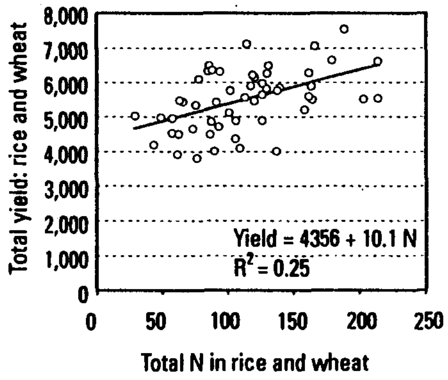

Figure 17. Relationship Between total N and total rice and wheat yields combined

Multivariate Analysis of Grain Yield Production

Multivariate analysis was used to estimate the contributions of various factors to rice and wheat yields. Multiple regressions involving various combinations of inputs—such as nitrogen, phosphorus, potassium, FYM, irrigation, seed rate, etc.—and their interactions were fitted to estimate their effects on grain yields of rice and wheat. Very few of these regressions produced statistically significant results. Possible reasons for the general lack of observed associations include:

1. A high degree of imbalance in the combination of inputs used as well as variability in the range of application of inputs by farmers.
2. Errors associated with the measurements taken, which were based on the memory of farmers interviewed.
3. "Noise" produced by factors not included in the model. However, a workable multifactor model was found in both rice and wheat for the interaction between nitrogen levels with altitude domain classes. In this model, the three domain classes were used as dummy variables. The results for the two crops are as follows.

Multivariate model for wheat – The following model was produced for wheat:

$$Y_w = 1902 + 5.64\,N - 668\,D_h - 260\,D_m + 0.27\,N{\cdot}D_h + 1.69\,N{\cdot}D_m$$

where

Y_w = wheat grain yield (kg/ha)

N = total nitrogen applied (kg/ha)

D_h and D_m = dummy variables for high and midaltitude classes, respectively, and

$N{\cdot}D_h$ and $N{\cdot}D_m$ = interactions between N levels and D_h and D_m

The model has an adjusted R^2 value of 73%, and an analysis of variance produced an F value of 29.65 (significant at $P<0.001$). These findings indicate that 73% of the variation in yields between farms can be accounted for by differences in N application rates and factors associated with the altitude domain classes. A closer look at the fitted model reveals a highly negative effect of D_h (high altitude domain) on wheat yield, followed by D_m (middle altitude), implying that D_L (low altitude) has the highest overall effect on wheat yields. This statistically significant "low altitude effect" is likely due in part to better irrigation, warmer average temperatures, higher fertilizer use, and greater soil N and organic matter content in low altitude fields. Below, the complete model is divided into three separate models representing the three altitude domains:

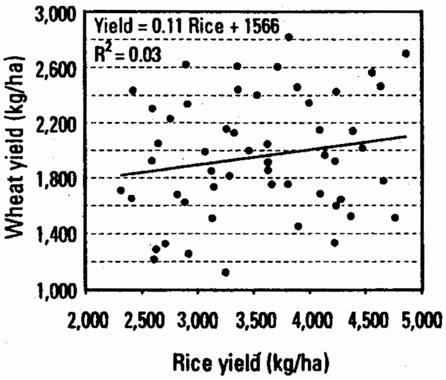

Figure 19. Absence of relationship between rice and wheat yields

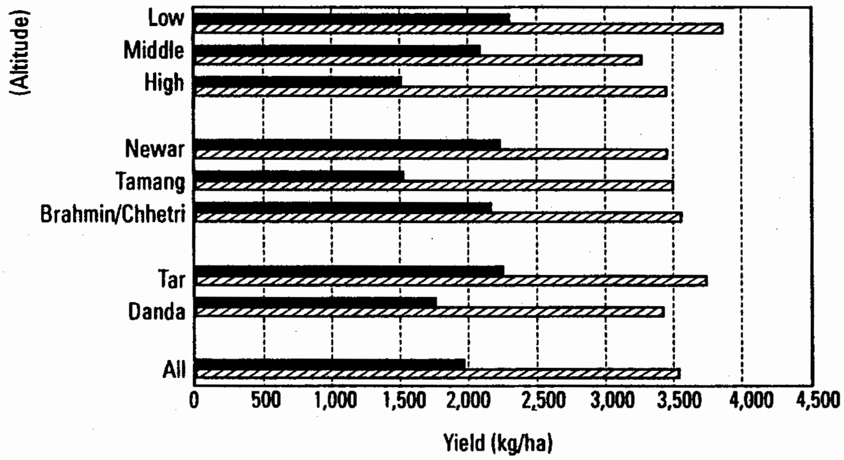

Figure 18. Effect of different factors on rice and wheat yields

High altitude domain (D_h):

