IMPACTS OF IRRIGATION DEVELOPMENT ON AGRICULTURAL PRODUCTIVITY, RESOURCE ALLOCATION AND INCOME DISTRIBUTION: A LONGITUDINAL ANALYSIS FROM PALAWAN, THE PHILIPPINES

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ABSTRACT

Yao, Richard Tolentino. M.S., Purdue University, August, 2005. Impacts of Irrigation Development on Agricultural Productivity, Resource Allocation and Income Distribution: A Longitudinal Analysis from Palawan, the Philippines. Major Professor: G.E. Shively.

This study evaluates the impacts of irrigation development on farming communities in Palawan. This study focus on three major issues: (1) production efficiency in the lowland communities directly affected by irrigation; (2) activity and asset allocation in upland communities indirectly affected by irrigation; and (3) income distribution and poverty incidence patterns within and between these two communities. To study technical efficiency in the lowlands, a stochastic frontier analysis using an error decomposition technique is used on an unbalanced parcel-level data set from the lowlands. To study activity and resource allocation in the uplands, a seemingly unrelated regressions approach is employed. Results from these regressions are cross-examined using two-way tables and detailed case studies. In studying the distributional impact of irrigation development, selected inequality measures are calculated. The Gini-decomposition technique is used to further examine distributional impacts between population classes within the two groups of communities. To examine the poverty-alleviating benefits of irrigation, poverty indices and poverty decomposition techniques are used.

Analyses suggest that, despite the many reported set backs and problems associated with the operation of irrigation facilities in Asia, particularly in the Philippines (e.g., Levine, 1977; Bromley, 1982), irrigation has benefited many farmers in the study sites – both the targeted lowland farmers and the adjacent upland farming communities. Analysis shows that lowland farmers experienced higher technical efficiency in rice production and improved income distribution with irrigation development.

Results also indicate that, through off-farm employment, irrigation serves as a channel through which lowland agricultural development provided important economic, environmental and distributional benefits in the adjacent uplands. Policies in areas with similar conditions should be cognizant of the strong role of off-farm employment in altering labor allocation by upland households.

Overall, results show strong benefits from irrigation development. One unfavorable impact of irrigation development is that it appears to have led to wider income inequality between lowland and upland communities. The lowlands became relatively better-off and the uplands became relatively worse-off. However, upland households with off-farm work were found to be less worse-off in absolute terms and better off in relative terms than those with no off-farm work.

CHAPTER 1

INTRODUCTION

1.1 Overview

The irrigated rice ecosystem is regarded as Asia's most important agricultural ecosystem, largely because it provides the greatest amount of food to most of its people (IRRI, 2003). Over the past three decades, rice yields in developing countries of Asia more than doubled, and irrigation development was an important contributing factor (IFAD 2001; Hussain, et al., 2002; FAO, 1999). Rice yields in lowland irrigated areas are 50% higher than in rainfed areas, and exceed yields in upland rainfed areas by even greater amounts (Rosegrant and Pingali, 1991). Not surprisingly, irrigation is the largest recipient of public agricultural investments in developing countries (World Bank, 1995). In the 1960s and early 1970s, the introduction of modern rice varieties suited to irrigated conditions, combined with high world prices led to a rapid growth in investments in irrigation projects (Hayami and Kikuchi, 1978). Large-scale investments in irrigation projects helped contribute to agricultural development, resulting in irrigation being extended to 64 percent of potentially irrigable lands in Asia (Schoengold and Zilberman, 2005). As a consequence, most locations in the continent highly suitable for irrigation have been developed.

Further expansion of irrigation continues to be a priority, but efforts now must focus on smaller catchments and more marginal lands. There have also been a growing number of reports on the negative environmental and social effects of large dams and poorly managed irrigation systems (Bromley, 2000; World Bank 1998; Schoengold and Zilberman, 2005; Easter and Welsch, 1986). These factors are reported to have shifted World Bank's thrust from the establishment of new irrigation facilities to the improvement of existing irrigation facilities (Easter, 2000). This new thrust is anchored on better management of existing water systems, along with greater use of more efficient irrigation technologies, which is expected to be increasingly important in the coming decades (Schoengold and Zilberman, 2005). For instance, the World Bank is reported to be helping to modernize rice irrigation schemes and improve dam safety in a number of developing countries (Mekong Info, 2004). The importance of investments and reinvestments in irrigation development can be attributed to the fact that irrigation development, particularly for lowland rice ecosystems, brings considerable benefits to recipient lowland communities. In terms of the irrigated rice ecosystem, these benefits may include increased agricultural productivity, increased farm employment, and expansion of agricultural land (David and Otsuka, 1994). In looking broadly at irrigation, one question that naturally arises is *what are the economic, environmental and distributional impacts of irrigation over time?*

This thesis addresses the general question raised above by studying production efficiency in a lowland irrigated community, activity and resource allocation in an adjacent upland community, and income distribution and poverty in these two adjacent communities. The study sites for this thesis are located in the southern district of the province of Palawan, the Philippines. A series of four household surveys were carried out in this location covering a 10-year cropping period (1994 to 2003). A total of 907 household interviews, distributed over four survey years (1995, 1997, 1999 and 2002), were conducted.[1]

To study technical efficiency in the lowlands, a stochastic frontier regression analysis using an error decomposition technique is used on an unbalanced parcel-level data set from the lowlands. To study activity and resource allocation in the uplands, the seemingly unrelated regressions approach is employed. Results from these upland regressions are cross-examined using two-way tables and detailed case studies. In studying the distributional impact of irrigation development, selected inequality measures are calculated. The Gini-decomposition technique is used to further examine distributional impacts between population classes within the two groups of communities. To examine the poverty-alleviating benefits of irrigation, poverty indices and poverty decomposition techniques are used.

1.2 Background and Research Questions

Under normal climatic conditions (i.e., without El Niño), agricultural productivity increases with irrigation development. Although there was a slowdown in the expansion of rice areas in the Philippines in the past four decades, growth in rice output still accelerated due to rapid growth in yields and higher cropping intensity, both of which were facilitated by agricultural intensification (David and Otsuka, 1994). Agricultural

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[1] The author participated in all four rounds of the survey, the first as a field assistant, the last as the field team leader.

intensification is often accompanied by the adoption of labor saving technologies (e.g., use of tractors, mechanical threshers, herbicides) and use of modern rice varieties (i.e., high yielding varieties) which require more labor for crop care and harvesting activities (Baulita-Inocencio and David, 1995).

Irrigation is typically a lowland phenomenon. But in cases where agricultural intensification occurs near upland communities, the benefits from irrigation, especially gains in off-farm employment, may indirectly affect adjacent upland communities. In Palawan, this has been previously documented as an increase in the number of upland workers hired to work on lowland farms subsequent to irrigation development (Shively, 2001; Shively and Martinez, 2001; Shively and Pagiola, 2004). Such a pattern is consistent with findings from other regions where employment opportunities have been found to increase after the development of irrigation systems (Ramasamy, et al., 1992; Herdt, 1987; Chambers 1988; Barker et al., 2000; Schoengold and Zilberman, 2005). Shively (2001) reports that, despite a decrease in labor demand per hectare on irrigated lowland farms (vis-a-vis rainfed farms), an increase in the number of croppings per year can compensate, resulting in an overall gain in days of employment.

Given that irrigation is envisioned to increase crop yields and modernize agricultural production practices, this thesis begins by examining the technical efficiency of lowland rice production over time. A number of empirical studies support the conjecture that increased efficiency in rice production is a key element in agricultural development initiatives in poor Asian countries (e.g., Dhungana et al., 2004; Battese and Coelli, 1992; Battese and Coelli, 1995; Dawson et al., 1991; Wadud and White, 2000; Llewelyn and Williams, 1996). This motivates us to ask *does irrigation development* *enhance technical efficiency in rice production?* The answer to this question is the subject of the first part of this thesis, in which the on-site impacts of irrigation development are investigated.

Without the Green Revolution, and if the crop yield trends of 1955-65 stagnated, there likely would have been more agricultural expansion into forested areas and other environmentally fragile lands than was widely observed (Avery, 1997). Many frontier areas are inhabited by indigenous peoples. Thus, the agricultural intensification that accompanied the Green Revolution (much of it irrigation development) probably led to less agricultural expansion than was observed. The second portion of this thesis studies the off-site impacts of irrigation development. Focusing on the activity and resource allocation of adjacent upland communities who inhabit the watersheds (including the headwaters) supplying water to the lowland irrigation systems, part two investigates the question *does lowland irrigation development influence activities and asset allocation in the adjacent upland communities, and if so, how?*

Taking into account that the study communities consist of poor farming households, with households in the lowland communities relatively better off than the households residing in the uplands, the third part of this thesis investigates irrigation's distributional impacts and poverty-alleviating benefits to the study communities. This is motivated by asking *how does irrigation development influence income distribution and poverty incidence in the study communities?*

The impacts of agricultural intensification in the areas studied have been investigated before. Shively and Martinez (2001) previously found that irrigation development in lowland communities led to an increase in aggregate labor demand due to an increase in the number of rice croppings per year. This increase in labor demand enabled households in adjacent upland communities to participate in lowland off-farm work, resulting in a decrease in time spent on forest clearing. In this way, agricultural intensification in a lowland setting seems to have contributed to a decrease in area expansion and deforestation in an upland setting. While encouraging, Shively and Martinez's findings were based on short-run analyses. The question of what the intermediate and longer-term impacts of irrigation development might have been requires a longitudinal analysis. In response, this study aims to measure the intermediate impacts of irrigation development over a 10-year period.

1.3 Structure of the Thesis

This thesis has six chapters. Chapter 1 motivates the study and provides an overview of the thesis and its overall objectives. Chapter 2 describes the data and the methods of collection. Chapter 2 also includes a description of the study sites. Although the study sites have been described elsewhere (see Garcia, et al., 1995; Shively, et al. 1998; and Shively and Martinez, 2001), this chapter supplements and updates previous documentation.

This thesis seeks to adopt a comprehensive approach to studying the impacts of irrigation development on the study communities. Chapter 3 focuses on the principal beneficiaries of irrigation development, the lowland farming communities. We examine how irrigation affected the technical efficiency of rice production using a stochastic production frontier and inefficiency analysis. We use a production function in which yield is taken to be a function of labor, fertilizer and pesticides. A stochastic frontier model with error decomposition and time-varying technical efficiency is adopted for the analysis.

Chapter 4 presents results from an investigation into the impacts of irrigation on the adjacent upland communities. We study how upland households' livelihood activities are influenced by agricultural intensification in the adjacent lowlands. Different households involve themselves in different portfolios of livelihood activities, and the extent to which a household allocates resources to a particular activity, say off-farm work, may be affected by specific household constraints and participation in closely related activities, such as forest clearing, handicrafts and fishing. Recognizing that resource allocation decisions are made jointly, a Seemingly Unrelated Regression approach is adopted to estimate activity regressions for the upland sample. Results of the regression analyses are cross-examined using two way tables and case studies of five upland households.

Chapter 5 completes the study by investigating the influence of irrigation development on income distribution in the study communities. We use inequality indices and Lorenz curves for this analysis. To analyze further irrigation's impacts on income distribution within and between groups, Gini decomposition techniques are used. We also conduct poverty analysis using poverty indices and poverty decomposition techniques proposed by Foster, Greer and Thorbecke (1984) to study the welfare impacts of irrigation.

Chapter 6 summarizes the results. Policy recommendations are formulated and policy lessons are distilled. Areas for further research are suggested.

CHAPTER 2

DATA AND THE STUDY COMMUNITIES

2.1 Overview

Data for this study come from the Philippine's island province of Palawan (Figure 2.1). Palawan is widely regarded as the country's last ecological frontier. This reputation can be attributed to its sparse population and the fact that it has the most intact ecosystem in the country (Sandalo, 1996). The province contains one of the few remaining continuous tracts of "primary" forest in the country (Dressler, 2004). Parts of these primary forest areas and adjacent forest margins serve as home to a number of upland indigenous peoples who, at the time of survey, continue to practice traditional, swidden-type agriculture.

Survey respondents were residents in selected villages in the Municipalities of Brooke's Point and Bataraza, both located in Palawan's southern district. This district serves as an important lowland rice growing area in the province as well as home to a number of upland indigenous communities who mainly inhabit the hillsides and interior forests. Household surveys were administered in villages located mainly in two catchments – the Tamlang catchment in Brooke's Point and the Marangas catchment in Bataraza. These two catchments have very similar topographic features characterized by the existence of relatively level coastal plains to the east which envelop the irrigated lowland rice communities and adjacent rolling to hilly and steeply forested areas to the west which are inhabited mainly by upland indigenous communities.

Over the last decade, the lowland farms in these sites underwent a transformation from rainfed to irrigated conditions. This resulted in a shift from rice and corn production under rainfed conditions into mainly rice production under irrigated conditions. The Marangas Communal Irrigation System (CIS) started operating in early 1995 covering an irrigated area of about 500 hectares. The Tamlang CIS started in late 1998 covering almost 1,000 hectares of lowland rice plots. The dam-type irrigation systems in both sites were constructed by the Philippine National Irrigation Administration (NIA) in cooperation with the irrigators' associations organized by NIA to manage and maintain the irrigation facilities. Both Marangas and Tamlang CIS were part of a total of 24 small-scale irrigation projects built by NIA throughout the province. Most rice farms in these irrigated areas were owned and/or operated by migrant rice farmers from other farming areas in the country.

The adjacent upland communities mainly consist of households belonging to the *Pala'wan* tribe who formerly occuppied exclusively the alluvial plains or lowlands until the late 1940s (Brown, 1996). With the influx of more wealthy migrant farmers in the lowlands in the 1940s, these tribesmen sold (or were dispossessed of) most of their flat lands and migrated into the forested hillsides. Replicating their previous lowland social structure, these tribesmen formed several small villages (or hamlets) in the uplands headed by a *panglima* or tribal leader. A number of these villages comprise the upland communities of this study. During the time of the survey, the upland households in these villages actively interacted with the lowland communities through a number of social and economic events which include *tabuan* (a small weekly market) and *tampor* (a traditional cockfighting event). However, the economic activity that is the major focus of this study is the upland households' off-farm employment on lowland farms.

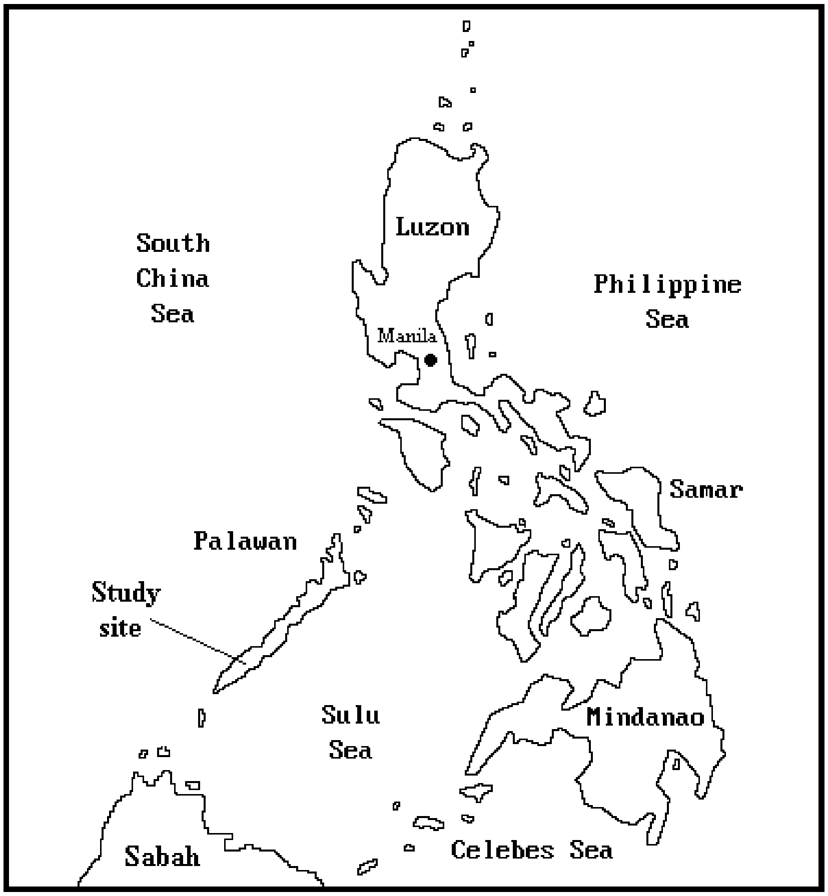

Figure 2.1. Map of the Philippines Showing the Location of the Study Site

2.2 The Survey Period

In total, the survey duration covers a 10-year cropping period, from 1994 to 2003. Specifically, the study observed four different cropping years: 1994/1995, 1996/1997, 1999/2000 and 2002/2003. For simplicity, these cropping years are designated as 1995, 1997, 1999 and 2002, respectively. Different cropping years are characterized by different conditions. The year 1995 is considered as the base year where no operational dam-type irrigation system existed. Most lowland rice farmers heavily depended on rainfall and dikes to meet their water management needs. A few households were able to divert water from nearby rivers and distribute this water to their rice fields. Having no operational irrigation facility in 1995, all lowland households produced only one crop in that year. The analyses in the next chapters refer to 1995 as the year with “no irrigation” or the “rainfed” year. During this year, the average household income per capita in for lowland households was lowest among the four observed years. This is illustrated by the bar graph for the lowland sample in 1995 shown in Figure 2.2.

On the other hand, the years 1997, 1999 and 2002 are regarded as years “with irrigation”. These three are classified as favorable, average and unfavorable based on average incomes (Table 2.1).

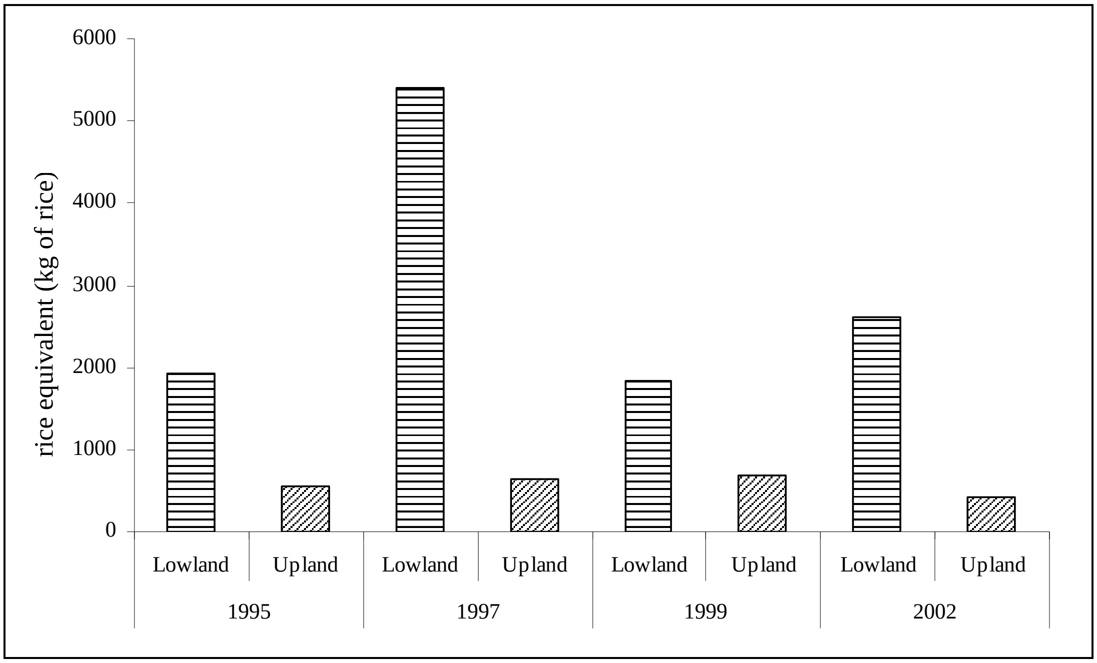

Figure 2.2. Average Income per Capita (1995-2002)

Table 2.1. Classification of Observed Years Following Irrigation Development

Sample	Favorable	Average	Unfavorable
Lowland	1997	2002	1999
Upland	1999	1997	2002

In 1997, one of the two lowland study sites, Marangas, had a fully operational irrigation facility providing irrigation access to about half of the total households in the lowland sample. In terms of income and rice yields, 1997 is classified as a favorable year in the lowlands. During this year, the lowlands experienced favorable climatic conditions for rice growing with a low incidence of pest and diseases. These conditions resulted in high crop yields and almost no crop failure, and greatly contributed to the attainment of the highest income per capita for the observed lowland sample (see Figure 2.2). Figure 2.2 shows that, in the uplands, 1997 can be classified as an average year: income per capita during this year is higher than in 2002 but lower than 1999.

The cropping year 1998/1999 was the first in which the irrigation facilities in both lowland sites operated at full capacity. However, despite this condition, an El Niño-induced period of prolonged drought occurred during the latter part of 1998. This resulted in unfavorable growing conditions. Low crop yields and/or crop failures resulted in negative incomes for many lowland rice farmers. During this cropping year, according to several farmers, residents experienced a high incidence of pests and diseases. These unfavorable conditions did not seem to affect agricultural production in the rainfed uplands. In fact, this year favored upland communities and allowed them to achieve the highest average income per capita among the four observed years. Given the highlighted conditions, 1999 can be considered an unfavorable year in the lowlands and a favorable year in the uplands. In terms of average income per capita, 2002 can be considered an average year in the lowlands and an unfavorable year in the uplands.

2.3 The Survey Samples

About 940 face-to-face household interviews were conducted in the years 1995, 1997, 1999 and 2002 in the lowland and upland communities using similar survey instruments. A total of 907 valid household responses were compiled from these formal surveys forming two sets of four-year panels – a lowland panel (n=386) and an upland panel (n=521). The author, together with researchers from SEAMEO-SEARCA and Purdue University, was involved in the collection of these household data over the eight-year period.[2] Table 2.2 shows details of the lowland and upland panel data sets that form unbalanced panel data sets. The 1995 sample has a total 157 household responses. The sample size was higher in 1997 and 1999 with totals of 214 and 203, respectively. The 2002 sample is largest, with a total number of responses of 333.

Table 2.2 Composition of the Unbalanced Samples (1995-2002)

Year	Lowland		Upland		Pooled	
	Number of Households	Percent	Number of Households	Percent	Number of Households	Percent
1995	36	9.3	121	23.2	157	17.3
1997	112	29.0	102	19.6	214	23.6
1999	104	27.0	99	19.0	203	22.4
2002	134	34.7	199	38.2	333	36.7
Total	386	100.0	521	100.0	907	100.0

Respondents were interviewed up to four times. About 91% of the lowland respondents were interviewed more than once. About 80% of upland respondents were

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[2] Different survey years were funded by different funding institutions (Australian Centre for International Agricultural Research and McArthur Foundation – 1995; Ford Foundation – 1997; World Bank – 1999; and National Science Foundation – 2002).

interviewed more than once (they had a higher tendency to resettle or migrate to other places for economic or cultural reasons). Table 2.3 presents the number of times household respondents were interviewed over the four survey periods. Attrition issues are not addressed in this study.

Table 2.3. Number of Interviews of Household Respondents

Number of Times Interviewed	Lowland		Upland		Pooled	
	Number of Households	Percent	Number of Households	Percent	Number of Households	Percent
4	27	7.0	28	5.4	55	6.1
3	211	54.6	93	17.8	304	33.5
2	113	29.3	296	56.8	409	45.1
1	35	9.1	104	20.0	139	15.3
Total	386	100.0	521	100.0	907	100.0

2.3.1 The Lowland Sample

Two kinds of panel data sets have been constructed for the lowland sample: one is organized on a *per household* basis while the other is organized on a *per parcel* basis. The household panel has one observation per respondent per year. Hence, the number of observations is equal to the number of household interviews. The parcel panel contains multiple observations for each household within each year. Each observation represents production for a single cropping on a parcel. The number of observations per household depends on the number of rice parcels cultivated by the household as well as the number of croppings for any particular year. For example, if the respondent had two parcels and two croppings in 2002, then he would have one observation for 2002 in the household panel and four observations for 2002 in the parcel panel. Thus, while the household panel has 386 observations (Table 2.4), the parcel panel has 817 observations (Table 2.5).

The lowland panel data sets display a pattern of a shift from a rice- and corn-based farming system to a rice-based farming system brought about by the transformation of lowland farms from rainfed to irrigated production (Table 2.4). The 1995 lowland sample consists of 36 lowland farms under rainfed condition. This is the year without irrigation, in which 61% of the observed plantings were of corn and 39% were of rice. In 1997, about 57% of the lowland croppings were irrigated and the remainder were rainfed. During this year, 90% of the croppings were of rice and 10% were of corn. In 1999, 93% of the parcels received irrigation (both Tamlang and Marangas CIS were operating in full capacity). Accordingly, in 1999, all observations represent irrigated rice cultivation. In 2002, there were isolated problems in the operation and maintenance of the irrigation systems in both sites which might have contributed to a reduction in irrigation coverage resulting in a 92% rate of irrigation. This one percentage point slide corresponded to a one percentage point drop (to 99%) in rice production with 1% of 1999 croppings corresponding to corn. With regard to cropping intensity, the average number of croppings per farm per year in 1995 was 1.00. This increased to 1.76, 1.94 and 1.93 in 1997, 1999 and 2002, respectively.

The lowland panel shows a pattern of increasing mechanization in the area as demonstrated by increasing proportion of farmers owning hand tractors (Table 2.4).[3] In 1995, only 2.8% of lowland farmers owned tractors. However, the years following irrigation development saw an increase in the proportion of respondents owning a tractor (to 27.7, 27.9 and 29.9 percent respectively in 1997, 1999 and 2002). On the other hand, ownership of carabao (a draft animal) showed a steady decline in both sites (from 94% in

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[3] A hand tractor is a two-wheeled tractor also known as power tiller or one-axled tractor.

1995 declining to 80%, 70%, and 67% in 1997, 1999 and 2002). This might indicate that, although not abrupt, farm mechanization has slowly been taking over the land preparation activities. Although carabao remained widely used in doing the primary plowing of rice plots, secondary plowing, cultivation and leveling were being gradually replaced by mechanized labor. In terms of farmsize, workers per household and household size, no clear patterns emerge in the lowland panel.

There were three major variable inputs used in rice production in the study sites: labor, pesticides and fertilizer. A summary of hired labor from the parcel level panel data shows that, with the onset of irrigation development, the average number of hired workers per cropping per hectare doubled from 18 workdays in 1995 to 43, 40 and 60 workdays in 1997, 1999 and 2002, respectively (Table 2.5). The cost of pesticides per cropping per hectare increased several fold from P170 in 1995 to P1,266, P1,542 and P1,259. This steep rise reflects the limited types and amounts of pesticides used on rainfed plots (i.e., usually only insecticides). On irrigated rice plots, different kinds and greater amounts of pesticides are applied because new kinds of pest controls must be administered when new kinds of pests arise (e.g., golden apple snails and broadleaf weeds). For this reason, herbicides, molluskacides and rodenticides were added to the portfolio of pesticides used on lowland farms. With regards to the amount of fertilizer use, amounts of fertilizer applied per cropping per hectare decreased in the post irrigation years. This can be attributed to the lower fertilizer use efficiency of one-crop rainfed corn compared to irrigated rice. The amount of fertilizer applied decreased from 234 kg per hectare in 1995 to 168, 169 and 140 kg in 1997, 1999 and 2002, respectively.

Table 2.4. Lowland Household Panel Summary

Item	Marangas			Tamlang				All lowland sites			
	1997	1999	2002	1995	1997	1999	2002	1995	1997	1999	2002
% irrigated	79.2	98.0	49.5	0.0	12.0	87.7	26.0	0.0	47.4	92.8	37.0
Cropping intensity (croppings/year)	2.07	2.06	2.02	1.06	1.42	1.83	1.86	1.06	1.76	1.94	1.93
Household size	5.58	5.22	5.73	5.89	4.96	4.55	5.38	5.89	5.29	4.88	5.54
Farmsize per capita (ha/person)	0.56	0.51	0.72	0.97	1.12	0.90	0.87	0.97	0.83	0.71	0.80
Number of carabaos (heads)	1.24	1.43	1.14	1.53	1.64	1.15	1.11	1.53	1.43	1.29	1.13
% of farms with own carabao	69.5	70.6	68.3	94.4	90.6	69.8	66.2	94.4	79.5	70.2	67.2
% of farms with own tractor	23.7	27.5	27.0	2.8	32.1	28.3	29.6	2.8	27.7	27.9	29.9
Farmsize (ha)	2.75	2.18	3.68	4.57	4.76	2.83	4.06	4.57	3.70	2.51	3.88
Workers	2.08	1.69	1.90	2.03	2.13	1.74	2.04	2.03	2.11	1.71	1.98
Number of farms	59	51	63	36	53	53	71	36	112	104	134

Note: Total number of household interviews = 386.

Table 2.5. Lowland Parcel Panel Summary

Item	Marangas			Tamlang				All lowland sites			
	1997	1999	2002	1995	1997	1999	2002	1995	1997	1999	2002
% cultivating rice	99.2	100.0	99.4	38.6	77.4	99.0	98.1	38.6	90.0	99.5	98.7
% cultivating corn	0.8	0.0	0.6	61.4	22.6	1.0	1.9	61.4	10.0	0.0	1.3
% owned	54.7	80.0	33.8	87.1	79.6	85.0	69.2	87.1	65.2	82.4	51.6
% renting	45.3	20.0	66.2	12.9	20.4	15.0	30.8	12.9	34.8	17.6	48.4
Rice yield (kg/ha)	3,629	3,120	3,452	2,585	2,926	1,932	2,346	2,585	3,375	2,558	2,899
% with siltation problem	18.0	57.3	42.0	-	-	60.0	44.0		10.4	58.9	43.0
Quantity of fertilizer (kg/ha)	153	154	112	234	187	186	168	234	168	169	140
Cost of pesticides (pesos/ha)	1,755	1,813	1,545	170	594	1,244	977	170	1,266	1,542	1,259
Amount of labor (workdays/ha)	41	36	58	18	46	45	62	18	43	40	60
% using fertilizer	98.4	95.5	85.9	92.6	97.2	98.0	94.9	92.6	98.0	96.7	90.4
% using urea (45-0-0)	93.7	92.7	71.8	92.6	77.8	65.7	59.0	92.6	87.9	79.9	65.4
% using complete (14-14-14)	27.6	27.3	44.9	40.7	59.7	33.3	40.4	40.7	39.2	30.1	42.6
% using ammophos (16-20-0)	33.1	27.3	34.6	37.0	38.9	66.7	73.1	37.0	35.2	45.9	53.8
% hiring upland laborers	48.4	45.5	73.9	37.1	31.2	25.0	42.8	37.1	43.0	35.7	58.2
Number of parcels	128	110	157	70	93	100	159	70	221	210	316

Note: Total number of lowland rice parcel cultivations observed = 747.

2.3.2 The Upland Sample

The upland sample contains 521 valid responses. In contrast with the lowland sample, the upland sample consists of only one data set, namely an unbalanced household panel. Over the eight-year period, at least 84% of the upland respondents cultivated rice on their upland plots. On average, the areas planted to rice were larger in 1999 and 2002 compared to those in 1995 and 1997. Visits to the upland areas reveal that two of the reasons for the increase in the area planted to rice were higher dependence on rice as a staple food as well as the emergence of more developed rainfed rice cultivation in the uplands. More bunded rice plots were constructed in the uplands. This was made possible by the presence of several creeks and spring water sources. Some former upland rice cultivation plots were converted to bunded plots. However, despite the developments of bunded rice production, average rice yields in 1999 and 2002 were less than one ton per hectare (Table 2.6). In terms of corn, the proportion of upland respondents growing this crop has been declining. The average area planted to corn increased from 0.45 ha in 1995 to 0.55 ha in 1997, but then declined to 0.47 and 0.40 ha in 1999 and 2002, respectively.

The proportion of upland households who engaged in off-farm work increased from 1995 to 1997 from 62% to 81%, respectively. This figure dropped slightly in 1999 and 2002 but remained higher than the 1995 level. With regards to upland clearing activities, about 57% of upland households were engaged in forest clearing prior to irrigation (in 1995). But this dropped considerably in 1997, 1999 and 2002 to less than 30%. In part, this can be attributed to the presence of irrigation development in the adjacent lowland communities. The average size of area cleared exhibited a decreasing trend from 1997 to 2002 (from 0.99 in 1997 to 0.82 and 0.66 ha in 1999 and 2002). These are the years when the Tamlang lowlands were transformed from rainfed to irrigated conditions.[4]

Table 2.6 Upland Household Panel Summary

Item	1995	1997	1999	2002
% of households planting rice	84.3	85.3	84.8	89.4
% of households planting corn	75.2	72.5	60.6	60.3
Area planted to rice (ha)	0.34	0.34	0.74	0.60
Area planted to corn (ha)	0.45	0.55	0.47	0.40
% of households who own carabao/s	33.9	33.3	38.4	34.7
Rice yield (kg/ha)	776	1732	897	757
Corn yield (kg/ha)	882	1295	1308	960
Yield of rice and corn (kg/ha)	825	1344	943	752
% of households engaged in off-farm work	62.0	81.4	63.6	68.8
% of households engaged in forest clearing	57.02	16.67	23.23	26.63
Cleared Area (ha) – all	0.38	0.16	0.19	0.18
Cleared Area (ha) – only those who cleared	0.67	0.99	0.82	0.66
% of households residing far from lowlands	25.62	14.71	19.19	20.60
Farmsize (ha)	2.62	2.04	2.00	2.04
Income per capita (pesos/person)	3,122	3,864	3,225	2,762
Income per hectare (pesos/ha)	8,052	10,436	7,460	6,961
Education of household head (years)	1.64	1.20	1.62	1.69
% of migrant households	14.88	18.63	21.21	8.04
% of households belonging to *Pala'wan* tribe	90.9	85.3	89.9	91.0
% of households with tenurial instrument (CSC)	71.90	45.10	56.57	55.28
Number of farms	121	102	99	199

Most upland respondents reside in villages near the lowlands. A number of households who were living near the lowlands were engaged in off-farm employment. Data show that, on average, about 80% of the upland respondents could reach the lowlands by less than an hour walk while 20% took 1 to 3 hrs of walking time. The upland sample is used for analyzing the activity and resource allocation in the uplands using the seemingly unrelated regression approach. The income (total income per capita

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[4] This decline in cleared area closely corresponds to the decline in corn production, and reflects the growing importance of off-farm wages as a replacement for cash crop income, derived largely from corn.

including the imputed value of retained rice production) and population class variables (with and without off-farm work) are also used to construct for the distributional analysis in Chapter 5.

2.3.3 The Distribution Sample

Three panel data sets are constructed for the distributional and poverty analysis presented in Chapter 5. These are: (1) a pooled income data set; (2) a lowland income data set; and (3) an upland income data set. The pooled sample is constructed by pooling together the income per capita data from the lowland and upland samples. In this data set, a population class variable is included to identify the lowland household from the upland households. This variable is used for the Gini decomposition and poverty decomposition analyses. Incomes are deflated using the prevailing average prices of a kg of rice for a particular year.

The lowland household panel was used to construct the lowland income panel data set. Lowland income is composed of income from sale of rice, sale of other agricultural products (livestock, poultry, tree crops), business, land rental fees, and wage income (including non-farm and off-farm). Lowland income can become negative because it reflects income net of input costs. As expected, lowland farm incomes are heavily dependent on the sale of rice. Five lowland households experienced negative household incomes for each of the 1999 and 2002 lowland samples. The lowland sample includes an indicator variable for small and large farms which is used for the decomposition analyses.

The upland income panel data set is composed of upland household incomes and includes: (1) the imputed values of rice crop retained for home consumption; (2) sales of agricultural products; (3) off-farm wages; (4) incomes from sale of collected forest products; and (5) other income. We include the imputed value of rice retained for home consumption in our measure of total household income since upland households operate on a semi-subsistence basis. For this reason, we call income per capita for the upland sample total income per capita. Since almost all upland households produce rice or do not spend much on agricultural inputs (in fact, most do not purchase any chemical inputs at all), all upland incomes are non-negative. In addition to the income per capita variable, the upland sample also contains an indicator variable for participation in off-farm employment. This is used for the Gini and poverty decomposition analyses.

2.4 Irrigated Lowland Rice Production

With irrigation, more than 75% of lowland rice farms have at least two croppings per year. The first rice cropping, also called the *main cropping*, occurs between May and October. Based on the 29-year (1966 to 1994) rainfall average in the southern district of Palawan, about 61% (850 mm) of the total annual rainfall is distributed evenly in these months, providing most lowland farmers with sufficient water. The second rice cropping usually occurs between November and April, and receives, on average, 39% of total annual rainfall. This limited amount of rainfall contributes to water shortages on some lowland farms, even those covered by irrigation. Water shortages sometimes lead to relatively low dry season yields or in some cases complete crop failure.

Access to irrigation water is also dependent upon the distance of a lowland farm to the water source. Rice farms which are situated closer to the main irrigation canals have better access to irrigation water, allowing some of them to have a good supply of water even during the dry season. Those relatively few farms with the best access to irrigation water sometimes have been able to produce three rice crops per year using early maturing rice varieties. The average lowland rice yield is three metric tons per hectare.

Lowland rice production in the study sites involves three major groups of operations: (1) land preparation and planting; (2) field operations, including application of fertilizer and pesticides; and (3) harvesting, threshing and hauling. Here we briefly discuss the typical rice farming operations. For detailed information about smallholder rice farming operations in the Philippines, one may visit the web site of the training unit of the International Rice Research Institute (IRRI) at www.training.irri.org.

In the lowland study sites, land preparation for the main cropping usually starts after the first few heavy rains in the month of May, the onset of the rainy season. Typically, the first land preparation activity is *primary plowing* where rice farmers use carabao-drawn mouldboard plows to invert the soil which was recently softened by heavy rains. After this operation, the rice plot remains untouched for one week. This allows weeds and crop residues to decompose and weed seeds in the soil germinate. A secondary plowing immediately follows, in which a carabao-drawn plow or a hand tractor (also called power tiller) is used to break chunks of inverted soil into smaller pieces while at the same time crushing the newly germinated weed seeds to hasten their decomposition. One week after this operation, the field is leveled. In addition to plowing and leveling, farmers also clear the fields and repair bunds for water management and weed control purposes. Farmers then plant rice by broadcasting seeds evenly into the prepared field. During the early years of the survey, in 1997, most lowland rice farmers planted rice using the transplanting method. However, in the more recent survey years, farmers have shifted to the broadcasting method to save on labor costs. This can be attributed to the fact that, on irrigated rice fields, the introduction of low-cost herbicides raises the profitability of direct seeding over the transplanting method (Baulita-Inocencio and David, 1995). In the study sites, only those (very few) farmers who grew rice for seed production continue to rely on the transplanting method.

Field operations follow planting. These rely mainly on manual labor and begin with manual spraying of pre-emergence herbicide using a backpack sprayer. This is followed by side-dressing of granular fertilizer. At this stage, the water level is lowered to allow the fertilizer to penetrate the soil. This is followed by several sprayings of insecticides. Field operations usually end with topdressing with urea fertilizer to aid in increasing the density of the rice grains. After field operations, lowland farmers simply wait for the rice grains to mature depending upon the rice variety used. Some varieties need 120 days to mature while others need only 85 days. The latter variety can be used for three rice croppings per year.

After the field operations, farmers usually wait for about two weeks for the rice to become ripe for harvesting. During this waiting period, farmers usually buy rice sacks as packaging materials for the harvested grains. Lowland farms situated far from the main road start to negotiate with local “tricycle” operators (owner-drivers of a motorcycle with a sidecar) for hauling their produce. Also, lowland farmers, especially those who cultivated a relatively large rice area (greater than 3 hectares), try to make arrangements with laborers who will be hired for harvesting and threshing operations.

Harvesting operations require a lot of manual labor in a short period of time. For this reason, the wage rises steeply on a seasonal basis. The amount of labor that can be supplied by the family or fellow lowland households is typically insufficient during the harvest season. Most lowland households hire laborers from the uplands during the harvest season to fill the labor gap.

Harvesting operations basically include the manual cutting of mature rice plants at about four inches from the base. These cut shoots are bundled and piled in preparation for threshing operations. A small mobile mechanical thresher comes to the place where threshing and packing is to occur. Laborers hired for harvesting are also involved in threshing. The lowland farm employer typically divides the total harvest into 12 parts. One part is given to the laborers, one part goes to the owner of the mechanical thresher and the remaining 10 parts go to the farm owner.

The final step requires hauling the 10 parts of the harvested crop to the place for drying – using either solar or mechanical means. After this, the rice is packed into new rice sacks, each weighing approximately 50 kg. Farmers usually do not sell all of their newly-dried rice. Most of them retain a certain amount for home consumption. A few farmers who have safe storage facilities store first and sell when prices rise.

Lowland farm inputs fall into two categories: fixed and variable. Major fixed inputs include land, tractors and carabaos. Over the survey period, average lowland farm sizes have been varying in both sites with no regular patterns. However, the panel data indicate that, on average, lowland farms in Tamlang were always larger than those in

Marangas in all survey years. In terms of carabao ownership, in Tamlang, the proportion of farms with at least one carabao was declining from 1995 to 2002. Marangas, on the other hand, seemed to have a more stable proportion of households with carabao. With regards to tractor ownership, in 2002, the proportion of respondents who owned two-wheeled tractors was slightly higher in Tamlang (29.9%) compared to Marangas (27.0%).

The major variable farm inputs are labor, fertilizer and pesticides. As mentioned earlier, lowland irrigation development contributed to an increase in aggregate labor demand in the lowlands. This increase in labor demand became more evident between 1999 and 2002, where there was an increase in the proportion of lowland households who hired upland workers (from 36.5% to 56.0%, respectively). This trend indicates an increasing dependence of lowland farms on off-farm labor from the uplands.[5]

During the first five years of irrigation development (1995 to 2000), upland households hired to work on lowland farms were typically paid on a per day basis, and as a result receive lower compensation than lowland laborers who typically received a share of the crop as payment. Upland laborers also received a lower daily wage for doing manual labor (Shively, et al., 1998). However, over time, as a number of upland households became accustomed to doing harvest work in the lowlands, they developed better harvesting skills and were sometimes paid on a per share basis, bringing their effective wage in line with that received by lowland households.

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[5] Although this is speculation, we expect that this upland labor dependency is to increase in the future, as evidence suggests some upland households are relocating from more remote upland areas into upland homelots closer to the lowland farms, primarily to engage in off-farm work.

All lowland farms applied granular fertilizers on their plots. They used four major kinds of granular fertilizers. These were urea (45-0-0), ammonium phosphate (16-20-0), ammonium sulfate (21-0-0-20) and complete (14-14-14). Over the survey period, the proportion of rice parcels that applied urea steadily decreased in both sites (from 93% in 1995 down to 88%, 80% and 65% in 1997, 1999 and 2002, respectively). The proportion of those using ammonium sulfate increased in Tamlang (from 37% in 1995 to 39%, 67% and 73% in 1997, 1999 and 2002). The use of complete fertilizer shows no distinct trend over the survey period.

Foliar fertilizers contain rice growth hormones and soil micronutrients. These have been used by several farmers in both sites, although foliar fertilizer was applied at a higher proportion of Marangas parcels in 2002 (41% compared to 19% in Tamlang). The higher proportion in Marangas can be attributed to the earlier introduction of irrigation at that site which placed those farmers at an earlier stage on the adoption curve.

2.5 Rainfed Upland Agricultural Production

Compared with lowland farms, which concentrate on rice monocropping, upland farms are usually quite diversified. Upland households engage mostly in cultivating annual crops, predominantly rice and corn. Rice (*Oryza sativa*) is mainly grown for home consumption while yellow corn (*Zea mays*) is grown for sale. Other annual crops cultivated include string beans (*Vigna unguiculata*), sponge gourd (*Luffa cylindrica*) , okra (*Abelmoschus esculentus*), eggplant (*Solanum melongena*) and various kinds of introduced and native rootcrops. These crops are usually grown both for home consumption as well as for sale. Fruit trees, including cashew (*Anacardium occidentale*), mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), avocado (*Persea americana*) and cacao (*Theobroma cacao*), are grown by most upland households. A majority of upland households planted three major varieties of banana with plantain being the most common. Most upland households grow plantain for sale.

Upland rice yields are extremely low, averaging less than one ton per hectare. Low rice yields can be attributed to low-input cultivation practices and poor growing conditions. Typically, native upland rice varieties are planted on steep, highly erodible soils.[6] Almost all upland households grow rice only for home consumption. The amount of upland rice harvested is usually insufficient to meet the household rice requirement for eight months. The cassava crop, which is grown for its fleshy edible rootstocks, serves as the staple once rice stocks are exhausted.

Large government reforestation programs implemented in the uplands in the early 1980s and again in the late 1990s emphasized tree planting and agroforestry practices. These programs were only moderately successful but did increase the number of trees grown in the area. Forest trees such as yemane (*Gmelina arborea)*, mahogany (*Swietenia macrophylla*), and narra (*Pterucarpus indicus*) can be found, as can fruit trees including cashew, mango, cacao, jackfruit and avocado.