$$Y_h = 1234 + 5.91\,N$$

Midaltitude domain (D_m):

$$Y_m = 1642 + 7.33\,N$$

Low altitude domain (D_L):

$$Y_L = 1902 + 5.64\,N$$

These models suggest that D_m has the highest response to N input levels, followed by D_h and D_L. However, yield response rates to N application do not differ significantly among the three domains. Even if such findings were significant, it would be impossible to generate more specific conclusions from these models. Altitude strata represent a complex assortment of factors that must undoubtedly confound the analysis (altitude, land type, ethnic group, accessibility, use of P and FYM, etc.). To resolve the yield contribution of each factor would require as many domains as there are combinations of these factor levels, an analysis that is beyond the scope of this paper.

Multivariate model for rice – A model similar to that for wheat produced the following relationship:

$$Y_r = 3532 + 5.89\,N - 709\,D_h - 759\,D_m + 4.63\,N{\cdot}D_h + 4.39\,N{\cdot}D_m$$

An adjusted R^2 value of 24.8% was significant at the $P = 0.002$ level, with an F value of 4.43. The low but significant value for R^2 indicates that nitrogen levels and domain classes do affect yields in rice. However, the strength of the model is insufficient for predictive purposes. As before, the domain effects were negative relative to D_L (not shown in the model). The interactions as well as the main effects of N are statistically non-significant, however, despite their high estimated coefficients. The breakdown for the three domains is as follows:

High altitude domain (D_h):
$Y_h = 2823 + 10.5\,N$
Midaltitude domain (D_m):
$Y_m = 2773 + 10.3\,N$
Low altitude domain (D_L):
$Y_L = 3532 + 5.89\,N$

As in wheat, the low altitude domain (D_L) has greater overall productivity than the middle (D_m) and high (D_h) domains, and similar to wheat, response to N applications was higher in D_h and D_m than in D_L. Similarly, differences in yield by altitude are most likely attributable to the same factors identified for wheat: better infrastructure, higher input use, greater N and organic matter content, and warmer climate at low altitudes.

Other Issues in the Rice-Wheat System

Crop establishment, especially poor plant population of wheat, was identified as an important problem during the diagnostic survey. Poor plant population most likely results from one or more of several factors, including late wheat planting, poor land preparation (both manually and by bullock), and/or poor seed quality.

Late wheat planting, in turn, often results from a long turnaround time between rice harvesting and wheat planting. In experiments studying the effects of delayed planting on wheat yields, a 1% loss in yield potential was observed for each day that planting was delayed beyond the last week of November (Ortiz-Monasterio et al. 1994). Farmers typically plow 3-4 times before planting wheat, and such plowing is time-intensive. Long turnaround time may also be caused in part by excess moisture at the time of rice harvest, which makes land preparation for wheat more difficult. This problem may be compounded by heavy soil type, which retains more water and thus further retards land preparation. However, in this study, very little association was observed between planting date and wheat yields, a finding that may be explained by the many confounding variables involved in the analysis.

Traditional plowing may also contribute to poor plant population. All farmers surveyed used wooden plows for land preparation. These tend to produce cloddy fields and non-uniform seed depth, both of which can impede plant stand development. Furthermore, the many plowings required in traditional methods can accelerate soil moisture loss, leaving less moisture for germinating wheat seed. Future research should evaluate the potential of improved tillage equipment for enhancing crop establishment in wheat in the hills.

Poor seed quality is an additional constraint to healthy plant population. Almost all farmers surveyed reported using their own seed for both rice and wheat crops. Poor seed quality (especially in wheat) causes poor germination and poor initial plant population. Additional data is needed on the quality and germination of wheat seed at the time of planting. Improved storage systems for wheat during the wet monsoon period would also help maintain seed viability. Information on improved storage systems is currently available and should be extended to farmers.

The replacement of old wheat varieties with new, improved lines is another important issue. The results from this study show that most farmers currently use RR21, a variety released in the 1970s. Thus researchers must seek answers to the question of why farmers are not adopting newer varieties that possess higher yield potential and better disease resistance. They must also explore strategies for facilitating the adoption of these new, improved varieties of rice and wheat. 'Seed villages' must be developed or, alternatively, farmers within villages must be identified to produce and store new varieties of seed. Such people could then be provided with seed from new germplasm as it becomes available and help popularize the seed among fellow villagers.