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[6] A few upland households in the area were observed to be growing rice on bunded, terraced plots which allow them to capture rainwater where they could use rainfed farming methods practiced by migrant lowland households prior to irrigation. This practice may be partly attributed to the interaction of upland households with the lowland farming communities.

2.6 Household Incomes in the Study Communities

The households in the study communities can be grouped into two groups based on the agro-ecosystem inhabited – lowland or upland. The lowland group is relatively better off in terms of income since their incomes come from commercial rice production using relatively modern farming techniques. The upland group is composed of semi-subsistence farmers cultivating the forest margins they inhabit. Agricultural production is characterized by minimal inputs and use of traditional multi-crop plots which consequently give low yields. Commercial crop production in the uplands remains limited.

The lowland group belongs to the dominant Philippine ethnic class or the "mainstream" society giving this group more opportunities to become involved in cash generating activities. Lowland households can obtain income from off-farm work (i.e., wage work on other lowland farms), non-farm income (e.g., operation of public utility vehicles, local government office work, small trading activities), and small and medium scale businesses (small variety store, rice mill, and petty trading).

As a marginalized group, in contrast, the *Pala'wan* upland group has fewer livelihood opportunities and typically subsistence oriented. They focus efforts on small scale agriculture and exploitation of the forest resource base. Specifically, the group's major income sources are: upland agricultural production, off-farm wage work (mainly on lowland farms), sale of collected forest products, and other sources (e.g., handicrafts, fishing). Over the eight-year period, the proportions of nominal incomes from these sources varied, but farm production was the biggest source of income in the uplands (see Figure 2.3). It consistently contributed more than 50% of total household income. The proportions of income from sale of farm produce were considerably higher in 1999 and 2002 than 1995 and 1997. This may be attributed to the fact that in the latter years, the adjacent lowland areas were benefiting from irrigation and increasing their demand for upland products. Upland real income levels and shares are discussed and analyzed in Chapters 4 and 5 of this thesis.

2.7 Summary

This chapter provides a background for the analyses in Chapters 3, 4 and 5. Readers are oriented about the structures of the panel data sets used in the subsequent analysis. For Chapter 3, two lowland panel data sets are constructed – the household panel and the parcel panel. The lowland parcel level data set is used for the stochastic frontier and efficiency analysis. Chapter 4 uses the upland household level data set for activity analysis. Chapter 5 uses three data sets – pooled, lowland and upland – for inequality and poverty analyses.

The survey years 1997, 1999 and 2002 were classified as favorable, average and unfavorable in terms of growing conditions. The 1995 survey year serves as the base year for all the analyses in the thesis.

As a primer for Chapter 3, which deals with technical efficiency of rice production in the lowlands, typical production practices were described. To brief the reader about activity and resource allocation in the uplands, upland agricultural production and other upland activities were discussed. As an introduction to distributional impact and poverty analysis, the composition of household incomes in the study communities was summarized.

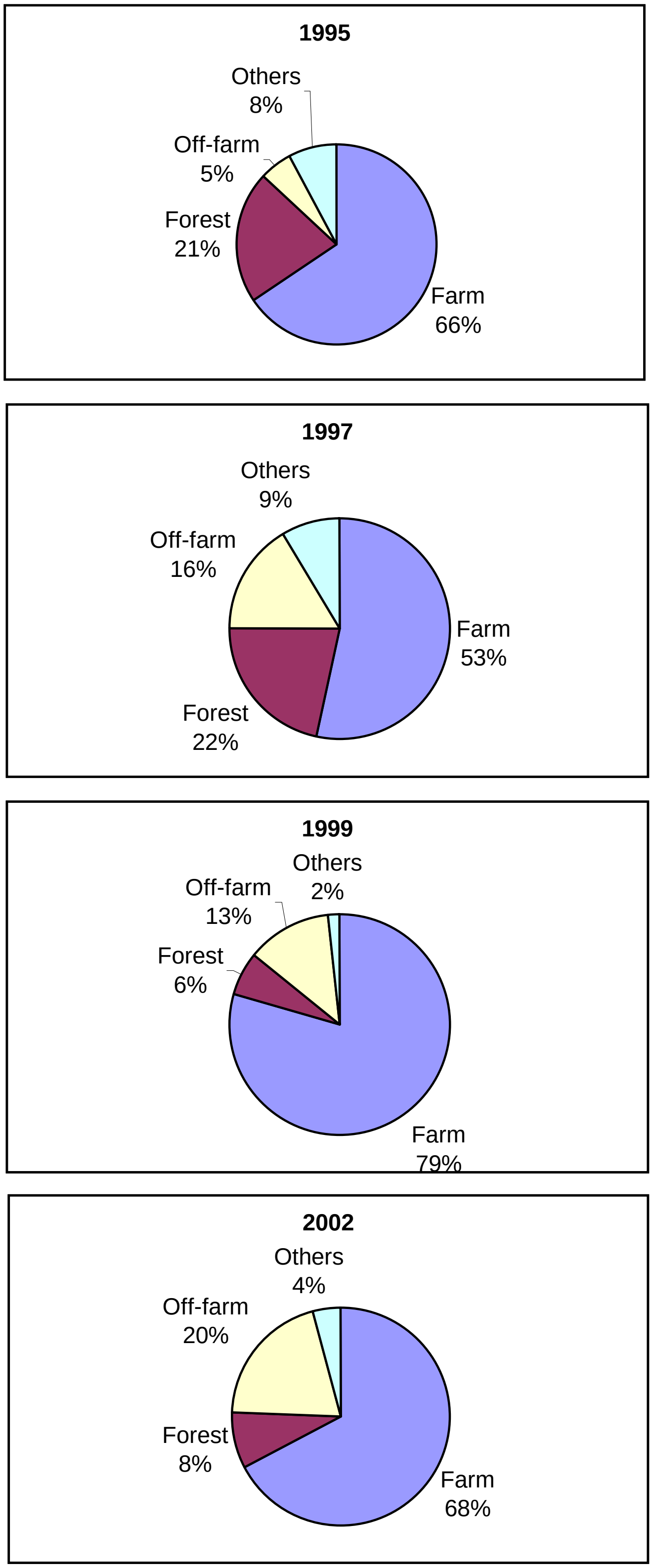

Figure 2.3 Upland Income Distributions in 1995, 1997, 1999 and 2002

CHAPTER 3

EFFICIENCY OF RICE PRODUCTION IN THE LOWLANDS

3.1 Overview

This chapter studies the impact of irrigation development on the technical efficiency of lowland rice farms. The topic of efficiency in rice production has been of longstanding interest to economists. One of the first studies to focus on this topic was Barker, Herdt and Rose's (1985) seminal work reviewing trends and changes in the Asian rice economy beginning the early 1940s.

Several related empirical studies from the Philippines have applied a stochastic production frontier to analyze rice production. Early attempts to measure farm specific technical efficiency on Philippine rice farms include Kalirajan and Flinn (1983) and Kalirajan (1984; 1986; 1990). All of these studies used cross-sectional data to construct a production frontier. Dawson et al. (1991) is one of the first to estimate a stochastic production frontier using panel data. For that study, data came from two sets of rice producers in the Central Luzon region in the Philippines, collected through IRRI's "Central Luzon Loop Survey".[6] More recently, Shively and Zelek (2003) examined the issue of irrigation and production efficiency in Palawan, using the first three rounds

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[6] The Central Luzon region is known as the rice granary of the Philippines. IRRI stands for the International Rice Research Institute which is headquartered in Los Baños, Philippines.

(1995, 1997 and 1999) of the lowland panel used in this study. This chapter aims to contribute to this body of empirical work by modeling technical efficiency effects in stochastic frontier production using four years of data (1995, 1997, 1999 and 2002).

Shively and Zelek (2003) estimated a time-invariant stochastic frontier model using parcel-level random effects. In contrast, this study adopts a time-varying stochastic frontier using the method of maximum likelihood for the simultaneous estimation of the parameters of the stochastic frontier and the model of technical inefficiency. This model is derived from the model developed by Battese and Coelli (1995) which allows the estimation of both technical change in the stochastic frontier as well as time varying technical inefficiencies, given that the inefficiency effects are stochastic.

This chapter is motivated by the questions "Does irrigation development enhance technical efficiency in rice production? And if so, what factors contribute to technical efficiency?" The first question is addressed by the stochastic frontier model and the follow-on question is addressed by the technical efficiency model. To examine the input allocation of farm respondents with reference to the profit maximizing input levels, the expected profit model is used for this analysis. The models highlighted above are discussed below.

3.2 The Models

Two approaches are widely used to estimate technical efficiency. The first approach is based on non-parametric, non-stochastic, and linear programming techniques (i.e., data envelopment analysis or DEA). One advantage of the non-parametric methods is that they do not require the specification of a functional form. However, one drawback of this approach is that it does not account for the possible influence of measurement error and other noise in the data (Coelli, 1995). Another drawback is that using the DEA method to model inefficiency in production (e.g., agricultural production) requires a two-step methodology. The first step involves the use of DEA to model inefficiency as a function of variables and the second step involves specific farm characteristics used in a regression approach (e.g., Tobit framework) to explain variations in measured inefficiencies. One drawback of the two-stage method is the inconsistency in the assumptions regarding the distribution of inefficiencies. The one-stage, parametric approach for the simultaneous estimation of parameters overcomes this inconsistency since the inefficiency effects, which are defined as a function of the household's specific factors, are incorporated directly into the likelihood function. This one-stage statistical approach is used for this study since it allows one to estimate the determinants of inefficiency of producing units simultaneously with the stochastic frontier production function. It is also worth mentioning that, in assessing efficiency in agricultural production, the stochastic frontier approach is preferred because of the inherent stochasticity involved (Färe et al. 1985; Kirkley et al. 1995; Coelli et al. 1998). This approach, however, imposes an explicit and possibly restrictive functional form on the technology.

The analysis of this chapter relies upon two related economic models to measure production efficiency. The first is the *stochastic frontier and inefficiency model* and the second is the *expected profit model*. The first model attempts to measure the technical efficiency of farmers in producing rice per unit of land, with reference to a production frontier that represents the best practice technique. The second model attempts to measure producer efficiency in terms of allocating inputs with reference to profit maximizing input levels. The expected profit model uses the estimated coefficients of the the stochastic frontier model to compute input levels that maximize expected profit.

3.2.1 The Stochastic Frontier and the Inefficiency Models

The stochastic frontier model is used to estimate frontiers which envelop, rather than intersect data (Kumbhakar and Knox Lovell, 2000). The first stochastic frontier model was proposed independently by Aigner, Lovell and Schmidt (1977) and by Meeusen and van den Broeck (1977). Dillon and Anderson (1995) point out that the model has been applied and modified in both agricultural and non-agricultural research (e.g., Bagi and Huang (1983); Battese and Corra (1977); Kalirajan (1982); and Waldman (1984)). Dillon and Anderson (1995) add that early works on SFA did not include time-varying technical efficiency. Cornwell, Schmidt and Sickles (CSS) (1990) and Kumbhakar (1990) were among the first to propose a stochastic production frontier model with time varying technical efficiency.

The stochastic frontier model has an error term with two components assumed to be independently distributed of each other and of the regressors. The first component, V_{it}, is a symmetric, idiosyncratic component that accounts for purely random events (e.g., weather, luck), while the second component, U_{it}, is a non-negative random variable obtained through truncation at zero of the normal distribution. This captures the inefficiency effects relative to the stochastic frontier. The random component, V, is independently and identically distributed with $N(0, \sigma_V^2)$ while the technical inefficiency component, U, is assumed to follow some specific distribution form. Here it is assumed that U has a half-normal distribution, $N^{+}\left(Z_{it}\delta, \sigma_U^2\right)$.[7] Equations 3.1 and 3.2 represent the stochastic production frontier and the technical inefficiency models, respectively:

$$Y_{it} = \exp(X_{ijt}\beta + V_{it} - U_{it}) \tag{3.1}$$

$$E_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it}) \tag{3.2}$$

where the dependent variable Y_{it} represents rice yield (kg/ha) of the i^{th} parcel at time t, X_{it} is a n x k vector of values of production related input quantities and indicator variables for the i^{th} parcel at time t. The parameter vectors β and δ are to be estimated together with the variance parameters expressed as $\sigma^2 = \sigma_V^2 + \sigma_U^2$ and $\gamma = {\sigma_U^2}/{\sigma^2}$. The variance parameter, γ, is defined by Battese and Corra (1977) as the total variation in output from the frontier which is attributed to the effect of technical efficiency.

The technical efficiency is defined as $E_{it} = exp(-U_{it})$ which is predicted using the conditional expectation of $\exp(-U_{it})$, given the composed error term in Equation 3.1, Z_{it} is a vector of demographic and socio-economic characteristics (e.g., age, education, farmsize, tenure) determining inefficiency which may vary over time. The inefficiency model's random component, W, is not identically distributed nor required to be non-negative (Battese and Coelli, 1995).

The parameters of these two equations are estimated simultaneously using the software package Frontier 4.1 (Coelli, 1996). The unbalanced panel data are used to estimate the stochastic production frontier and inefficiency model in Cobb-Douglas form

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[7] Alternative approaches allow the technical inefficiency component, U_{it}, to have a gamma or an exponential distribution (Greene, 1990).

(see Equations 3.3 and 3.4 below).[8] A single equation model is justified, since input allocations and output are observed, implying the general input allocation case where technological relationships can be estimated directly without explicit assumptions that restrict either behavior or technology (Just et al., 1983). As mentioned earlier, the single equation model allows the estimation of all the parameters in one step thus avoiding the inconsistencies compared to the two-stage estimation process. The estimating equation is:

$$\begin{aligned}\ln Y_{it} &= \beta_0 + \beta_1 \ln(labor_{it}) + \beta_2 \ln(fertilizer_{it}) + \beta_3 \ln(pesticide_{it}) + \beta_4 season_{it} \\ &+ \beta_5 site_{it} + \beta_6 irrdry_{it} + \beta_7 tractor_{it} + \beta_8 draft_{it} + \beta_9 tenure_{it} + \beta_{10} y97_{it} \\ &+ \beta_{11} y99_{it} + \beta_{12} y02_{it} + V_{it} + U_{it}\end{aligned} \tag{3.3}$$

where

$$\begin{aligned}U_{it} &= \delta_0 + \delta_1 educ_{it} + \delta_2 age_{it} + \delta_3 fsize_{it} + \delta_4 tractor_{it} + \delta_5 draft_{it} + \delta_6 wrkrs_{it} \\ &+ \delta_7 tenure_{it} + \delta_8 y97_{it} + \delta_9 y99_{it} + \delta_{10} y02_{it} + W_{it}\end{aligned} \tag{3.4}$$

Except for the intercept parameters β_0 and δ_0, the explanatory variables in Equations 3.3 and 3.4 have the indices i and t which represent the i^{th} cropping activity (parcel i=1,2,3,…,404) at time t (t=1,2,3 and 4). Y_{it} is the dependent variable for the stochastic frontier model which represents the rice yield in kg/ha. The independent variables are defined as follows: $labor_{it}$ is the amount of labor used for rice production in workdays/ha, $fertilizer_{it}$ is the amount of fertilizer used in kg/ha, $pesticide_{it}$ is the cost of pesticides used in pesos/ha. Also included are nine binary variables: $season_{it}$ (1 if wet

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[8] Initially, the full trans-log functional form was used, but testing this form using Hausman's specification test indicated an inconsistent estimation of the coefficients. This might be due to serious multicollinearity where the estimated coefficients of the translog model exhibit high Variance Inflation Factors (VIFs), ranging from 11.6 to 34.9. Also, the translog model would not provide coefficients leading to interior maxima in the optimization process. For this reason, the more restrictive Cobb-Douglas functional form is adopted.

cropping season and 0 otherwise), $site_{it}$ (1 if observed in Marangas and 0 if in Tamlang), $irrdry_{it}$ (1 if the parcel cultivated during the dry season was irrigated and 0 otherwise), $tractor_{it}$ (1 if the cultivator owns at least one hand tractor and 0 otherwise), $draft_{it}$ (1 if the cultivator owns at least one carabao and 0 otherwise), $tenure_{it}$ (1 if the cultivator owns the parcel and 0 otherwise), and $y97_{it}$, $y99_{it}$ and $y02_{it}$ (indicators for the years 1997, 1999 and 2002, respectively). The indicator variable $y95_{it}$ is dropped from the frontier and inefficiency models and serves as the reference year in both models.

The inefficiency model decomposes the technical inefficiency term, U_{it}, into a set of parcel cultivator's socioeconomic characteristics, z_{it}, and an unknown vector of coefficients, δ. The identified characteristics that are hypothesized to explain technical inefficiency are: $educ_{it}$ (the number of years of formal education of household head), age_{it} (the age of household head in years), $fsize_{it}$ (the total size of the farm in hectares), $wrkrs_{it}$ (the number of farm workers in the household), and w_{it} (the random variable defined by the truncation of the normal distribution).

Both the frontier and the inefficiency models have the set of year indicator variables which might account for other factors which were not included in the models. For the frontier model, these factors might include climatic condition, the incidence of pests and diseases and the rice varieties used by the sample farmers. For the inefficiency model, these factors might include access to credit, efficiency of farm workers, and other income generating activities of the households.

3.2.2 The Expected Profit Model

The elasticity estimates for the labor, fertilizer and pesticide inputs from the Cobb-Douglas production function serve as parameters for the expected profit model. The expected profit model, which also takes the Cobb-Douglas form, is used to show rice yield (kg/ha) as a function of farm production inputs, where respondents are assumed to be profit maximizers who optimize solely on rice farming. Parcel cultivators are assumed to be price takers in both input and output markets. This model is based on Fan (1991), who uses a parcel level production function. However, the model for this exercise is extended on a per parcel and per cropping basis. The expected profit model is used to model the two different cropping seasons – wet and dry. Before moving directly to the expected profit function, we begin with the yield model

$$Y_{it} = A\prod_{j=1}^{k} X_{ijt}^{\beta_{jt}} e^{\varepsilon_{it}} \tag{3.5}$$

where the i index represents a particular cropping of rice in a specific parcel at a given time t, the term Y_{it} represents rice yield in kg/ha for cropping i at time t, X_{ijt} is designated as the j^{th} input of interest (labor, fertilizer and capital), β_{jt} is the elasticity of the marginal product for input j at time t. The expected profit function is derived from Equation 3.5 as

$$E(\pi_{it}) = p_t E(Y_{it}) - \sum_{j=1}^{k} R_{ijt} X_{ijt} \tag{3.6}$$

where $E(\pi_{it})$ represents the expected profit for cropping i at time t, p_t is the price of a per unit of output at time t, and R_{ijt} is the price of a unit of input j in cropping i at time t. To obtain the optimality condition for profit maximization, expected profit is differentiated with respect to the matrix of input variables X_{ijt} to give:

$$p_t \frac{\partial E(Y_{it})}{\partial X_{ijt}} = R_{ijt} \quad , \forall_{ijt} \tag{3.7}$$

where the left hand side represents expected marginal revenue and the right hand side equal to marginal cost, R_{ijt}.

As mentioned earlier, we adopt the admittedly restrictive Cobb-Douglas functional form for the yield equation. Yield is a function of labor (L), fertilizer (F), pesticides (P), and yield shifters, namely: $\varepsilon_{it} = \beta_4 season + \beta_5 site + \beta_6 irrdry + \beta_7 tractor + \beta_8 draft + \beta_9 tenure + \beta_{10} y97 + \beta_{11} y99 + \beta_{12} y02 + V_{it} + U_{it}$. This equation is:

$$Y_{it} = L_{it}^{\beta_{Lt}} F_{it}^{\beta_{Ft}} P_{it}^{\beta_{Pt}} e^{\varepsilon_{it}} . \tag{3.8}$$

Equation 3.8 is used to solve for the factor demand equations presented in the results section of this chapter.

It is worth mentioning that the expected profit model formulated above might have some limitations. These include: (1) the Cobb-Douglas functional form might not capture the true functional form, leading to possible misspecification error; (2) deviations between the observed and profit maximizing input levels could be due to factors not included in the model; (3) the behavioral assumption that cultivators are expected profit maximizers might be incorrect since parcel cultivators could also be risk averse and hence maximize utility; and (4) there might be errors in the estimation process since we do not account for price expectations, even though rice prices were unknown at the time of rice planting and this might influence farmers' decisions.

3.3 Data

The panel data is composed of a total of 747 observations from 300 unique rice farming households in Palawan, Philippines. We used for this panel the empirical application of the stochastic production frontier and technical inefficiency model. The panel data set has four cross sectional cropping years – 1995, 1997, 1999 and 2002. For each observed cropping year, a household respondent can have one to three rice cropping seasons. Usually, respondents have two cropping seasons per year, one during the wet season (May to October) and another during the dry season (November to April). For all the observed years, about 73% of the respondents cultivated rice twice a year, 23% cultivated once, and 4% cultivated three times. In 1995, the year without irrigation, respondents had only one rice cropping season. However, in 1997-2002, the years following irrigation development, respondents with access to irrigation were able to have two to three cropping seasons per year.

During the study period, the observed number of land parcels cultivated and/or managed by each respondent ranged from one to three parcels. Each parcel may have had one to three cropping seasons per year. Table 3.1 presents the structure of the panel data set where a household respondent can give multiple responses in a given year. For instance, the typical pattern is for the respondent to have two rice parcels and to cultivate each parcel in two cropping seasons. In this case, the respondent can provide four data points in a particular year. The observations in the panel come on a per parcel and per cropping season basis (Table 3.2). Each observed parcel that was cultivated with rice in a particular season in a particular year is given a unique panel identification number. Each specific cropping activity of a unique household can be observed up to four times (since we have four years in the panel). Five parcels appeared four times in the panel data set. About 110 parcels appear in the data set three times, and 108 and 181 observations appear twice and once in the data set, respectively.