Sub-optimal nutrient use and low nitrogen use efficiency are also major issues for both crops. Intensive cropping systems (such as the rice-wheat system) have substantial nutrient requirements. Sub-optimal and unbalanced nutrient use can accelerate the process of soil nutrient depletion, greatly jeopardizing the sustainability of the rice-wheat system. Some farmers reported using FYM in their fields, but the quality is rather poor, and FYM alone is incapable of replenishing nutrients in an intensive cropping system. Research and demonstrations on balanced nutrient management, improved FYM quality, and a balance between organic and inorganic fertilizer sources should be emphasized to improve the sustainability of the rice-wheat system.

The problem of sub-optimal input use, especially of nitrogen, is compounded by low uptake efficiency of the nitrogen applied, particularly in rice. Inefficiency of applied N is a consequence of several factors, among them poor plant population and sub-optimal timing of N applications. If increases in yields are to be economical – that is, if factor productivity is to be increased – nitrogen use efficiency will have to be improved in years to come. Since N use efficiency can be improved significantly through better crop management practices, even in the absence of greater input use, it is an extremely important research issue for increasing rice-wheat system productivity in Nepal's mid-hills.

Conclusions

This benchmark study has highlighted the effects of agro-ecological domain, soil fertility, and crop management on the productivity and sustainability of the rice-wheat system in Nepal's mid-hills. Land type, physiography, infrastructure, and ethnicity – all components of agro-ecological domain – had important effects on rice and wheat yields. Meanwhile, soil fertility and crop management practices—particularly fertilizer use and efficiency, pest management, seed storage, timeliness of planting, seed quality, and land preparation—were equally important determinants of system productivity. Below, we discuss possible mechanisms by which these factors affect total system productivity.

Agro-ecological factors

Agro-ecological domain was strongly correlated with variability in farm productivity. In general, middle and low altitude *Bhramin* and *Chhetri* farmers had more fertile soil, more *Tar khet* land, greater input use, and greater average productivity than high altitude *Tamang* farmers. This may be due partly to altitude-specific differences in land type and soil fertility. On the other hand, agro-ecological domain also appears to affect farmers' access to inputs (i.e., fertilizers and machinery). High altitude communities have less access to the infrastructure (i.e., roads, irrigation) necessary for these inputs. Finally, ethnicity or social group – practically indistinguishable from agro-ecological domain in our study – may influence farmer's management practices in any number of ways. Cultural values and/or social circumstances may help explain why high-altitude *Tamang* farmers use less inorganic input, more farmyard manure, and have a greater range in planting date than middle and low altitude *Bhramin* and *Chhetri* farmers. In any case, such a relationship is ambiguous, and likely confounded by the strong correlation between ethnicity and agro-ecological domain within the study area. Future research should address the mechanisms by which agro-ecological domain affects productivity, as well as the nature and magnitude of the influence of ethnicity. In this way, more specific recommendations can be developed for overcoming constraints to system productivity.

Soil fertility and crop management factors

Soil fertility and crop management practices were also important determinants of rice and wheat productivity. Nitrogen and phosphorous management – particularly N and P application rates and N uptake efficiency – were key factors affecting yields of both crops. Farmers who used higher N and P application rates had consistently higher yields than farmers who used less N and P. This suggests that nutrient availability is a limiting factor for system productivity, and that greater application of N and P fertilizers would help farmers tap the inherent yield potential in this system.

Optimal plant nutrient levels are also constrained by the efficiency of plant nutrient uptake. N uptake efficiency in rice is less than half that observed in wheat, representing a major potential constraint to rice production. Such inefficiency is due in part to sub-optimal timing and spacing of the nitrogen applied. As fertilizer application rates increase, solutions must be identified to increase the efficiency of applied nutrients and eliminate wastage in order to increase the return on farmers' investments.

Organic matter management, especially improved manure quality, deserves special attention to enhance the sustainability of the rice-wheat system. Farmyard manure is a major component of hill farming systems. However, in a region with scarce timber resources, it is also an important source of cooking fuel. Future studies should seek to illuminate the importance of FYM in soil nutrient management relative to its importance as a domestic power source.