Table 3.1 A Tableau of Responses of the Lowland Unbalanced Panel Data Set

	1995				1997				1999				2002			
	Wet		Dry		Wet		Dry		Wet		Dry		Wet		Dry	
Farmer 1	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Farmer 2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Farmer 3	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Farmer 300	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2

Table 3.2 Composition of the Lowland Unbalanced Panel Data Set

No. of times observed	Frequency	Percentage
4	5	1.2
3	110	27.2
2	108	26.7
1	181	44.8
Total	404	100.0

As mentioned earlier, we are using an unbalanced panel data set. The unbalanced characteristic is attributed to attrition and missing data where a total of 869 observations are unobserved in the panel.[9] The major reasons for loss of data include the following: (1) a number of farmers were not available for interview for all the four rounds of the survey due to out migration, death or unknown transfer; (2) the sites underwent a transformation from rainfed to irrigated farming systems and in 1995 only rainfed parcels were observed and only during the wet season; (3) in 1995 only the Tamlang site was

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[9] In order for the panel data set to be balanced, the observations appearing in a given year should appear in the other years. However, different years of the panel have different number of observations. Some observations in the latter years were not observed in the previous years and vice versa. The panel has a total of 404 unique observations. Multiplying 404 by 4 cross sectional years will give $n = 1616$. Our actual n is equal to 747 observations, thus, the number of missing observations is 1616 – 747 = 869.

surveyed while Tamlang and Marangas sites were both surveyed in subsequent years; and (4) the structure of the panel is on a per parcel per cropping basis, and some farmers may have elected not to plant a given parcel in a given planting season in some years.

The unbalanced panel data set might have systematic problems of attrition. However, this study does not attempt to address the attrition issue but focuses mainly on using the available panel data set to estimate the technical inefficiency effects model of Battese and Coelli (1995). Given the specifications of the stochastic frontier model, the panel does not need to be balanced (Battese and Broca, 1997) since it already takes into account the unbalanced features of the panel data (Battese, Coelli and Colby, 1989).

A summary of means and standard deviations of the variables used in the stochastic frontier and inefficiency models are presented in Table 3.3. For the period covered, the average rice yield in the study site was about 3.0 tons per ha. This is slightly higher than the average for Region 4 of about 2.8 tons per ha for the same period.[10] In the observed four rounds of survey, average yield was highest in 1997 at about 3.4 tons/ha and lowest in 1999 at 2.6 tons/per ha. This suggests that 1997, on average, was the most productive year per unit of land. We attribute this to favorable climatic conditions and low incidence of pest and diseases. In contrast, 1999 had unfavorable climatic conditions, in large part due to the occurrence of an El Niño, coupled with a relatively high incidence of pest and diseases (e.g., high rodent infestation).

The figures in Table 3.3 show that, in terms of observed levels of farm inputs, a typical one hectare rice parcel in the sample uses about 49 workdays of labor, 166 kg of

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[10] Region 4 is the largest among the country's 16 regions which contain the island province of Palawan. The 2.8 tons per ha is the average rice yield for the years 1995, 1997, 1999 and 2002.

fertilizer and P1440 worth of pesticides per cropping season. The amount of labor and pesticides usage dramatically increased in the years following irrigation development. In contrast, the average amount of fertilizer used was 56% higher in 1995 compared to the years with irrigation.

It was evident that the sites' climatic condition makes irrigation services more important during the dry season. On average, about 39% of the total annual rainfall comes during the dry season. In 1995, 26 out of the 27 observations were observed during the wet season. In 1997, with the inclusion of the irrigated rice farming respondents from the Marangas site, the proportion of dry season cultivation for the year reached 27%. With the full operation of irrigation facilities in both study sites in 1998, the proportion of parcels cultivated during the dry season was higher at 45% and 44% in 1999 and 2002, respectively.

Over the study period, the respondents had an average of about eight years of formal education. Data in Table 3.3 show that a typical head of a farm household is about 47 years old with a total farm area of 3.6 ha and has one household member working with him/her full-time to do the farming operations. The data set also indicates that there is a 47% chance that an observed lowland rice parcel hired upland laborers to complete the labor requirements of a particular cropping season.

With regard to land tenure, the highest proportion of land ownership occurred in 1995 sample at 89% while in 2002 only about half of sample owned the land they tilled. As mentioned earlier, there was no respondent from Marangas who was interviewed in 1995. It is also interesting to note that as the sites transformed from rainfed to irrigated conditions, the proportion of respondents who owned at least one hand tractor was increasing, while the proportion of those who owned carabaos (or draft animals) was gradually declining. This might suggest that households are gradually shifting to mechanized farming operations.

Table 3.3 Summary of the Lowland Panel, 1995-2002, 747 Observed Parcels

Item	1995	1997	1999	2002	All
Yield (kg/ha)	2585	3375	2558	2899	2919
	(1413)	(1164)	(1361)	(1559)	(1433)
Labor (workdays/ha)	19.4	42.9	40.3	59.8	48.4
	(10.6)	(22.4)	(29.9)	(32.3)	(30.6)
Fertilizer (kg/ha)	253	162	176	154	166
	(110)	(71)	(129)	(83)	(98)
Pesticide (pesos/ha)	584	1391	1549	1273	1346
	(400)	(931)	(1189)	(1176)	(1123)
Education (years in school)	8.3	7.9	8.2	8.0	8.0
	(3.9)	(3.2)	(3.2)	(3.4)	(3.3)
Number of workers	2.3	2.1	1.6	2.0	1.9
	(1.4)	(1.4)	(1.0)	(1.3)	(1.3)
Farmsize (ha)	4.9	3.6	2.6	4.1	3.6
	(2.5)	(2.6)	(1.7)	(3.6)	(2.9)
Age of household head (years)	45.3	46.3	45.9	47.8	46.8
	(12.7)	(13.3)	(13.9)	(13.4)	(13.5)
% of parcels cultivated during the wet season	96.3	61.3	52.6	52.9	56.6
	(19.2)	(48.8)	(50.0)	(50.0)	(49.6)
% of parcels with tractor	0.0	27.6	30.1	30.8	28.6
	(0.0)	(44.8)	(46.0)	(46.2)	(45.2)
% of parcels with irrigation during the dry season	0.0	27.1	45.0	44.2	38.3
	(0.0)	(44.6)	(49.9)	(49.7)	(48.6)
% of parcels with own carabao	85.2	78.9	73.2	68.9	73.4
	(36.2)	(40.9)	(44.4)	(46.4)	(44.2)
% of parcels owned by the cultivator	88.9	64.3	82.3	51.9	65.1
	(32.0)	(48.0)	(38.3)	(50.0)	(47.7)
% of parcels from Marangas	0.0	63.8	52.6	50.0	52.6
	(0.0)	(48.2)	(50.0)	(50.0)	(50.0)
% of parcels hiring upland workers	29.6	42.2	35.9	58.0	46.6
	(46.5)	(49.5)	(48.0)	(49.4)	(49.9)
Number of observations	27	199	209	312	747

Note: Figures in parentheses are standard deviations.

3.4 Results

The maximum likelihood estimates for the parameters of the stochastic frontier and inefficiency model are presented in Table 3.4. Four different regression models for the production function are reported in the table. Model 1 is an Ordinary Least Squares (OLS) regression; Model 2 is a stochastic frontier with time varying technical inefficiency following the model developed by Battese and Coelli (1992); Model 3 is a stochastic frontier with time varying technical efficiency simultaneously estimated with inefficiency effects but without any explanatory variables in the inefficiency effects portion of the model; and Model 4 is the full model, a stochastic frontier regression with time varying technical inefficiency simultaneously estimated with inefficiency effects, this time including the complete set of *z*-regressors in the inefficiency model. Model 4 is considered the full model.

All point estimates for the four regression models exhibit the expected signs of the coefficients that are consistent with economic theory. All four models gave positive elasticities of the marginal products of labor, fertilizer and pesticides. The sum of these three estimates of elasticiticites represent the returns to scale (RTS) in yield where all the three models exhibit decreasing RTS. Model 1 gave the highest RTS at 0.89 followed by Model 2 at 0.76. RTS dramatically decreased when the inefficiency model is included. Models 3 and 4 have RTS of only 0.23 and 0.19, respectively. The statistical source of this dramatic decline in RTS is unclear.

Estimates for the variance parameter, γ, that captures the total effect of technical efficiency, in Models 3 and 4 are 0.995 and 0.998, respectively. These γ estimates are very close to 1 and both have very high t-statistics. This indicates that most of the total variation in output from the production frontier is attributable to technical efficiency. This makes the study of inefficiency highly relevant in the sample.

The coefficients of determination (adjusted R^2 and pseudo R^2) differ widely between different models.[11] Although Models 1, 2 and 3 have the same set of regressors, their respective coefficients of determination vary. Model 1 has the highest coefficient of determination (adjusted R^2) while Model 3 has the lowest. On the other hand, Model 4, which has the most regressors, gives the highest coefficient of determination among the four models. This also indicates that Model 4 provides the greatest explanatory power.

3.4.1 The Stochastic Frontier Model

Focusing on Model 4, the regression estimates of the elasticities of the marginal products of the three major factors of production (labor, fertilizer and pesticides) are all significantly different from zero at $\alpha = 0.10$. As mentioned above, these elasticities imply decreasing returns to scale. The magnitude of contribution of labor to yield (0.15) is the highest among the three factors. A 1% increase in the amount labor in will increase yield by 0.15%. This impact is at least five times greater than the yield contribution of fertilizer or pesticide. This economic analysis can be extended by computing the marginal value products for the wet and dry seasons. This information is presented in Tables 3.11 and 3.12. The last sections of these tables (labeled as "MVP2") present the

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[11] The *McFadden pseudo R^2* is the goodness of fit measure used for Models 2, 3 and 4. The formula used for computing this *pseudo R^2* include the estimated restricted ($\hat{L}_R$) and the estimated unrestricted ($\hat{L}_R$) log-likelihood values from the frontier regression written as: $McFadden\ \ pseudo\ \ R^2 = 1 - \dfrac{\ln(\hat{L}_U)}{\ln(\hat{L}_R)}$.

relative contributions of the three factors of production (computed as pesos of rice output per peso increase in the input of interest).

Results of the stochastic frontier model suggest higher yield during the wet season. Model 4 reveals a significantly positive coefficient for *season* which indicates that wet season yields, on average, are higher than dry season yields. This supports the idea that ample and evenly distributed rainfall during the wet season contributes to an increase in rice yields. The positive coefficient for *site* says that, on average, rice yield in Marangas is higher than in Tamlang.

Based on field observations and comments from several lowland farmers in the study sites, irrigation matters more during the dry season cropping since during the wet season, rainfall is usually sufficient to grow rice in both irrigated and non-irrigated parcels.[12] Thus we initially included in Model 4 the irrigation dummy variable, *irrig*, and we found that there is no significant difference in yield between irrigated and non-irrigated parcels. For this reason, the $irrdry_{it}$ variable (an indicator variable, $irrdry = 1$ if the parcel was cultivated as irrigated during the dry season) is used as an explanatory variable. It indicates that dry season yields are higher in irrigated plots compared to rainfed plots (significant at $\alpha = 0.10$). The relatively weak point estimate for *irrdry* might be due to yield variability of dry season cropping between years. For instance, in 1999, the sites were hit by the El Niño, thus planting during the dry season in that observed year resulted in low yields, even with irrigation, since the river that supplies water to the irrigation dam dried out. But in 1997, on average, an observed parcel during

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[12] The 30-year average monthly rainfall shows that, on average, 61% of amount of rainfall falls during the wet season cropping months (May to October) while only 39% of which falls during the dry months (November to April).

the dry season, controlling for other factors, will give a significantly higher yield if it is irrigated.

One of the most laborious tasks of rice production is land preparation. Typically, the draft power from farm animals (usually doing plowing tasks) and tractors (usually harrowing and cultivating tasks) are required for the operations. We attempt to ascertain the importance for a producer of owning a hand tractor and/or draft animal. The estimation results in Model 3 indicate that we reject the hypothesis that tractor owners have the same yield as those who do not own a tractor (at $\alpha = 0.05$). The significantly higher yield of tractor owners might be due to the fact that rice producers do not have equal access to tractor services. A producer who owns a tractor would be able to have a more systematic scheduling of tractor activities while the one who does not still needs to schedule his/her farm operations based on the availability of tractors for hire in the field. In contrast to tractor services, results indicate that lowland farmers appear to have a relatively more equal access to draft animal services as indicated by the $draft_{it}$ coefficient being not significantly different from zero. Draft animal services appear to be more readily available than tractor services since about 73% of the observations have a carabao compared with only 29% with a tractor.

The results for *tenure* in Model 4 indicate that, on average, the yield in rice parcels cultivated by tenants is not significantly different from parcels cultivated by their respective landowners. It appears here that land tenure security, in the short run, does not have any immediate direct impact on rice yield. However, the lack of statistical significance could be due to random error in the observation of the variable as opposed to a lack of economic effect.

The inefficiency frontier model in Equations 3.1 and 3.2 takes into account the effects of technical change and time-varying technical inefficiency. In the stochastic frontier equation (Equation 3.1), the indicator variables for year accounts for Hicks-neutral technological change while the year indicators in the inefficiency effects (Equation 3.2), indicates the change in inefficiency for the years 1997, 1999 and 2002, with 1995 as the base year. The distributional assumptions on the inefficiency effects make it possible to determine the effects of technical change and the time-varying pattern of inefficiency effects on top of those effects captured in the explanatory variables and the intercept parameters, β_0 and δ_0.

The stochastic frontier model provides strong point estimates for the indicator variables for 1997, 1999 and 2002. After controlling for the effects of the explanatory variables and the intercept parameter, $\beta_{0,}$ the negative coefficients of the three indicator variables indicate that rice yields in these years are significantly lower compared with the base year. This indicates that other factors not included in the model contributed to less favorable growing conditions in 1997, 1999 and 2002 compared with 1995.

3.4.2 The Inefficiency Model

The coefficient estimates for the inefficiency model suggest an interesting story of with regard to technical inefficiency in the sample. The coefficient for *educ* is positive and significant which indicates that farmers with more education tend to be less efficient farmers.[13] This result might seem counterintuitive to some readers. However,

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[13] Since we are dealing here with an inefficiency model, a negative coefficient in the model indicates an increase in efficiency.

conversations and casual observations at the study sites suggest that, in rice farming households, those with formal education tend to involve themselves in non-farm activities. This tends to make rice production a second priority in these households, thereby diminishing the quality of their farm management.

To further explore this conjecture, some simple extensions to the analysis are used. Pairwise correlation analysis indicates that the number of years in school is negatively associated with hiring of farm laborers. Given this scenario, we initially hypothesized that households with more years in school, who rely heavily on hired labor, are less efficient rice producers. To test this hypothesis, we added four new variables into the inefficiency model of Model 4. These variables are composed of the ratios of family, hired lowland, hired upland and shared labor to total amount of labor used in rice production. Results indicate that all these four labor sources, controlling for other factors, decrease technical inefficiency. Testing for the difference between labor source coefficient estimates, our t-test results indicate that we can reject the hypotheses that the coefficient for family labor ratio is the same as that of the coefficients for hired lowland and hired upland labor ratios. But we fail to reject the hypothesis that the coefficient for the family labor ratio is the same as coefficient for exchange labor ratio. The results indicate that hired labor (both from uplands and lowlands), is significantly more efficient than family labor. But, despite the fact that more educated lowland households use higher proportions of hired labor, they are still less efficient. A possible reason for their lower overall efficiency might be due to their overall poor management of the farm, considering that they give less priority to farm production and more priority to non-farm work.

An auxillary regression was also used in which the ratio of income from rice to total household income was included as regressor. Regression results show, controlling for other factors, farmers who have a higher proportion of their income coming from rice production, are more efficient. A side regression with the log of yield as the dependent variable and the rice income ratio as an explanatory variable indicates that, in the study sites, households who get a higher proportion of their income from rice production have significantly higher yields at $\alpha = 0.05$.

The coefficient for *wrkrs* in the inefficiency model is significant and negative. This might indicate that households with more farm workers are more technically efficient since they can supply more readily available family labor to rice production. The coefficient for *age* is positive but not statistically significant. The positive coefficient might imply that households headed by younger farmers, particularly those who are more physically capable of carrying out farming operations, could provide more family labor than older farmers. This pattern is consistent with Battese and Coelli's (1995) finding from rice producers in the Indian village of Aurepalle.

The point estimate for *fsize* is positive and significant at $\alpha = 0.01$. This indicates that smaller farms in the study sites tend to be more efficient, perhaps because it is easier to manage a small farm. The negative coefficients for *tractor* and *draft* indicate that owners of either of these farm assets tend to be more technically efficient. However, only the coefficient for *tractor* is significant at $\alpha = 0.10$. Thus, in statistical terms, tractor ownership is more important in increasing technical efficiency compared to carabao ownership.

Although *tenure* does not appear to have a strong association with yield, it has a negative relationship with inefficiency, significant at $\alpha = 0.01$. This indicates that a producer in the study sites who cultivates his own land tends to become more efficient than one who does not own the cultivated land (e.g., tenant, renter, sharecropper). This is similar to the finding of Ahmed et al. (2002).

In terms of the year indicator variables, with 1995 as the base year, we see that outcomes in 1997, 1999 and 2002 were more efficient in the study sites. However, it is interesting to note that 1997 was the only year that gave the most significantly negative coefficient (or the highest gain in efficiency). One might have expected that 1999 and 2002 should have had the highest gains in efficiency. This pattern in technical efficiency may reflect consequences of the climatic condition and the incidence of pests and diseases during the observed time period. In 1997, several farmers reported that they had favorable growing conditions with few pest and disease problems. However, in 1999 farmers reported that their low yields were due to drought and a high incidence of pests and diseases. 2002 is seen here as the year that might represent the average between 1997 and 1999.

These results highlight some of the major factors through which technical change might have influenced technical efficiency in a typical rice production parcel in the study sites. Important conditioning variables include land tenure, household labor supply, age, size of landholding, mechanization and human capital. Technical efficiency in rice production also seemed to have been lowered by unfavorable growing conditions in the sites.

Table 3.4 Maximum Likelihood Estimates of the Stochastic Production Frontier and the Technical Inefficiency Model

	Model 1		Model 2		Model 3		Model 4	
	Coeff	Std Error	Coeff	Std Error	Coeff	Std Error	Coeff	Std Error
Stochastic production frontier								
Production frontier constant	4.093***	0.392	5.265***	0.362	7.655***	0.172	7.583***	0.149
Log of labor (work-days)	0.625***	0.066	0.509***	0.061	0.178***	0.025	0.152***	0.026
Log of fertilizer (kg)	0.152***	0.036	0.146***	0.032	0.020	0.014	0.026*	0.015
Log of pesticide (pesos)	0.122***	0.026	0.100***	0.023	0.034***	0.009	0.018**	0.009
Season (1-wet, 0-dry)	0.311	0.200	0.349*	0.186	0.327***	0.085	0.298***	0.066
Site (1-Marangas, 0-Tamlang)	0.376***	0.096	0.373***	0.100	0.270***	0.043	0.287***	0.036
Irrdry (1-irrigated in dry season, 0-otherwise)	0.129	0.206	0.199	0.184	0.139	0.090	0.132*	0.069
Tractor (1-with tractor, 0-otherwise)	0.102	0.097	0.049	0.096	0.111**	0.044	0.044	0.035
Carabao (1-own carabao/s, 0-otherwise)	0.130	0.098	0.121	0.091	0.026	0.045	0.055	0.041
Tenurial status (1-landowner, 0-otherwise)	0.118	0.097	0.124	0.090	-0.058	0.045	-0.039	0.036
Indicator for 1997	-0.531***	0.264	-0.335	0.230	-0.322***	0.115	-0.368***	0.088
Indicator for 1999	-0.925***	0.265	-0.771***	0.230	-0.395***	0.122	-0.309***	0.097
Indicator for 2002	-1.101***	0.266	-0.800***	0.234	-0.516***	0.124	-0.382***	0.093
Technical inefficiency model								
Inefficiency constant							-14.294***	2.135
Education (years in school)							0.162**	0.079
Number of farm workers							-0.348**	0.144
Age (years)							0.033	0.021
Farmsize (ha)							0.566***	0.109
Tractor (1-with tractor, 0-otherwise)							-1.147*	0.645
Carabao (1-own carabao/s, 0-otherwise)							-0.765	0.899
Tenurial status (1-owner, 0-otherwise)							-2.153***	0.677
Indicator for 1997							-15.848***	0.994
Indicator for 1999							-1.681*	0.968
Indicator for 2002							-3.024***	0.970
Sigma-squared	1.353		2.194***	0.180	2.433***	0.134	14.374***	1.650
Gamma			0.626***	0.039	0.995***	0.002	0.998***	0.000
LR test of the one-sided error			70.87		522.79		1016.75	
Log-likelihood function	-1166.273		-1130.836		-904.875		-657.897	
Adjusted R^2 / McFadden Pseudo R^2	0.244		0.076		0.060		0.316	
Returns to scale	0.898		0.756		0.233		0.196	

Note: *** - significant at $\alpha = 0.01$; ** - significant at $\alpha = 0.05$; * - significant at $\alpha = 0.10$

3.4.3 Generalized Likelihood Ratio Test

To test a hypothesis of no inefficiency effects and/or simpler distributions, generalized likelihood-ratio tests were conducted for Model 4.[14] Results of the tests in Table 3.5 provide very strong evidence of rejecting the three null hypotheses at α = 0.05. The first null hypothesis, $H_{01,}$ states that inefficiency effects are absent from the model. The second null hypothesis, H_{02}, says that randomness or stochasticity is absent in the inefficiency effects. H_{03} implies that the socioeconomic characteristics of parcel cultivators are jointly not significant.

Table 3.5 Hypotheses Tests for Parameters of the Inefficiency Model

Hypothesis	Log-likelihood	$\chi^2_{0.95} - value$	LR test statistic
H_{01}: $\gamma = \delta_0 = \delta_2 = \ldots = \delta_{12} = 0$	-904.875	18.307	494.522*
H_{02}: $\gamma = 0$	-700.506	14.067	85.783*
H_{03}: $\delta_1 = \delta_2 = \ldots = \delta_{12} = 0$	-683.294	14.067	51.359*

Note: * indicates that the test statistic exceeds the critical value for the chi-square test at α = 0.05, thus the null hypothesis is rejected.

The calculated likelihood ratio (LR) test statistic for H_{01} very much exceeds the critical chi-square value at α = 0.05. This indicates the presence of a strong inefficiency effect in the sample. The second LR test provides strong evidence to reject H_{02}, which implies that that inefficiency effects in the stochastic frontier are related to the socioeconomic characteristics of the respondents and to the year when the particular outcome was observed. There is also strong evidence to reject H_{03}. This suggests that the regressors in the inefficiency model are jointly significant despite the insignificance of some individual regressors.

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[14] The formula used for the likelihood ratio test statistic is LR = –2 (log-likelihood restricted – log-likelihood unrestricted) which is distributed chi-squared, with degrees of freedom equal to the number of restrictions imposed.

Given the results in Table 3.5, one concludes that the inefficiency effects in the stochastic frontier are stochastic and are related to the socioeconomic characteristics of rice cultivators. These findings extend the stochastic frontier model developed by Shively and Zelek (2003) which did not include the analysis of inefficiency effects.