The issue of nutrient mining – the removal of more nutrients from the soil than are put back through external inputs – must also be addressed by future research. For example, when grain and most crop residues are removed by farmers at harvest, large quantities of potassium are mined from the soil. However, no farmers currently report applying potassium fertilizers. While soil tests do not reveal a deficiency in soil potassium at present (Table 7), the appearance of such a deficiency is inevitable given current management practices. Scientists must be alert to future symptoms of nutrient mining and develop strategies to avoid it.

More timely seeding and improved seed management can also improve rice-wheat productivity in the study area. In both crops, timely sowing is known to promote higher yields and increased input efficiency. One of the more promising strategies for fostering timely planting, particularly in wheat, is the adoption of reduced tillage technologies. As they require fewer passes and less labor for land preparation, such technologies shorten the turnaround period between rice harvesting and wheat planting, leading to timely sowing and improved yields. Given proper technique, they also yield more uniform seed depth and improved soil moisture conservation, both of which contribute to improved plant stand. Just as importantly, reduced tillage technologies represent significant cost savings for farmers. While most such technologies would need to be compatible with the animal-powered tillage systems of the mid-hills, small-farm machinery employing reduced tillage technologies may also be suitable in some contexts, particularly on larger, low altitude *Tar Khet* fields. Such reduced tillage small-farm machinery has already shown great promise for lowland rice-wheat systems of the Tarai (Hobbs et al. 1997). The adoption of higher quality seed is another important step for improving plant stand and grain yields, particularly in wheat. Village-level seed multiplication programs and improved seed storage would improve seed quality and thereby improve productivity for both crops. Improved seed storage is especially important for wheat, which must be stored through the wet monsoon season.

Finally, improved pest management, particularly in rice, could help minimize losses to biological pests. This should address not only field pest problems, but also those encountered as part of grain storage. In this study, N application rates were positively correlated with pest infestation, suggesting that pests may target plant stands that exhibit more vigorous growth. As yields increase due to greater use of inputs, pest problems will likely increase as well. To provide a more meaningful recommendation on the relationship between nutrient use and pest incidence, future research should evaluate the combined effects of pest and nutrient management on yield for rice and wheat.

Future objectives

The 54 fields and farms sampled in this benchmark survey will be monitored continuously over the next few years. During this period, changes in crop management, productivity and farm resources will be recorded. Trends in area, production, and productivity of rice and wheat crops will also be documented. At the same time, farmers' problems will be identified and the research modified to address these problems. One important outcome from this survey is the creation of a long-term multipurpose database. This will constitute a rich source of data on changes in farm management practices, farm resources, pest incidence, and other variables critical to an understanding of trends in system productivity. It is intended to benefit scientists, planners, and policy makers in their pursuit of new solutions to overcoming the constraints to greater productivity and sustainability in rice-wheat cropping in the hill environment. Finally, this data will provide a definitive answer to the question of the sustainability of rice-wheat systems in the mid-hills of Nepal.

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Appendix A

Baseline Survey Participants

Table A1. Participants in the monitoring benchmark survey, Naldung, Kavre District, Nepal, 1994

Name	Position	Organization
Chiranjibi Adhikari	Agronomist	Agronomy Div. Khumaltar
Gopal P. Parajuli	Pathologist	Plant Pathology Div. Khumaltar
Y. G. Khadka	Soil Scientist	Soil Science Div. Khumaltar
S. M. Shrestha	Ag. Engineer	Engineering Div. Khumaltar
N. B. Gurung	Technician	Entomology Div. Khumaltar
R. N Mahato	Junior Technician	ADO, Kavre

Appendix B

Costs of Cultivation for Wheat and Rice Naldung, Kavre, Nepal, 1994

	Wheat			Rice		
	Person Days	Rate (Rs/day)	Cost (Rs)	Person Days	Rate (Rs/day)	Cost (Rs)
Land Preparation						
Plowings/plankings	3.3	450	1,485	4	450	180
Trimming/leveling						
Male	15	60	900	15	80	1,200
Female	12	40	480	12	60	720
Seedbed preparation/ Transplanting						
Labor (Male)	25	50	1,250	11	50	550
Seed required (kg)	138	6	828	60	10	600
Fertilizer						
Total N (kg)	59	10.5	620	55	10.5	578
Total P (kg)	34	12	408	38	12	456
Total FYM (t)	5			2.9		
Seedling pulling labor				8	40	320
Transplanting labor				33	40	1,320
Weeding				32	40	1,280
Harvesting	36	40	1,440	26	40	1,040
Threshing/cleaning						
Male	12	60	720	8	60	480
Female	18	40	720	14	40	560
Total		**8,851**				**11,644**