3.4.4 Analysis on the Predicted Technical Efficiency Ratings

Using results from the stochastic frontier and inefficiency model, scalar efficiency ratings were derived for each observation. These ratings, which represent how the observed outcome fared compared to the best practice technique, are summarized in Table 3.6. Efficiency ratings vary widely, ranging from 0.0% to 95.7%. The 1997 sample had the narrowest range from 22.4% to 95.6%. The highest efficiency score was attained in 2002. The average efficiency rating for each year ranges from 51.0% in 1995 to 70.3% in 1997. These average efficiency ratings fall within the range for the Philippines (50% to 89%) presented in the meta-analysis conducted by Thiam, Bravo-Ureta and Rivas (2001).

The coefficients of skewness indicate that 1997 and 2002 samples are significantly negative skewed. The negative skewness of technical efficiency ratings implies that only a small fraction of the parcels are lagging behind. With regards to kurtosis, the year 1999 has a significantly platykurtic distribution while the rest of the years have mild and insignificant amounts of kurtosis. This implies that the distribution of the technical efficiency ratings in 1999 is flatter than normal.

The distribution of the efficiency ratings may not be considered normal because they were predicted using a model that utilized a conditional expectation which thus give an unknown distribution. For this reason, two approaches can be used to determine if the predicted efficiency ratings are statistically different between years. These are the unpaired t-test and the Mann-Whitney two-independent-samples test.

Table 3.6 Summary of the Predicted Technical Efficiency Scores

Mean and Range	1995	1997	1999	2002	All
Mean	0.510	0.709	0.538	0.591	0.605
Standard deviation	0.244	0.171	0.246	0.241	0.235
Minimum	0.000	0.224	0.000	0.000	0.000
Maximum	0.914	0.956	0.944	0.957	0.957
Kurtosis	0.022	-0.770	-0.112	-0.771	-0.637
Coefficient of skewness	2.210	2.815	1.989	2.881	2.614
N	27	199	209	312	747

Note: Figures in parentheses are standard errors.

The results of the t-test indicate that the efficiency ratings in the 1997 sample were significantly higher than the samples in 1995, 1999 and 2002 at α = 0.01 (Table 3.7). This result is consistent with the average yields where the yields in the 1997 sample are significantly higher than the other years (Table 3.8).

The average efficiency level in 1999 is significantly lower than that in 2002 at α = 0.01, but is not significantly different than 1995 at any conventional level (Table 3.7). This might indicate that, although irrigation development helps to increase technical efficiency, the occurrence of a climatic shock in 1999 (i.e., El Niño) brought efficiency back down to the "no irrigation" level. This shock might also explain why the efficiency level in 1999 is significantly lower than in 2002.

The mean difference in technical efficiency between 2002 and 1995 is 7.2 percentage points, a difference that is statistically significant at α = 0.10. The pair with the largest mean difference is 1997-1995 with 18.5 percentage points (statistically significant at $\alpha = 0.01$). The mean differences between the years with irrigation (except 1999) and the year with no irrigation are significantly positive. This implies that the levels of technical efficiency in all the years with irrigation are higher compared to the year with no irrigation.

Table 3.7 Technical Efficiency Statistics from Two-Tailed Unpaired T-Test Between Years.

Statistic	1997-1995	1999-1995	2002-1995	1999-1997	2002-1997	2002-1999
Mean difference	0.199	0.028	0.081	-0.171	-0.117	0.053
Standard Error	0.037	0.050	0.048	0.021	0.020	0.022
Lower limit	0.126	-0.071	-0.014	-0.212	-0.156	0.011
Upper limit	0.272	0.127	0.177	-0.129	-0.079	0.096
T-statistic	5.365	0.557	1.686	-8.097	-5.978	2.461
p-value	0.000	0.578	0.093	0.000	0.000	0.014

Note: H_0: mean difference is $TE_{Y1} = TE_{Y0}$, two-tailed at $\alpha = 0.05$

Table 3.8 Rice Yield (kg/ha) Statistics from Two-Tailed Unpaired T-Test Between Years

Statistic	1997-1995	1999-1995	2002-1995	1999-1997	2002-1997	2002-1999
Mean difference	790	-28	314	-817	-476	341
Standard Error	245	279	311	126	129	133
Lower limit	307	-578	-297	-1064	-729	81
Upper limit	1273	523	925	-570	-223	602
T-statistic	3.222	-0.098	1.012	-6.505	-3.698	2.577
p-value	0.002	0.922	0.312	0.000	0.000	0.010

Note: H_0: mean difference is $Y_{Y1} = Y_{Y0}$, two-tailed at $\alpha = 0.05$

The Mann-Whitney test was also used to compare the predicted technical efficiency rating in different years with different number of observations. At $\alpha = 0.05$, the non-parametric test results indicate that the efficiency levels between 1995 and 1997, 1997 and 1999, 1997 and 2002, and 1999 and 2002 are significantly different from each other (Table 3.9). Only for the pairs of years 1995 and 1999, and 1995 and 2002 do we fail to reject the null hypothesis that the medians are equal. In general, the unpaired t-test and the Mann-Whitney test gave similar results. This might suggest that the general distribution of the technical efficiency ratings is not far from normal.

Table 3.9 Mann-Whitney Two-Independent-Samples Test of the Predicted Technical Efficiency Ratings Between Years

Statistic	1995-1997	1995-1999	1995-2002	1997-1999	1997-2002	1999-2002
z-statistic	3.508	1.61	1.706	-6.685	-4.887	2.894
P-value	0.001	0.108	0.088	0.000	0.000	0.004

Note: H_0: median of year_1 = median of year_0, two-tailed at $\alpha = 0.05$

To illustrate the distributions of the predicted technical efficiency ratings on a yearly basis, they are aggregated into histograms in Figures 3.1 to 3.4. The probability distribution histogram for the efficiency ratings of the 1995 sample, have a mode of 55% and appears to include observations with extremely low and extremely high efficiency ratings (as indicated by the fat tails on both right and left sides). The 1995 sample has the fattest tails among the four years.

The probability histogram for the 1997 sample, which has the highest efficiency mode of 90%, appears skewed left indicating a concentration of cropping activities on the higher efficiency side. The 1997 sample also has the highest minimum (20.2%) and maximum (95.8%) predicted efficiency ratings among the four samples.

The 1999 and 2002 samples appear to have more variable technical efficiency scores compared with previous years. Despite their similarities in having more uniformly distributed efficiency levels, the two graphs support the unpaired t-test that 2002 is significantly more efficient since it can be seen from Figures 3.3 and 3.4 that the distribution for the 2002 sample is more concentrated on the higher efficiency side (0.55

to 1.00) as compared to the 1999 sample which is more concentrated on the lower efficiency side (0.05 to 0.50).

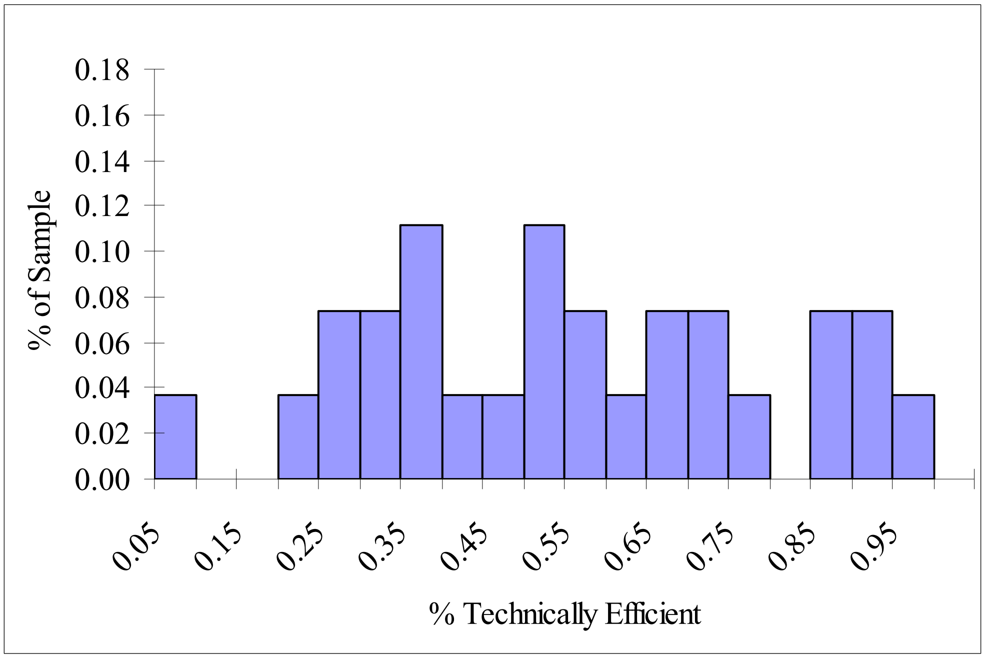

Figure 3.1 Probability Histogram of the Predicted Technical Efficiency Ratings for 1995 (n=27)

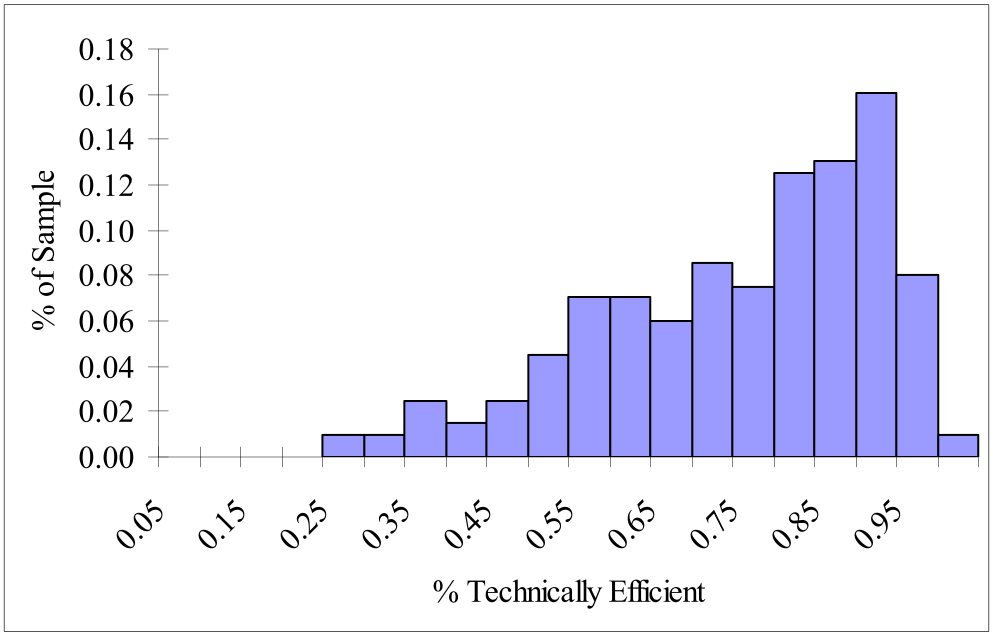

Figure 3.2 Probability Histogram of the Predicted Technical Efficiency Ratings for 1997 (n=199)

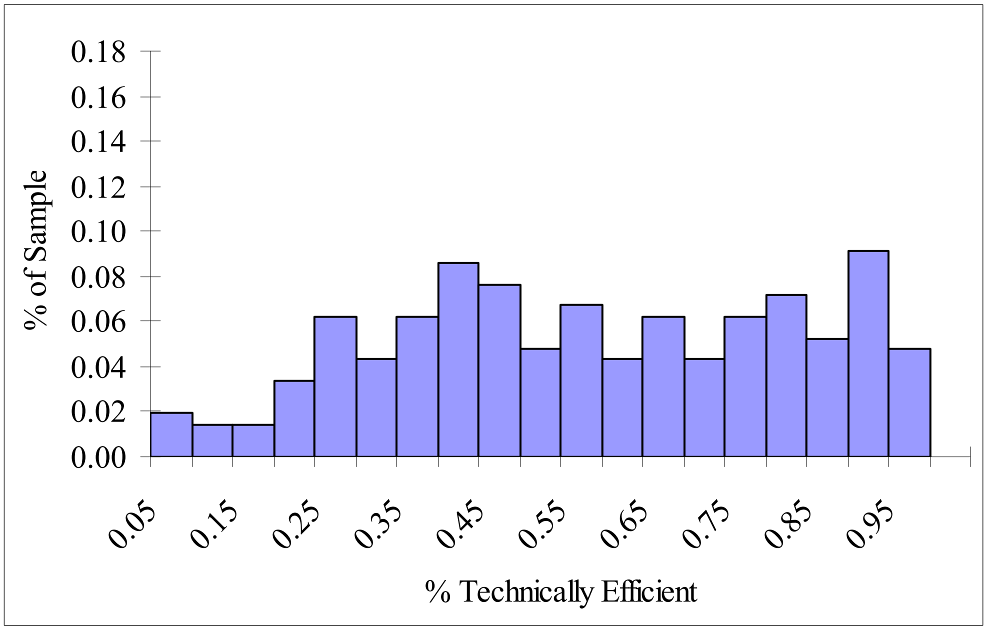

Figure 3.3 Probability Histogram of the Predicted Technical Efficiency Ratings for 1999 (n=209).

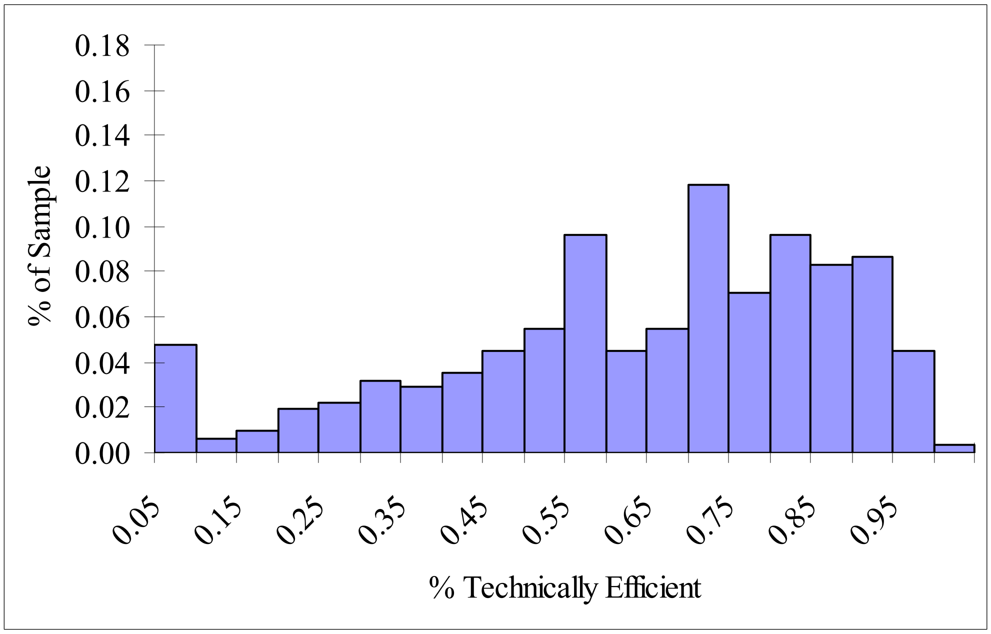

Figure 3.4 Probability Histogram of the Predicted Technical Efficiency Ratings for 2002 (n=312).

3.4.4 Expected Profit Model and MVPs

The previous section examined technical efficiency by comparing observed output levels with the output levels of the best practice technique. In this section, we use the coefficient estimates of the production inputs of the stochastic production frontier model to estimate the profit maximizing input levels and the marginal value products. This expected profit model provides insights into how well the observed cropping activities faired as compared to the expected maximum profit levels. The computed marginal value products also aid in the assessment of the individual contributions of inputs to yield and profit.

3.4.4.1 Expected Profit Model Results

The expected profit model estimates the profit maximizing input levels, yield, and the maximum attainable profit for every observed cropping season. Table 3.10 reports the data that were used as input to the model. The rice prices listed in Table 3.10 are the observed average prices of paddy rice at the local level, as prices were not observed at the household level. These prices serve in place of individuals' price expectations for rice, since the actual price of rice at harvest time is unknown at the time of rice planting and farmers' expected prices were not recorded in the survey. In contrast, the prices of inputs (wage, fertilizer and pesticide) reported in Table 3.10 were computed by averaging across all reported prices in the lowland panel.

While the nominal prices of rice and labor have steadily increased over the years, prices of fertilizer and pesticides have fluctuated. The latter case can be attributed to the emergence of cheaper fertilizer products in 1999 and the introduction of cheaper pesticide products in the market in 2002.

The expected profit maximization problem was solved by substituting Equation 3.8 into Equation 3.6. Solving this maximization problem gave three straightforward factor demand equations derived from Equation (3.7). These factor demand equations, which must be solved simultaneously, are equations (3.9), (3.10) and (3.11).

Table 3.10 Average Prices of Rice and Variable Inputs

Item	Symbol	1995	1997	1999	2002
Rice (Pesos/kg)	p	6.5	7.0	7.5	8.0
Wage (Pesos/work-day)	r_L	49.95 (14.79)	97.12 (24.16)	104.75 (23.74)	162.42 (59.62)
Fertilizer (Pesos/kg)	r_F	5.24 (1.45)	7.98 (2.12)	7.77 (1.38)	9.93 (0.54)
Pesticide (Pesos/ha)	r_P	284 (400)	1392 (931)	1549 (1188)	1273 (1176)
N		27	199	209	312

Note: Figures in parentheses are standard deviations.

$$L^* = \left[r_L \left(pe^{\alpha} \beta_L \right)^{-1} \left(\frac{\beta_P r_L}{\beta_L r_P} \right)^{-\beta_P} \left(\frac{\beta_F r_L}{\beta_L r_F} \right)^{-\beta_F} \right]^{\frac{1}{\beta_L + \beta_F + \beta_P - 1}} \tag{3.9}$$

$$F^* = \frac{\beta_F r_L}{\beta_L r_F} \left[r_L \left(pe^{\alpha} \beta_L \right)^{-1} \left(\frac{\beta_P r_L}{\beta_L r_P} \right)^{-\beta_P} \left(\frac{\beta_F r_L}{\beta_L r_F} \right)^{-\beta_F} \right]^{\frac{1}{\beta_L + \beta_F + \beta_P - 1}} \tag{3.10}$$

$$P^* = \frac{\beta_P r_L}{\beta_L r_P} \left[r_L \left(pe^{\alpha} \beta_L \right)^{-1} \left(\frac{\beta_P r_L}{\beta_L r_P} \right)^{-\beta_P} \left(\frac{\beta_F r_L}{\beta_L r_F} \right)^{-\beta_F} \right]^{\frac{1}{\beta_L + \beta_F + \beta_P - 1}} \tag{3.11}$$

Elasticity estimates (β_j) for the marginal products of labor, fertilizer and pesticides from the stochastic frontier model were plugged into the expected profit function to estimate the profit maximizing input levels of labor (L^*), fertilizer (F^*) and pesticides (P^*) per ha of land. These estimates have been graphed along with the observed average levels of input use. The graphs reveal interesting patterns of input use as the sites transformed from non-irrigated in 1995 to the years 1999 and 2002 with fully operational irrigation facilities. However, despite the full operation of irrigation facilities, a certain percentage of the observed parcels remained under rainfed condition. Thus, even in 1999 and 2002, we can still see in Figures 3.5 to 3.9 the profit maximizing and observed input levels for a small group of rainfed parcels.

Figure 3.5 graphs observed labor use and the computed expected profit maximizing level of labor.[15] The pattern suggests that, before irrigation, the profit maximizing level of labor for rainfed production in the wet season was higher than that for irrigated production. This pattern is consistent with Coxhead and Jayasuriya (1986), who argue that new farming practices brought about by irrigation development (such as mechanization and use of herbicides) tend to decrease labor use. The desired labor input level decreased in the early years of irrigation and further declined in the later years.

In contrast to the profit maximizing rates of labor use, observed labor use exhibits an opposite pattern. In 1995, the observed labor usage of 20 workdays/ha is extremely low compared to the profit maximizing level of 67 workdays/ha. In 1997, with 57% of the observed parcels irrigated, the average level of labor in the sample significantly increased vis-à-vis 1995 levels and came closer to converging with the profit maximizing amount of labor. Also, in 1997, the observed labor allocation converged with the desired

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[15] The *expected profit maximizing level* is also referred to in this section as the *profit maximizing level* or the *desired level*.

level during the dry season cropping on irrigated parcels. However, the observed labor use on rainfed parcels, and on irrigated parcels in the wet season, were higher than the expected profit maximizing level.

By 1999, 93% of the observed parcels were irrigated. During this year, the actual amount of labor used for all cropping seasons (for both irrigated and rainfed parcels) is nearer to the profit maximizing levels than in 1997. Wet and dry season croppings on irrigated parcels have labor levels slightly higher than the respective profit maximizing levels. For rainfed parcels, we observed labor levels slightly higher than the desired levels in both wet and dry seasons.

In the 2002 sample, 93% of the observed parcels were irrigated. In this year, it appears that the observed amount of labor (for both irrigated and rainfed parcels for both wet and dry cropping seasons) appears to be much higher than the profit maximizing level. The increasing trend in actual labor use stands in contrast to the downward trend for the profit maximizing level of labor.

With regard to fertilizer use, our data indicate that in 1995, 1997 and 1999, farmers in the sample were applying fertilizers above the profit maximizing levels (see Figure 3.6). This trend changed in 2002 when the desired fertilizer level slightly increased while actual fertilizer application level decreased. Parcels which operated under rainfed conditions show the closest correspondence between observed and desired levels of fertilizer. Irrigated parcels received fertilizer at slightly more than the desired level.

The author’s long-term experience at the study sites provides insights into input use. For example, we know that farmers spray pesticides to their rice plots almost every week during the vegetative growing stage. Observation suggests farmers were spending far too much working capital on pesticide application, often in the absence of reliable pest management information. This notion is supported by results in Figure 3.7, which illustrates that, for all the observed cropping seasons for all years, farmers were applying pesticides far above the expected profit maximizing level. This result is consistent with Zilberman and Castillo (1994) who argue that rice farmers in the Philippines apply pesticides even when total costs exceeds total benefits, thus indicating pesticide overuse. The observed over-application of pesticides in the study sites is also consistent with Rola and Pingali (2002) who argue that indiscriminate use of pesticides has the tendency to produce larger pest-related yield losses since applying pesticides routinely disrupts the pest-predator balance.

The case of over application of pesticides in the site also accords with the work of Carlson (1979) who points out that the farmer's problem of imperfect information regarding the number and types of pests leads him to apply pesticides and other controls to maximize long-run expected income. Given this scenario, farmers spend a relatively large amount of money as a form of insurance in the hope of reducing the variability of rice yields.

Figure 3.8 is a graph of profit maximizing yields across all croppings and years. The desired rice yields appear virtually steady, varying between 3.5 and 4.5 tons/ha. In contrast, observed yields vary between 1.0 and 4.5 tons/ha. The highest yields were observed in 1997. 1999 appears as the worst production year, with observed yields falling below profit-maximizing levels, particularly the wet cropping season on rainfed plots, which registered about 70% lower than profit-maximizing yield. 2002 was an average production year. Wet season yields reached the desired level, despite the fact that dry season croppings were about 50% below the desired level.

In contrast to the expected profit maximizing yield levels (which seem relatively stable over time), the maximum attainable profit appears to have been increasing over time (see Figure 3.9). This is reflective of the rising price of output through time. The price of paddy rice started at P5.50/kg in 1995 and increased to P8.00 in 2002. However, despite the steadily rising desired profit levels, observed profits have fallen short in most cropping periods. Figure 3.9 shows that, during the years 1997 and 2002, observed profits were higher during the wet season than during the dry season. It is also interesting to note that the difference between the observed profit level on irrigated and rainfed plots was virtually the same across years. Consistent with the regression analysis, the graph shows that irrigation is not that important during the wet season but is extremely important during the dry season. During the dry season, the observed profits for irrigated parcels were higher than those for rainfed parcels. This was particularly true during the dry season of 1999, when profits on irrigated parcels were 55% higher than those on rainfed parcels.

3.4.4.2 Marginal Value Products

The contributions of the factors of production to rice yield are represented by the marginal value products shown in Tables 3.11 (wet season) and 3.12 (dry season). We initially calculate the geometric means (GMs), marginal physical products (MPPs) and nominal marginal value products (MVPs) for the wet and dry seasons, respectively. To calculate the MPPs, the estimated coefficients for labor, fertilizer and pesticide inputs from Model 4 were used. The MPPs were used to calculate the MVPs. Two kinds of MVPs were computed for this exercise. These are labeled MVP1 and MVP2 in the tables. Both MVPs explain the additional peso value of rice generated by an additional unit of labor or fertilizer. For the pesticide input, MVP1 measures the additional peso of rice contributed by an additional peso expenditure on pesticide. MVP1 provides marginal values with different units of measurement of inputs: pesos of rice per workday of labor; pesos of rice per kilogram of fertilizer; and pesos of rice per peso of pesticide. The difference in measurement units makes it difficult to directly compare the marginal contributions of each input to the total value product. For this reason, MVP2 is presented to provide a method for directly comparing the marginal contributions of inputs. MVP2 units are: pesos of rice per peso of labor; pesos of rice per peso of fertilizer; and pesos of rice per peso of pesticide. Note that the unit of measurement for pesticide in MVP1 is the same as in MVP2.

The computed values for MVP2 show that, during the wet season, the marginal contribution of a peso spent on labor or fertilizer was higher on irrigated plots than on rainfed plots in 1997 and 1999 (Table 3.11). However, this pattern changed in 2002 when rainfed parcels produced higher MVP2s. For pesticides, the MVP2s on rainfed parcels were higher than on irrigated parcels in 1997, 1999 and 2002.

The MVP2s for the dry season suggest that irrigation promotes a higher return on every peso spent on labor as show by the higher MVP2s in irrigated plots for all the observed years. The contribution of the applied fertilizer was also higher on irrigated parcels in 1997 and 1999 but not in 2002. The return to peso spent on pesticides was higher on irrigated parcels in 1997. This changed in 1999 and 2002, when the return was slightly lower on irrigated plots.

3.5 Summary and Conclusions

This chapter examined productive efficiency in the study sites using a stochastic production and inefficiency model in conjunction with the expected profit model. Results from the stochastic production frontier regression indicate that rice yield is most responsive to additional labor input as exhibited by the higher coefficient estimate for labor compared with the coefficients for fertilizer and pesticides. However, looking at the marginal value products (peso of output per peso of input) in different survey years, this conjecture holds true in 1997 and 1999 only. In 2002, the yield response from labor turned out to be higher, in value terms, for fertilizer and pesticide. The lower yield response from labor in 2002 might be attributed to the allocation of labor above the expected profit maximizing level in that year, as illustrated in the graphs of the results of the expected profit model. It appears from the results that, in 2002, the turn-around to relatively higher marginal value products of fertilizer and pesticides might be attributed to allocation levels of these inputs relatively closer to the expected profit maximizing levels, while the observed amount of labor was even farther above profit maximizing level compared to the other two inputs. This scenario was the opposite of that in 1997 and 1999 where the amounts labor used were relatively closer to the profit maximizing level compared to those of fertilizer and pesticide. Thus, it is important for lowland rice farmers to have a working knowledge of the profit maximizing levels of inputs in order to have a more efficient use of inputs. This will help them to increase yields as well as somehow reduce over application (or under application) of essential production inputs. However, it is also important to note that the deviations of the observed from the profit maximizing level might have been affected by other factors that were not included in the stochastic production frontier and expected profit models.

Stochastic frontier regression results have shown that the technical efficiencies in rice production vary over time. This is also illustrated by different average and median efficiency ratings in four different rounds of the survey.[16] Results from the efficiency model indicate that higher efficiency levels were attained in the years following irrigation development. Although the level of efficiency in 1999 was adversely affected by an unfavorable climatic condition (i.e., El Niño), wherein the level of technical efficiency was pulled back to a level associated with rainfed conditions in 1995, the average technical efficiency ratings did not fall below the 1995 level. Thus, irrigation development seems to have contributed to an increase in technical efficiency on lowland irrigated farms. One might even speculate that, based on these results, irrigation probably helped to mitigate the adverse effects of an El Niño climatic disturbance (i.e., low rainfall and prolonged drought).

Based on the estimates of the inefficiency model, in which the technical inefficiency term, U_{it}, was decomposed into a set of socio-economic variables, we have seen some of the major factors through which technical change might have influenced technical efficiency in a typical rice production parcel in the study sites. The variables

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[16] For this reason, it is important to study agricultural production efficiency (via a stochastic frontier) using time varying efficiency.

that might have led to higher technical efficiency are land tenure, household labor supply, and mechanization. Those that might have contributed to lower technical efficiency are human capital (years in school of household head), age, and size of landholding. It is surprising to see that more educated farmers are less technically efficient. (But, perhaps this is because they prioritized non-farm work opportunities than on-farm work.) This is opposite to the findings of Battese and Coelli (1995) which shows that rice farmers in an Indian village who attended more years of schooling were technically efficient. However, non-farm employment opportunities might have differed between these two settings.

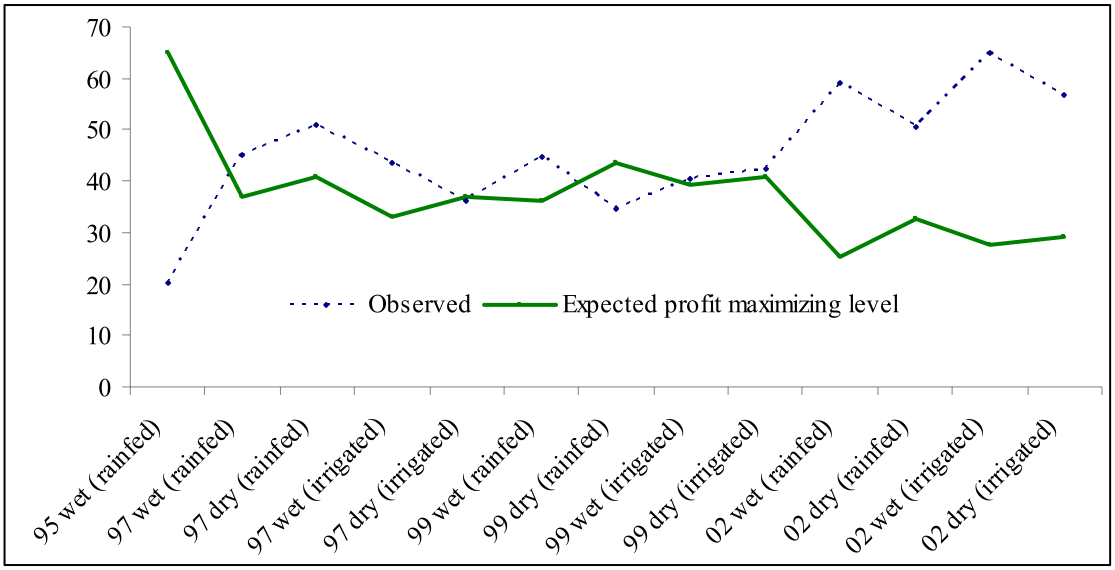

Figure 3.5 Observed vs. Expected Profit Maximizing Amount of Labor (workdays/ha/season)

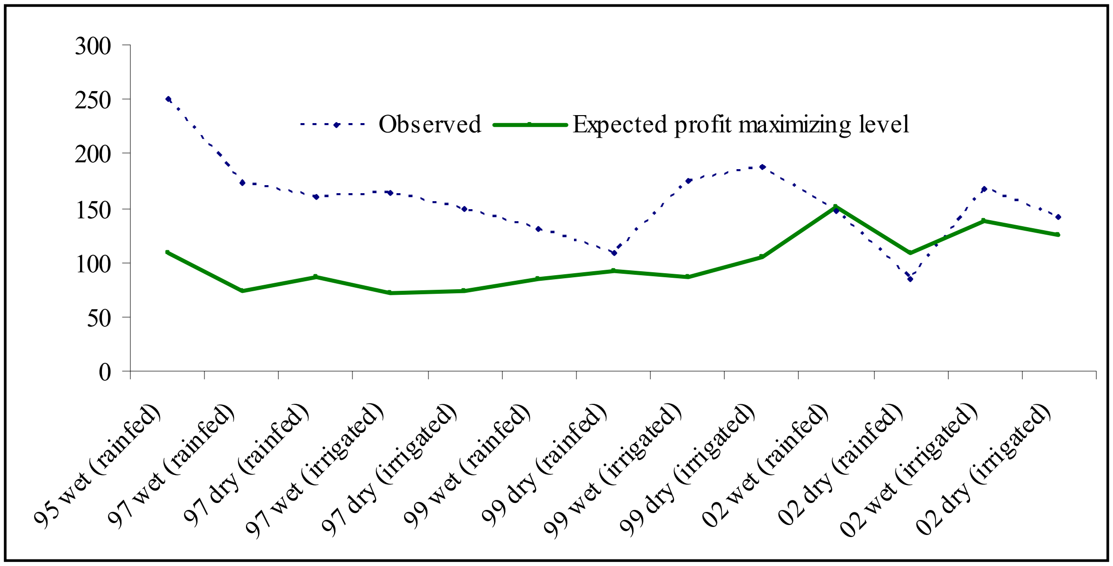

Figure 3.6 Observed vs. Expected Profit Maximizing Amount of Fertilizer (kg/ha/season)

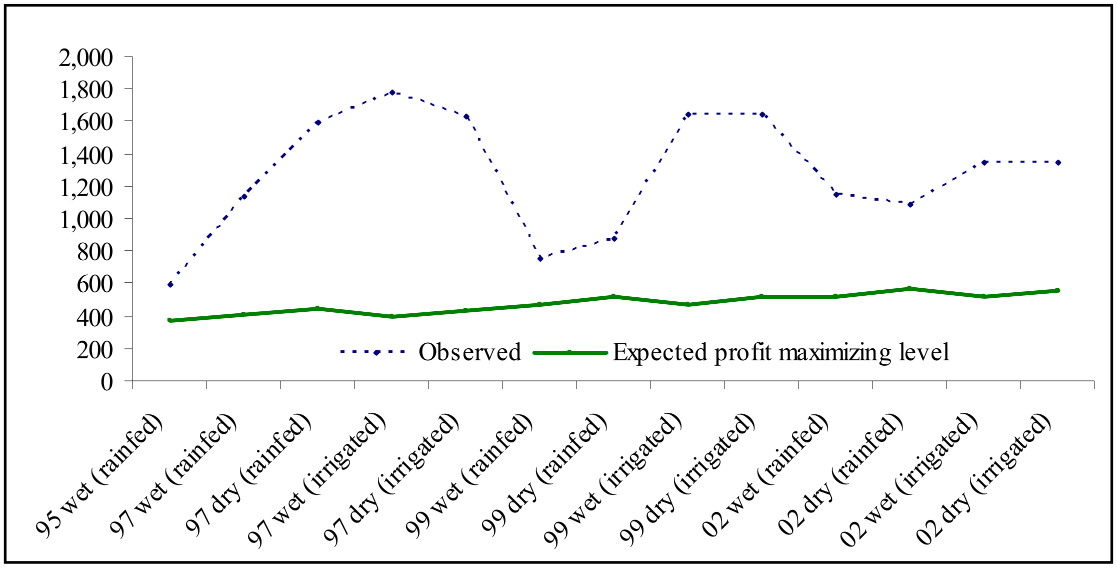

Figure 3.7 Observed vs. Expected Profit Maximizing Amount of Pesticides (pesos/ha/season)

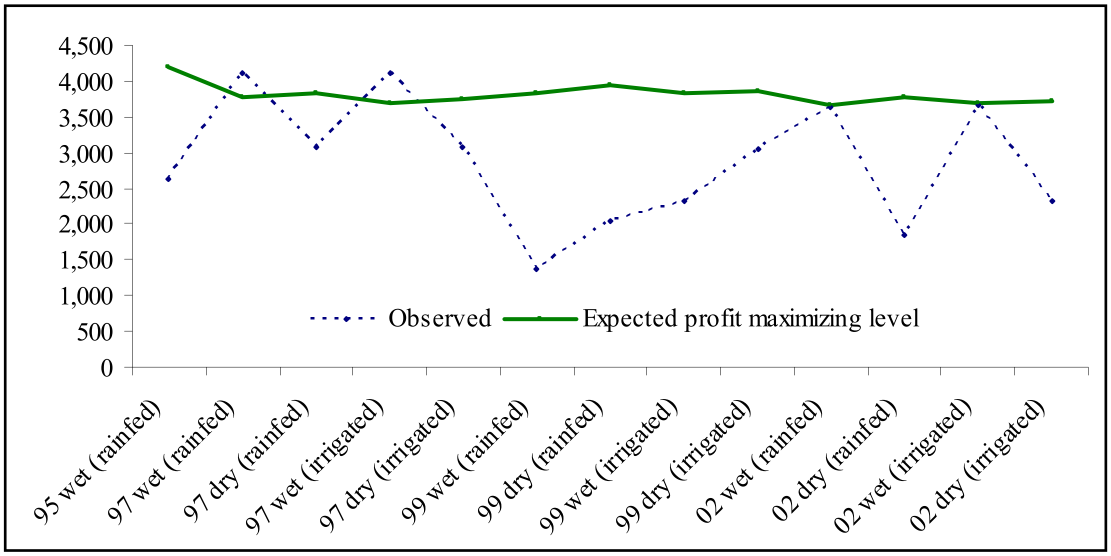

Figure 3.8 Observed vs. Expected Profit Maximizing Rice Yield (kg/ha/season)

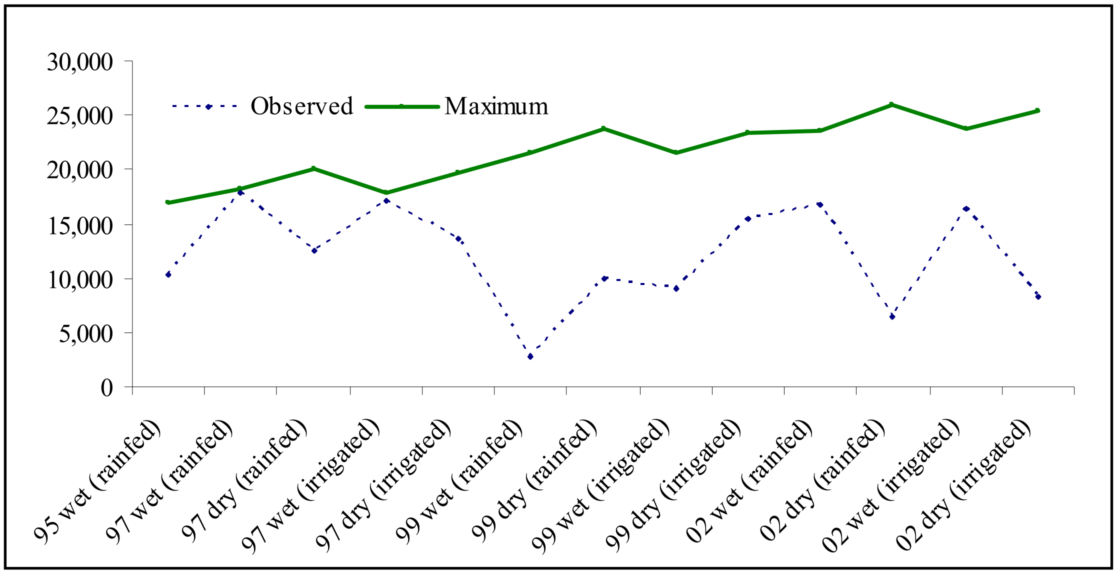

Figure 3.9 Observed vs. Expected Maximum Profit (pesos/ha/season)

Table 3.11 Wet Season Geometric Means, Marginal Physical Product and Nominal Marginal Value Products.

Item	Yield		Labor		Fertilizer		Pesticide	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Geometric Mean	(kg/ha)	(kg/ha)	(workdays/ha)	(workdays/ha)	(kg/ha)	(kg/ha)	(pesos/ha)	(pesos/ha)
1995	n/a	2,323	n/a	17.1	n/a	226	n/a	440
1997	3,966	3,065	38.2	40.8	148	153	1,592	848
1999	2,056	1,286	33.7	35.5	149	118	1,287	660
2002	3,324	3,342	60.6	49.3	155	127	1,006	708
Marginal Physical Product (MPP)			(kg of rice/ workday)	(kg of rice/ workday)	(kg of rice/kg of fertilizer)	(kg of rice/kg of fertilizer)	(kg of rice/ peso of pesticide)	(kg of rice/ peso of pesticide)
1995	--	--	n/a	20.6	n/a	0.27	n/a	0.09
1997	--	--	15.8	11.4	0.71	0.53	0.04	0.06
1999	--	--	9.3	5.5	0.36	0.29	0.03	0.03
2002	--	--	8.3	10.3	0.57	0.69	0.06	0.08
Marginal Value Product 1 (MVP1)			(pesos of rice/ /workday)	(pesos of rice/ workday)	(pesos of rice/ kg of fertilizer)	(pesos of rice/ kg of fertilizer)	(pesos of rice/ peso of pesticide)	(pesos of rice/ peso of pesticide)
1995	--	--	n/a	134.14	n/a	1.76	n/a	0.60
1997	--	--	110.40	79.88	4.95	3.70	0.31	0.45
1999	--	--	69.51	41.27	2.73	2.16	0.21	0.26
2002	--	--	66.66	82.38	4.53	5.56	0.47	0.66
Marginal Value Product 2 (MVP2)			(pesos of rice/ peso of labor)	(pesos of rice/ peso of labor)	(pesos of rice/ peso of fertilizer)	(pesos of rice/ peso of fertilizer)	(pesos of rice/ peso of pesticide)	(pesos of rice/ peso of pesticide)
1995	--	--	n/a	2.69	n/a	0.34	n/a	0.63
1997	--	--	1.1	0.82	0.62	0.46	0.31	0.45
1999	--	--	0.7	0.39	0.35	0.28	0.21	0.26
2002	--	--	0.4	0.51	0.46	0.56	0.47	0.66

Notes:

1. Geometric Mean (GM) was calculated using the formula: $GeoMean = G(a_1,....,a_n) \equiv \left(\prod_{i=1}^{n} a_i\right)^{\frac{1}{n}}$
2. The labor unit "workdays/ha" is number of workdays per ha per season. A workday could be a man-day, a man-animal-day or a man-machine-day. (*Note "3." is continued on the next page at the bottom of Table 3.12)*

Table 3.12 Dry Season Geometric Means, Marginal Physical Product and Nominal Marginal Value Products.

Item	Yield		Labor		Fertilizer		Pesticide	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Geometric Mean	(kg/ha)	(kg/ha)	(workdays/ha)	(workdays/ha)	(kg/ha)	(kg/ha)	(pesos/ha)	(pesos/ha)
1995	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1997	2,905	2,241	31.8	44.4	140	147	1,432	1,368
1999	2,622	1,315	36.6	26.6	151	94	1,214	570
2002	1,945	1,725	49.8	46.7	115	70	980	781
Marginal Physical Product (MPP)			(kg of rice/ workday)	(kg of rice/ workday)	(kg of rice/kg of fertilizer)	(kg of rice/kg of fertilizer)	(kg of rice/ peso of pesticide)	(kg of rice/ peso of pesticide)
1995	--	--	n/a	n/a	n/a	n/a	n/a	n/a
1997	--	--	13.9	7.7	0.55	0.40	0.04	0.03
1999	--	--	10.9	7.5	0.46	0.37	0.04	0.04
2002	--	--	5.9	5.6	0.45	0.65	0.03	0.04
Marginal Value Product 1 (MVP1)			(pesos of rice/ /workday)	(pesos of rice/ workday)	(pesos of rice/ kg of fertilizer)	(pesos of rice/ kg of fertilizer)	(pesos of rice/ peso of pesticide)	(pesos of rice/ peso of pesticide)
1995	--	--	n/a	n/a	n/a	n/a	n/a	n/a
1997	--	--	97.14	53.67	3.84	2.82	0.25	0.20
1999	--	--	81.62	56.32	3.44	2.77	0.29	0.30
2002	--	--	47.46	44.89	3.57	5.21	0.28	0.31
Marginal Value Product 2 (MVP2)			(pesos of rice/ peso of labor)	(pesos of rice/ peso of labor)	(pesos of rice/ peso of fertilizer)	(pesos of rice/ peso of fertilizer)	(pesos of rice/ peso of pesticide)	(pesos of rice/ peso of pesticide)
1995	--	--	n/a	n/a	n/a	n/a	n/a	n/a
1997	--	--	1.00	0.55	0.48	0.35	0.25	0.20
1999	--	--	0.78	0.54	0.44	0.36	0.29	0.30
2002	--	--	0.29	0.28	0.36	0.52	0.28	0.31

Note: 3. MPP was calculated by using the formula $MPP = \frac{\partial y_t}{\partial x_{it}} = \beta_i * \left(\frac{GeoMeanY_t}{GeoMeanX_{it}} \right)$, where β_i is the estimated coefficient of input *i* from the OLS model, $GeoMeanY_t$ is the geometric mean of yield at time *t*, $GeoMeanX_{it}$ is the geometric mean of input *i* at time *t*

CHAPTER 4

EMPLOYMENT, ASSET ACCUMULATION AND INPUT ALLOCATION DECISIONS IN THE UPLANDS

4.1 Overview

Land degradation is an important economic and environmental problem particularly in regions where poor households inhabit fragile ecosystems (Barbier, 1997; Anderson and Thampapillai, 1990). In the case of developing countries, like the Philippines, the poverty of farmers inhabiting the forest margins and forest areas is regarded as one important contributor to forest decline (Coxhead, Rola and Kim, 2001; WCFSD, 1999). In the Philippines, a number of studies have demonstrated that poor upland households' forest clearing activities contribute to land degradation and deforestation (Malayang, 2000; Severino, 2000; and Sajise and Ganapin, 1990).[18]

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[18] The term *upland* is defined by the Philippine Department of Environment and Natural Resources as land areas with slopes 18 percent and greater, but also includes the relatively leveled lands and plateaus at the upper elevations, which are usually not recommended for lowland rice cultivation unless some terracing structures are established (Sajise and Ganapin 1990). The term *upland communities* in this chapter refer to the clusters of households, about 90% belonging to the indigenous *Pala'wan* tribe inhabiting the forest margins (immediately above the irrigation service area) all the way up into the deep tropical rainforest covered by the study sites in the southern district of Palawan Province, Philippines. The topography of the upland study sites is predominantly sloping and hilly.

Furthermore, the degradation of forest resources is believed to threaten the future livelihood opportunities of these inhabitants.

While the role of low-income farmers in contributing to deforestation might seem unambiguous, observations from Palawan suggest a somewhat different pattern, where forest communities are adjacent to lowland farming communities where agricultural development is occurring. In such settings, adjacent lowland opportunities may serve as a magnet that pulls upland labor away from forest degrading activities and allows upland households to diversify income sources, thereby simultaneously reducing both income risk and environmental degradation.

At the study site, the advent of irrigation into lowland farming communities has intensified rice production, mainly by increasing the number of annual croppings from one to two. Although irrigation development has led to a decrease in labor requirement per cropping season (due to the use of labor saving input such as tractors and herbicides, the doubling of rice cropping contributed to an increase in the overall labor demand in a year (Shively and Martinez, 2001; Martinez and Shively, 1998). This increase in overall labor demand affected adjacent upland communities by allowing more upland households to participate in off-farm employment. Using data collected immediately before, and immediately after irrigation, Shively and Martinez (2001) suggested this pattern contributed to an improvement in upland environmental conditions by pulling upland households away from agricultural expansion and forest degradation. One question to ask is whether this pattern has been sustained over time.

This chapter examines the link between deforestation and irrigation development using panel data set from upland households. Data were collected in the upland study sites in Palawan through face to face interviews from 1994 to 2003. The analysis of this chapter is motivated by two research questions: (1) *What, if anything, has changed in these upland households over time?* and (2) *Over time, how has participation in the local agricultural labor market affected the decisions of upland households?* These questions are addressed by examining the upland households' behavioral patterns within the 10-year study period and how their decisions to engage in various economic activities such as agricultural expansion and income diversification have changed over time. Overall, the study focuses on the upland households' on-farm agricultural production, asset accumulation (which includes the extent of agricultural expansion and input purchase decisions) and off-farm employment.

This study extends previous work of Shively and Pagiola (2003) which covered the sample over the period 1994 to 2000 and Shively and Martinez (2001) which covered 1994 to 1997. These previous studies illustrated the initial gains to upland communities from agricultural intensification in the adjacent lowland communities through improved employment opportunities. Early findings also suggest that off-farm employment acted as a magnet, pulling upland households away from forest clearing activities. However, Shively and Pagiola (2003) found that some of the household initial gains in welfare and environmental conditions were reversed. This study uses a longer panel and a different method of analysis, thereby extending the empirical research highlighted above.

4.2 Methods

The analysis begins with the use of descriptive statistics from the unbalanced panel data set to investigate the question 'what has been happening to the upland communities over time?' We document the patterns of household behavior, decisions made, and shares of household income. Then, to address the question 'through which channels does lowland development influence household decisions in adjacent upland communities?' the same unbalanced panel data are analyzed using Seemingly Unrelated Regressions (SUR).

Upland households are engaged in various livelihood activities. These activities have a range of environmental impacts in the upland ecosystem. Different households involve themselves in different portfolios of activities, and the extent to which a household allocates resources to a particular activity, say off-farm work, may be affected by specific household constraints and participation in closely related activities, such as forest clearing, handicrafts and fishing. Recognizing that resource allocation decisions are made jointly, a SUR approach is adopted to estimate activity regressions for the sample.

The SUR (also known as Zellner's method), estimates the parameters of a system of regressions, accounting for heteroskedasticity, and contemporaneous correlation in the errors across equations (Greene, 2003). In this method, estimates of the cross-equation covariance matrix are based upon parameter estimates of the unweighted system. The SUR's multivariate set up allows one to jointly estimate a number of linear equations that has contemporaneous cross-equation error correlation. Initially, the equations appear unrelated, however, the equations are related through the correlation in the errors. For this reason, although the coefficient estimates from the SUR approach are identical to the estimates of individual models from the Ordinary Least Squares (OLS) regressions, the calculated standard errors differ.

The analysis uses two forms of the SUR model: (1) a base SUR model; and (2) a SUR model with village fixed effects. Let us begin with the base SUR model:

$$y_{im} = X_{ijm}\beta_{ijm} + T_{itm}\gamma_{itm} + \varepsilon_{im} \quad , \quad m = 1,2,3 \tag{4.1}$$

where

$$\varepsilon = \left[\varepsilon_{i1}^{'}, \varepsilon_{i2}^{'}, \varepsilon_{i3}^{'}\right]^{'} \tag{4.2}$$

and

$$E\left[\varepsilon \mid X_{i1}, X_{i2}, X_{i3}\right] = 0 \tag{4.3}$$

$$E\left[\varepsilon\varepsilon^{'} \mid X_{i1}, X_{i2}, X_{i3}\right] = \Omega \tag{4.4}$$

Equation 4.1 consists of three equations with parameters jointly estimated using a panel data set with 521 responses (i=521).[19] The shared set of regressors are composed of a group of indicator variables (T) for year t, which is included to capture the panel fixed effects of time, and a group of variables of j household characteristics which are believed to influence upland households' decisions. The β, γ and ε are unknown parameters to be estimated. The left-hand-side variables of the three equations are the dependent variables which represent the set of household decisions that are made jointly.

The second SUR model has a specification that captures the panel fixed effects of villages where we add the dummy variables (D_{ikm}) for k villages in Equation 4.1 to pool the standard errors for each group of household residing at a particular village. This gives rise to Equation 4.5.

$$y_{im} = X_{ijm}\beta_{ijm} + T_{itm}\gamma_{itm} + D_{ikm}\delta_{ikm} + \varepsilon_{im} \quad , \quad m = 1,2,3 \tag{4.5}$$

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[19] In the latter part of the chapter, this unbalanced panel data of 521 responses, is referred to as the *full upland sample* since another data set, called the balanced panel data set (a subset of the full upland sample), is used in the analysis.

To implement the SUR approach, we model two sets of upland household decisions. The first focuses on labor supply and asset accumulation. The second focuses on input purchase decisions. The labor supply and asset accumulation model is based on the empirical work of Shively and Pagiola (2003) which assumed that households jointly decide on how many days to devote to off-farm work, how much effort to expend on expanding their farm and how much fertilizer to purchase for agricultural production. The input purchase decision model uses the SUR approach to study the joint use of fertilizer, labor and pesticides on existing agricultural land.

After the regression analyses, regression findings are cross-examined using a two-way table, referred to here as the household decision matrix (see Table 4.1). The upland panel data set was sorted and tabulated to illustrate behavioral patterns of upland households over the study period, based on their decision to participate in off-farm work and/or engage in agricultural expansion activities.

Table 4.1 Upland Household Decision Matrix

		Decision to expand agricultural production	
		NO	YES
Decision to participate in off-farm work	NO	**(Q1)** No expansion, No off-farm work	**(Q2)** With expansion, No off-farm work
	YES	**(Q3)** No expansion, With off-farm work	**(Q4)** With expansion, With off-farm work

Table 4.1 shows that each upland household faces four choices or livelihood strategies. The first quadrant, Q1, represents the base scenario, where an upland household engages only in agricultural activities on the existing upland farm (and related livelihood activities) but not off-farm work and forest clearing. The second quadrant, Q2, is the choice, in addition to Q1, to clear a portion of forest land to expand agricultural production elsewhere, but not to engage in off-farm work. The third choice, Q3, is not to engage in forest clearing activities but to engage in off-farm work only. The fourth quadrant, Q4, is the choice to engage in both forest clearing and off-farm work activities. In Q4, therefore, the household decides to engage in both agricultural expansion and income diversification.

In using the decision matrix, we sort each resulting cell from the matrix by year and use this to examine each of the explanatory variables in the regression results in Tables 4.5 and 4.6. This approach is used to verify the regression results and shed light on some of the gaps that might need further analysis. The results of this analysis are presented in Section 4.4.5.

In addition to regression and decision matrix analyses, five upland households are chosen as case studies and examined in detail so as to illustrate key patterns in the data. In this way, some gaps in the regression results can be filled with reference to specific events in selected upland households.

Since our data were observed at different points in time, we have decided to convert the data expressed in nominal monetary terms into real values. These include data on cash income, loan amounts, values of purchased inputs and values of major agricultural products sold or retained for home consumption. These are all expressed in pesos per particular unit of measure. To convert these nominal values into real values, we use the average nominal price of one kg of paddy rice at each year as a deflator. For example, we divided the nominal income per capita in 1995 by the average price of rice in 1995. The resulting unit for this is the 1995 income per capita in kg of rice equivalents. For this reason, data that were initially expressed in monetary terms are all expressed in kg of paddy rice for the analysis of this chapter. This method is used since it can be considered as a better indicator of welfare changes given that rice is a major part of the household budget and it is the main staple food in the study sites.

Although we have at hand the provincial annual consumer price index (CPI) data for rice in Palawan, we opted not to use it as the deflator because the economic condition in the study sites seemed to be poorer compared to the Palawan average. During the four rounds of the survey, we observed that rice constitutes a relatively large portion of a typical upland household's "virtual' budget and thus serves as the best indicator of welfare changes. Therefore, to have a site-specific deflator, the prevailing average prices of a kg of rice for a particular year are used.

4.3 Data

As highlighted in Chapter 2, data collection began in the study sites in the 1994/1995 cropping year. At this time, adjacent lowland communities operated under rainfed conditions, cultivating rice and corn. The second household survey was done in 1997, to collect the data for the 1996/1997 cropping year when farms in the adjacent lowlands were undergoing a transformation from rainfed to irrigated farming conditions. The third and fourth household surveys took place in 2000 and 2003, with reference to the 1999/2000 and 2002/2003 cropping years. During these rounds, irrigation in the lowland sample was fully operational.

4.3.1 Socio-economic Characteristics

As mentioned in Chapter 2, about 90% of the upland household respondents are indigenous people belonging to the *Pala'wan* tribe. Over the study period, the average age of household heads in the full sample of 521 responses over the four years ranged from late thirties to early forties (Table 4.2). More than half (56.5%) of the household heads in the full sample did not have any formal education. On average, a typical household head has 1.5 years of formal education and occupies an upland farm that is slightly larger than two hectares.

Many studies have shown that, in rural areas in the developing world, farming households have very limited access to credit (Barbier and Bugress, 1992; Lopez, 1997; Deninger and Heinegg, 1995). This scenario holds true in the upland study sites, where less than a quarter of households in the sample were able to avail of credit. It appears that credit availability did not expand during the study period and actually may have declined somewhat over time. In the 1995 sample, the proportion of households who availed of loans was 22%. This proportion slightly increased to 23% in 1997, decreased to 18% in 1999 and fell to 12% in 2002. The average amount of loan per household was lowest in 2002 at only 36 kg of rice-equivalent per household and highest in 1997 at 174 kg of rice-equivalent.

On the other hand, the availability of agricultural labor per household which is represented by the average number of agricultural workers per household, started at 2.2 in 1995, then dropped to only 1.7 in 1997 but increased in 1999 and 2002 to 2.1 and 2.5, respectively. The trend of increasing number of workers occurred in the years with irrigation development (1997-2002).

4.3.2 On-farm Agricultural Production

Rice and corn are the two major agricultural products produced by upland respondents. During the study period, about 87% of the respondents cultivated rice, 66% cultivated corn and 94% cultivated rice and/or corn (Table 4.2). Rice is mainly grown for home consumption while corn is cultivated mainly for sale. Although a number of respondents cultivated other annual crops, such as rootcrops and vegetables, yields and production levels of these crops are difficult to measure accurately. Rice and corn, which are the two most important agricultural products, were measured with much greater accuracy and can be subjected to a more detailed analysis.

Data from the full upland sample indicate that, over time, upland households, on average, have been increasing the proportion of area planted to rice and corn. The proportion of rice planted area increased from 18% in 1995 to 22%, 50% and 40%

respectively in 1997, 1999 and 2002 (Table 4.2). This shows a doubling of the proportion of rice area in 1999 and 2002, when irrigation in the adjacent lowland became fully operational. On the other hand, the proportion of corn planted area increased from 21% in 1995 to 35%, 29% and 26% in 1997, 1999 and 2002. Although the proportion of rice and corn of area have been higher in the post irrigation years, rice emerges as the more preferred crop. This higher proportion of area allocated to rice and corn suggests that these annual crops might have contributed to the decline in the areas allocated for other uses, such as cultivation of other annual crops (i.e., rootcrops, vegetables) and fallow plots.

In terms of area cultivated to rice and corn (in hectares), average corn planted areas were greater than average rice planted areas in 1995 and 1997 (Table 4.2). This scenario was reversed in 1999 and 2002 when the average rice area became larger than average corn area. It appears that, on average, corn areas did not expand as much as rice areas. Although there was no increase in rice area between 1995 and 1997 (0.34 ha), rice areas increased to 0.74 ha and 0.60 ha in 1999 and 2002, respectively. Average corn area rose from 0.45 in 1995 to 0.55 in 1997, and then fell to 0.47 and 0.40 ha in 1999 and 2002, respectively.

Agricultural production requires a number of variable inputs but the three major inputs are labor, fertilizer and pesticides. Labor inputs, which take the unit of workday per ha of rice and corn crops, mainly include land preparation, planting, tending and harvesting. As expected, labor is an essential input in rice and corn production. Fertilizer (kg of granular fertilizer per ha of rice and corn) and pesticides (liters per ha of rice and/or corn) can be considered as non-essential inputs since upland households were able to produce rice and/or corn in the absence of these inputs. In the full sample, only 28% and 13% purchased fertilizer and pesticides, respectively.

Over time, the proportion of households who applied these three major agricultural inputs did not show clear patterns of use. However, a number of factors might be expected to affect input use, including demography, geography and socioeconomic factors. We hypothesize that, over time, with the continuing agricultural development in the adjacent lowlands, there are some spillover effects in the upland farming communities that influence input purchase decisions. This is discussed in Section 4.4.2 of this chapter.

In the Philippines and other rice growing countries, it is common for rice yields on irrigated rice farms to exceed yields on upland farms. In the case of the full upland sample, the average rice yield is only 0.9 tons/ha (compared to the average of 3.0 tons/ha in the lowland sample). In 1997, average rice yields reached a high of about 1.4 tons/ha, while average yields in 1995, 1999 and 2002 fell below the sample average (Table 4.2).

With regards to corn yield, the Province of Palawan had an average yield of about 2.0 tons/ha for the years 1995, 1997, 1999 and 2002.[20] On the other hand, the full upland sample average yield for corn is just above half of the provincial average observed at about 1.1 tons/ha. Over time, average corn yields in the study sites ranged from 0.9 tons in 1995 to 1.4 tons in 1999. The relatively lower corn yields in the sample can be attributed to the use of traditional upland farming practices of most respondents where corn is frequently intercropped with rice or root crops and not often grown in a monocrop

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[20] Source: Author’s calculations using BAS corn production data in Palawan in 1995 to 2002.

system. Moreover, corn is oftentimes grown on erodible upland sloping plots using minimal or no fertilizer and pesticides.

4.3.3 Agricultural Expansion Activities

The full upland sample shows that 31% of the respondents engaged in agricultural expansion in public forest lands. Some of the lands cleared had old growth forest and second growth forest, while it appears that more of these lands were previously cultivated and left fallow. The slash and burn practice of upland households is mainly to expand agricultural production primarily of rice, corn and rootcrops.

The panel data indicate that, over time, the number of households engaged in forest clearing activities and the area cleared by these households has been declining. Participation in forest clearing was cut by more than half from 57% in 1995 to 17%, 23% and 27% in 1997, 1999 and 2002. Despite the gradual increase in forest clearing participation between 1997 and 2002, the average area cleared has stabilized below the 0.20 ha level during this time period. The question of interest that arises from this pattern is *to what can we attribute these decreases in the rate and extent of forest clearing?*. We attempt to answer this question in Section 4.4.2 of this chapter.

Table 4.2 Socioeconomic and Agricultural Production Characteristics of Upland Households, 1995-2002

Item	1995	1997	2000	2002	All
Socioeconomic characteristics					
Age of household head (years)	39.0	38.6	39.8	43.2	40.7
% with formal education	43.8	36.3	48.5	44.7	43.5
Education of household head (years)	1.64	1.20	1.62	1.69	1.57
Farm size (ha)	2.62	2.04	2.00	2.04	2.20
% with loan	22.3	22.5	18.2	11.6	17.5
Amount of loan (kg of rice)†	114.2	174.2	144.5	35.8	101.8
No. of workers	2.2	1.7	2.1	2.5	2.2
% with tenure security	0.72	0.45	0.57	0.55	0.57
% who own carabao	0.34	0.33	0.38	0.35	0.35
Number of carabao owned	0.36	0.34	0.54	0.50	0.44
Number of carabao owned (no zeroes)	1.05	1.03	1.39	1.45	1.27
Site (1=Marangas, 0=Tamlang)	0.00	0.48	0.51	0.33	0.32
Agricultural Production					
% cultivating rice	84.3	85.3	84.8	89.4	86.6
% cultivating corn	75.2	72.5	60.6	60.3	66.2
% cultivating rice and/or corn	93.4	93.1	91.0	96.5	94.0
Area planted to rice (ha)	0.34	0.34	0.74	0.60	0.52
Area planted to corn (ha)	0.45	0.55	0.47	0.40	0.45
Area planted to rice and/or corn (ha)	0.79	0.89	1.20	1.01	0.97
% planted to rice (arice/farmsize)	0.18	0.23	0.50	0.41	0.34
% planted to corn (acorn/farmsize)	0.21	0.35	0.29	0.26	0.27
% planted to rice/corn (arico/farmsize)	0.40	0.57	0.79	0.67	0.61
Rice yield (kg/ha)	781	1374*	898	763	908
Corn yield (kg/ha)	882	1135*	1310	963	1052
Yield of rice and corn (kg/ha)	825	1210*	943	767	895
Amount of fertilizer (kg)	68	56	45	63	59
Amount of labor (days)	31	53	41	41	41
Amount of pesticide (liters)	0.207	0.010	0.189	0.193	0.160
Amount of fertilizer (kg/ha)	29	46	17	28	29
Amount of labor (days/ha)	123	125	109	145	129
Amount of pesticide (liters/ha)	0.165	0.005	0.106	0.126	0.108
Off-farm employment					
% engaged in off-farm work	61.2	80.4	63.6	69.8	68.7
Workdays (days/year)	17.0	28.9	23.1	30.5	27.6
Income from off-farm work (kg of rice)	98.5	419.8	279.0	343.4	289.2
Wage per work day (kg of rice)	3.46	8.87	8.22	8.32	7.28
Forest clearing activities					
% engaged in forest clearing	57.0	16.7	23.2	27.1	31.3
Area cleared (ha)	0.38	0.16	0.19	0.18	0.22
Number of responses	*121*	*102*	*99*	*199*	*521*

Note: * Yields for rice, corn and combined rice and corn were detected to have extreme outliers in the 1997 sample, most likely due to measurement error. These outliers have values more than 2 standard deviations from the mean. Rice and corn yields each have four outliers which were dropped from the 1997 sample.

4.3.4 Off-farm Work Employment

Our data indicate a relatively higher off-farm work participation of upland households in the post irrigation years. Compared to the initial 1995 level of 61.2%, the proportion of households engaged in off-farm work initially increased to a high of 80.4% in 1997. This initial gain in off-farm work participation decreased in 1999 to 63.6% but slightly increased in 2002 to 69.8% (Table 4.2). Despite the decline in employment in 1999, there was a rebound in 2002 which, on average, indicates that, over time, the proportion of households engaging in off-farm work has been increasing.

While participation in off-farm work has been increasing over time, our data also indicate that, compared with 1995, labor supplied by individual upland households, on average, increased by 121%, 30% and 57% in 1997, 1999 and 2002, respectively. The estimated increases in 1997 and 2002 are significant at the 1% test level, while the estimated increase for 1999 is not significantly different from zero.

Despite a non-significant increase in employment in 1999, compared with 1995, real household incomes from off-farm work were all significantly higher in 1997, 1999 and 2002, the years with irrigation development. Regression results with income from off-farm work (converted to kg of rice income equivalents) as the dependent variable and year indicator variables as independent variables indicate that income from off-farm work increased by 206% in 1997, 85% in 1999 and 118% in 2002 compared to the 1995 level. All these increases in real off-farm income are statistically significant at the 5% level.

Consistent with the findings of Shively and Martinez (2001) and Shively and Pagiola (2003) derived from shorter panels, we find that real wages increased with irrigation development. The finding from the longer panel data set used for this study is that it appears that the increase in wages has been sustained in the post irrigation years. The 1995 wage level of 3.5 kg of rice per workday more than doubled in 1997, 1999 and 2002 to 8.9, 8.2, and 8.3 kg of rice per workday, respectively. In percentage terms, the real off-farm wage rate of households who participated in off-farm work increased by 65%, 80% and 66% in 1997, 1999 and 2002, respectively. These changes are significant at the 1% test level. The increase in the real off-farm wage rates over time indicates both an increase in the attractiveness of off-farm work as a source of income and an increase in welfare for these participants in the agricultural labor market.

4.3.5 Household Income

Although wages and incomes have been rising in the post-irrigation years, overall household income appears to be declining over time. The computed average real income in the full upland sample indicates that a typical upland household had an income of 2,116 kg of rice-equivalents per year. Over the observed years, average household income was highest in 1997 at 2,608 kg of rice-equivalents and lowest in 2002 at 1,694 kg of rice-equivalents. Income per capita and income per worker were also lowest in 2002 (Table 4.3). The declining average household income from 1997 to 2002 might be attributed to land degradation.

Upland households rely on various activities within and/or outside their farms as sources of income. These sources can be categorized into four groups: agriculture, off-farm, forest and others. Agricultural income, which was the dominant income source for all the observed years, consists of the value of crops retained for consumption, sale of crops (both annual and perennial crops) and livestock. Off-farm income comes from wages earned from working on someone else's farm (typically a lowland farm). Forest income includes the sale of forest products such as timber (e.g., *Pterocarpus indicus, Intsia bijuga*) and non-timber products (e.g., Manila copal, honey, wild animals and plants). Other income includes remittances from relatives and friends, income from handicrafts and fishing.

Although the average total income and income per capita do not demonstrate a clear pattern over time, the income shares per income source demonstrate a pattern of increasing dependence of upland households to off-farm work as indicated by the tripling of the income shares from off-farm work in the years following irrigation development compared to the income share in 1995 of only 0.07 (Table 4.3). It appears that part of the decrease of the upland households' income share from forest products and other income sources in 1999 and 2002 have been absorbed by off-farm work. The income share of forest products declined from 0.17 and 0.21 in 1995 and 1997, respectively to 0.11 and 0.09 in 1999 and 2002, respectively. Thus, the abovementioned patterns might indicate that irrigation development in the adjacent lowlands contributed to a decrease in the intensity of forest products collection while intensifying off-farm work involvement of upland households.

Data also exhibit upland households' increasing participation on off-farm employment and declining dependence on income sourcing from forest products and other sources, average real income from off-farm work more than tripled in 1997 and 2002 and more than doubled in 1999 compared to the 1995 off-farm income level. The greater participation on off-farm work might be attributed to the significant decrease in income from forest products in 1999 and 2002 (significant at $\alpha = 0.01$). This is supported by the negative correlation between off-farm work income and income from forestry products.

The income share from other sources (e.g., handicraft making and fishing) decreased to 0.01 in 1999 and 2002 from 0.06 and 0.08 in 1995 and 1997 (Table 4.3). The proportion of upland households who received income from other sources declined dramatically from 44% in 1995 to 25%, 3% and 4% in 1997, 1999 and 2002. The decline in the dependence on other sources might have forced upland households to concentrate more on off-farm work activities and on-farm agricultural activities. However, although the proportion of households with other sources of income is decreasing, households who remained engaged in obtaining other sources of income increased their income from these other sources over time. This indicates that the households left in the handicraft making business were able to specialize while those who did not exited (Table 4.3). With regard to income from agricultural production, which includes the value of retained crops for home consumption, upland households were able to maintain an average production above the value of 1,000 kg of rice-equivalents for all the observed years. The agricultural income level was highest in 1999 with 1,762 kg of rice-equivalents and lowest in 2002 with 1,138 kg of rice-equivalents.

Table 4.3 Household Income, 1995-2002

Item	1995	1997	2000	2002	All
Total income (pesos)	12,707	15,648	14,423	11,855	13,283
Income per capita (pesos/person)	3,105	3855	3,474	3,010	3,286
Income per worker (pesos/worker)	6,496	10,372	8,659	6,162	7,538
Total income (kg of rice)	2,310	2,608	2,219	1,694	2,116
Income per capita (kg of rice)	565	642	534	430	523
Income per worker (kg of rice)	1,181	1,729	1,332	880	1,202
Agricultural income (kg of rice)	1,533	1,397	1,762	1,138	1,399
Off-farm income (kg of rice)	98	420	279	343	289
Forest income (kg of rice)	496	565	142	140	306
Other income (kg of rice)	183	226	37	73	122
Agricultural income (kg of rice) no zeroes	1,545	1,484	1,817	1,155	1,435
Off-farm income (kg of rice) no zeroes	161	522	438	492	421
Forest income (kg of rice) no zeroes	1,200	929	305	392	696
Other income (kg of rice) no zeroes	418	888	1,205	2,070	712
% of hh with income from ag prodn	0.99	0.94	0.97	0.98	0.98
% of hh with off-farm work	0.61	0.80	0.64	0.70	0.69
% of hh with forest income	0.41	0.61	0.46	0.36	0.44
% of hh with other income	0.44	0.25	0.03	0.04	0.17
Share of agricultural income	0.70	0.46	0.68	0.63	0.63
Share of off-farm income	0.07	0.25	0.21	0.27	0.20
Share of forest income	0.17	0.21	0.10	0.09	0.13
Share of other income	0.06	0.08	0.01	0.01	0.04
Number of households	*121*	*102*	*99*	*199*	*521*

Notes:

1. Philippine Peso to US Dollar equivalents: 1995 (P25.03/\$1); 1997 (P27.67/\$1); 1999 (P40.57/\$1); 2002 (P53.56/\$1) – Source: USDA-ERS
2. Average nominal loan amounts were divided by the nominal price of rice in the study sites at that specific point in time to derive kg of rice equivalent for comparison purposes.

4.3.6 The Balanced Panel Data Set

To take a closer look at how unique households have changed over the years, from the full upland data set (n=521), a subset of 172 responses was derived consisting of 86 pairs of households each appearing in 1995 and 2002. This sub-sample forms a balanced panel which allows the comparison of each household's off-farm work participation/non-participation and involvement/non-involvement in forest clearing activities between 1995 and 2002. A summary of the income data from this balanced panel data set is presented in Table 4.4.

Data show that both nominal and real total household income, income per capita and income per worker were all much higher in 1995 than in 2002. This indicates that, on average, the overall livelihood opportunities in the sites have been declining over time. Table 4.4's section on real household incomes by source (in kg of rice-equivalents) show that, while average incomes from agricultural production, forest products, and other income sources (e.g., handicrafts and remittances) have declined, the average real income from off-farm work increased (Table 4.4). The proportions of households with income derived from the given specific source shows off-farm employment to be the only growing livelihood activity in terms of upland households' participation while the all rest demonstrated a decline.

The increasing average income from off-farm employment reflects an increasing dependence of upland households to this income source. This might be the reason for the tripling of the share of off-farm work income to total household income (Table 4.4). While the income share from agriculture production slightly increased, the income shares from forest and from other livelihood activities have declined over time.

Table 4.4 Household Incomes of the Balanced Panel Data Set (1995 and 2002 Sample)

Item	1995	2002	All
Nominal Income			
Total income (pesos/household)	14,811	10,927	12,869
Income per capita (pesos/person)	3,425	2,539	2,982
Income per worker (pesos/worker)	7,421	5,287	6,354
Real Income			
Total income (kg of rice-equivalents) †	2,693	1,561	2,127
Income per capita (kg of rice-equivalents) †	623	363	493
Income per worker (kg of rice-equivalents) †	1,349	755	1,052
Average Real Income by Source			
Agriculture (kg of rice-equivalents) †	1,686	1,210	1,448
Off-farm (kg of rice-equivalents) †	97	171	134
Forest (kg of rice-equivalents) †	550	78	314
Other (kg of rice-equivalents) †	360	101	231
Agriculture (kg of rice-equivalents) no zeroes	1,705	1,224	1,465
Off-farm (kg of rice-equivalents) no zeroes	154	258	208
Forest (kg of rice-equivalents) no zeroes	1,279	293	901
Other (kg of rice-equivalents) no zeroes	449	242	378
Proportion of Households with Income from a Given Source			
% with agriculture prod	99	99	99
% with off-farm work	63	66	65
% with forest income	43	27	35
% with other income	80	42	61
Income Share by Source			
Share of agricultural income	0.66	0.69	0.67
Share of off-farm income	0.05	0.18	0.11
Share of forest income	0.16	0.05	0.11
Share of other income	0.13	0.08	0.11
Number of households	*121*	*199*	*521*

Notes: 1. Philippine Peso to US Dollar equivalents: 1995 (P25.03/$1); 1997 (P27.67/$1); 1999 (P40.57/$1); 2002 (P53.56/$1) – Source: USDA-ERS

2. † Average nominal loan amounts were divided by the nominal price of rice in the study sites at that specific point in time to derive the come up with kg grams of rice equivalent for comparison purposes.

3. * Yields for rice, corn and combined rice and corn were detected to have outliers in the 1997 sample. These outliers have values more than 2 standard deviations from the mean. Rice and corn yields each have four outliers which were dropped from the 1997 sample.

Data from the balanced upland panel reveal that the proportion of the same set of households who did off-farm work in 2002 is slightly higher than in 1995 (Table 4.5).[21] Despite the small increase in the proportion with off-farm work, the number of off-farm work days increased by 38% between 1995 and 2002. In spite of this increase, paired t-test results indicate that the number of work days per household is not significantly different between 1995 and 2002. However, we can be 95% confident that, on average, a typical upland household experienced an increase in real income from off-farm employment. This can be attributed to a significant rise in real wages in 2002.

The proportion of households engaged in forest clearing decreased from 57% to 38%. In addition, the average area cleared by households decreased significantly. The reduction in forest clearing can be attributed to two major events: (1) the total area cleared by the 86 households decreased from 33.6 ha to 20.5 ha; and (2) the proportion of households who stopped clearing forest (29%) was greater than those who started forest clearing (10%) (which is opposite to the case of off-farm employment where the proportion who entered is greater than the proportion who stopped).

Table 4.5 Off-farm Participation and Forest Clearing Activities, 1995 and 2002, 86 Upland Households, 172 responses

Year	% with off-farm employment	Total number of workdays	Average number of workdays	Income from wages (kg of rice-equivalents)	Average wage per workday (kg of rice-equivalents)	% who engaged in forest clearing	Total area cleared (ha)	Average area cleared (ha)
1995	62.8	1376	16	97	3.57	57.0	33.6	0.39
2002	66.3	1902	22	171	6.83	38.4	20.5	0.24
2002-1995	3.5	526	6	74	3.25	-18.6	-13.1	-0.15

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[21] About 13.9% of the 1995 sample who engaged in off-farm stopped in 2002 while 16.3% who did not have off-farm work in 1995 entered off-farm employment in 2002.

4.4 Results

4.4.1. What Has Changed in the Uplands?

From 1994 to 2003, as the adjacent lowlands were transformed from rainfed to irrigated farming conditions, the uplands communities were also observed to undergo changes in activities and behavior. The full upland panel demonstrates some distinct patterns in agricultural expansion activities, off-farm work involvement and income shares over time.

4.4.1.1 Agricultural Expansion and Off-farm Work

The pattern of decreasing forest pressure is exhibited by changes in the intensity of two major livelihood activities of upland households which are agricultural expansion in pubic forest lands and participation in off-farm employment. Figure 4.1 shows that, in 1995, the proportion of households who cleared forestlands (61%) is very close to proportion of those engaged in off-farm work (63%). This scenario changed dramatically as the adjacent lowland communities started to experience agricultural development (i.e., irrigation) where the proportion of those with off-farm work increased while the proportion of forest clearers decreased. In 1997, only 17% engaged in forest clearing and participation in off-farm work increased to 81%. The large gap between the two proportions remained in 1999 and 2002, although the gap decreased slightly.

With regard to the extent (average area) of clearing and off-farm employment of upland households, a similar pattern emerges. Figure 4.2 shows that, in 1995, respondents cleared, on average, about 0.40 ha of public forest land typically for annual crop cultivation. But in 1997, 1999 and 2002, average area cleared per respondent decreased to 0.16, 0.19 and 0.18 ha, respectively. On average, cleared area significantly decreased in the years following irrigation and the average number of days spent on off-farm work increased.

4.4.1.2 Income Shares

As mentioned in Section 4.3.4, a pattern of decreasing pressure to forest resources and an increasing dependence on off-farm work is revealed in the changes in the proportion of income generated from off-farm work and forest resources over time. This is illustrated in Figures 4.3 to 4.7. The income share of off-farm work in the 1995 sample was only 0.07. With the transformation of the adjacent lowlands to irrigated farming communities, this proportion increased at least three fold. The proportion of income from off-farm work was highest in 2002. There are two possible explanations for this increase in the off-farm income share. First is that the average real wage for off-farm work increased in 1997, 1999 and 2002 and despite a not very significant increase in the average number of workdays per household, real incomes from off-farm work significantly increased in the same years. Second is that, although the overall proportion of upland households involved in off-farm work appears lower in 2002 than in 1997, it was evident in the site that there was an increasing dependence of upland households on off-farm employment relative to other sources of income. Key informant interviews reveal that several upland households were employed full time as farm laborers on irrigated farms in later years of the survey. The number of full time farm laborers was also reported by key informants in the study sites to be increasing over time.

In the case of income share of the sale of forest products, the shares were 0.17 and 0.21, respectively, in 1995 and 1997 (Figures 4.3 and 4.4). These shares were significantly reduced to only 0.10 and 0.09, respectively in 1999 and 2002 (Figures 4.5 and 4.6). Consequently, real incomes from forest products significantly decreased in 1999 and 2002 compared to the real off-farm income in 1995. One possible reason for the decrease is that upland households have been relying more on off-farm work due to rising labor demand on the adjacent lowland farms. Another possibility is that forest resources in the nearby forest areas have been exhausted over the years. The more abundant supply of forest resources could only be found in the areas further up the mountains or deeper into the tropical rainforest. Figure 4.7 shows that for all years, agriculture is the main source of livelihood (63%) followed by off-farm work (20%) then by forest products (13%) and other sources (4%).

4.4.1.3 Upland Agricultural Activities

Upland agricultural activities provide upland households with food for home consumption and additional income from sale of the products in excess of consumption. We consider the amount of rice crop retained for home consumption as part of agricultural income and this contribute to making agricultural production a dominant livelihood activity source of the upland households with an average income share ranging from 46% to 70% in the four observed cropping years (Figures 4.8 to 4.12). Agricultural income can be broken down into five major income components: rice, corn, other annuals (mainly composed of root crops and vegetables), tree crops, and livestock. Of these five items, rice and corn account for the largest income shares which when combined together would account for about of 66% of the total agricultural income (Figure 4.12).

Between 1994 and 2003, changes in the area planted to rice and corn were observed in the study sites. A regression using area planted to rice as the dependent variable and year dummies as regressors shows a significant increase in area planted to rice in the years 1999 and 2002 compared to 1995. As a consequence, with the increase in area planted, there was a significant increase in income from rice in 1999 and 2002 compared to the 1995 level. This increase in income from rice corresponds to an increase in the income shares of rice in the agricultural income from 18% in 1995 to 40%, 48% and 41% respectively in 1997, 1999 and 2002.

On the other hand, regression results with area planted to corn (the cash crop) regressed on year dummies with 1995 as the base year suggest that, on average, areas planted to corn in the years 1997, 1999 and 2002 are not significantly different than in 1995. This indicates that while rice areas have been expanding in the uplands, areas planted to corn remain unchanged.

The regression results for area planted to rice appear consistent, to a certain extent, to the pie charts in Figures 4.8 to 4.12. The share of rice income to the total agricultural income increased from 28% in 1995 to 40%, 48% and 41% in 1997, 1999, and 2002, respectively, thus illustrating a pattern of increasing household dependence on rice production for home consumption and agricultural income. The increase in income share of rice can be attributed to both rice yields and area planted to rice. In 1997, while there was a significant increase in rice yield of 781 kg/ha compared to 1995, there was no significant increase in area planted to rice. In 1999 and 2002, where rice yields are not significantly different from 1995, area planted to rice, on average, significantly increased by about 0.39 ha and 0.26 ha in 1999 and 2002.

The increase in rice yields in 1997 and the expansion of rice areas in 1999 and 2002 might be explained by the technical change in the adjacent lowlands, which was occurring in 1996 to 2002. In 1997, it appears that there was an intensification of rice production in the uplands as indicated by higher expenditures of upland households (significant at the 5% test level) on variable inputs farm inputs such as fertilizer and pesticides. In 2002, on average, upland households expanded their rice cultivated areas. This might be attributed to the involvement of upland households in off-farm work employment in lowland rice farms. The 2002 Marangas sample demonstrates a positive association between the number of off-farm work days and the area planted to rice (significant at the 5% test level). This might indicate, paradoxically, that those who spent more days working on lowland farms in 2002 cultivated relatively larger upland rice plots.

Sections 4.4.1.1 to 4.4.1.3 reveal the changes that have been have been observed in the uplands and attributed these changes to the indirect effect of technical change in the adjacent lowland communities. A question that might arise from the discussions above is that *through which channels has agricultural development in the adjacent lowlands spilled-over into the uplands?* This question is answered in the next section.

4.4.2 How Does Lowland Development Spill Over to the Uplands?

To investigate how lowland development changes upland activity, we apply the SUR approach discussed in Section 4.2. The first group of regressions consists of labor supply, agricultural land accumulation and fertilizer use as the three jointly estimated dependent variables. The three fixed set of regressors for this group of equations include the indicator variables for year 1997, 1999 and 2002, the remoteness of residence from the lowland areas (which takes the value of 1 if it takes more than 30 minutes by foot and 0 otherwise), and the exogenous variables consisting of the socioeconomic characteristics age of household head, education of household head, number of agricultural workers, ownership of draft animal and tenurial security.

The second group of joint decisions consists of input allocations with dependent variables fertilizer per ha, pesticides per ha and labor per ha. The fixed sets of independent variables here are a bit similar to the ones in the first set of joint models and these are the indicator variables for year, remoteness of upland households from the lowlands, the indicator for site, the indicator variable to show if the household availed of credit, farm size, age of household head, education of household head, and the number of household workers.

4.4.2.1 Labor Supply and Asset Accumulation Decision Model Results

In the discussion of results in section 4.4.1, we observed higher off-farm work participation and lower forest clearing activities in the post irrigation years. In this section, we jointly estimate three decision models using the seemingly unrelated regression approach. We assume that a typical upland household jointly decides on three major household activities: (1) the number of days to be allocated for off-farm work – *offdays*; (2) the size of the forest area (in ha) to be cleared for expansion purposes -

cleareda; and (3) the amount of fertilizer (in kg) to be purchased and applied on their plots of rice and/or corn - *fert*.

The SUR estimates of Model 4.1 presented in Table 4.6, are consistent with the off-farm and forest clearing patterns discussion in section 4.4.1. The indicator variables for years in the *offdays* regression indicate that, controlling jointly for other factors, the number of off-farm days supplied by upland households was significantly higher in 1997 and 2002. On the other hand, the coefficients for the year indicators in the *cleareda* regression suggest a reduction in the area of forest clearing for all the years with irrigation development in the adjacent lowland (significant at $\alpha = 0.01$). For the *fert* regression, the year variables indicate higher fertilizer purchases by upland households in 1997, 1999 and 2002 (significant at $\alpha = 0.10$).

The negative association between the remoteness of the residence of upland households (remote) and the number of workdays might indicate that upland respondents whose residence can be reached by less than 30 minutes of walking time have the tendency to devote more days doing off-farm work since they are situated closer to the lowlands. However, the coefficient estimate for *remote* in this instance is not significant at any conventional level. A similar condition applies to the correlation between *cleareda* and *remote*. In terms of remote and the amount of fertilizer purchase, they are negatively correlated, which indicates that, on average, a typical upland household that is relatively far from the lowlands, controlling for other factors and decisions, will purchase 32 kg less fertilizer than the one living relatively closer to the lowlands. This is likely because of the difficulty of transporting the fertilizer to their residence by manually carrying them without any aid of transport vehicle since their respective residences along the forest margins are only accessible through narrow foot paths along gently sloping to steeply sloping terrain. Access to their remote residence becomes even more difficult when it rains.

In terms of the size of the upland farm, SUR estimates indicate that larger farms supply more labor to the lowlands. Also, as expected, larger farms purchase more amounts of fertilizer. These two positive coefficients for landholding size are significantly different from zero at the 1% test level. Although farm size is negatively associated with forest area cleared, there is insufficient evidence to reject the null hypothesis that larger farms clear the same area of land as smaller farms.

The coefficients for the age of household head are all negative in the three jointly estimated models. This indicates that younger households have the tendency to engage in more off-farm work activities, clear larger forest areas and purchase more fertilizer than older households. However, the coefficient for age is statistically significant (at $\alpha = 0.05$) only for the *offdays* regression. This might might indicate that the age of the household head is most important for determining the extent of off-farm work participation than clearing activities and/or fertilizer purchase.

Regression results also indicate that household heads with more years in school have the tendency to purchase more fertilizer than those with lesser or no formal education. Households with more workers clear larger areas of forest lands. Those who own carabao purchase more fertilizer. The positive association between tenure security and offdays indicates that households with secure land tenure have higher labor-force participation rates. However, this association is statistically weak.

Of the three models in the joint estimation, the fertilizer decision model has the highest explanatory power with an R^2 of 0.15. Despite the relatively low R^2, the three decision models all have likelihood χ^2 values higher than the 1% critical likelihood χ^2 values. This indicates a very high significance of the constructed joint models based on the Chi-square test of model significance.

4.4.2.2 Input Allocation Decisions

We examine here the factors that might be correlated with upland households' decisions regarding input allocation to agricultural production. We focus on the production of rice and corn which are observed to be the most important agricultural crops in terms of contribution to household income. We consider three major production inputs: labor (workdays per ha of rice and corn), fertilizer (kg per ha of rice and corn) and pesticides (liters per ha of rice and corn).

With the assumption that the decisions on how much input to allocate are made jointly, a seemingly unrelated regression approach is used to jointly estimate the models that relate to agricultural input allocation decisions. Model estimates are presented in Table 4.7. The indicator variables for year imply that, controlling for other factors over time, there are no significant changes in the amount of labor allocated per ha of rice and corn over time. With regards to fertilizer use, there appears to be a significant increase in the amount of fertilizer applied in 1997 compared to 1995. However, we fail to reject the null hypothesis that the amount of fertilizer applied per hectare of rice and corn in 1999 and 2002 is the same as in 1995. Thus, it appears here that the initial increase in labor supply (or labor intensification) for upland agriculture was not sustained over time since the amount of labor per hectare fell back to the initial level in 1995.

With regard to the amount of pesticides purchased by households, we see a significant decrease in the post-irrigation years. A possible explanation for this is that upland households who are engaged in off-farm work were able to obtain pesticides from their lowland farm employers at zero cost, perhaps as part of their compensation package. This explanation is supported by the negative correlation between the number of off-farm work days and the amount of pesticides purchased by households.[22] For this reason, there is a possibility that upland respondents who worked off-farm did not purchase pesticides. Thus, with irrigation development there were more upland households who engaged in off-farm work, and potentially more benefit from supply of pesticide products from their lowland employers.

Our data also indicate that upland households with access to credit were more likely to purchase fertilizer and pesticides (as substitutes to labor). This is supported by the fact that the amount of labor supplied to the lowlands is negatively correlated with the dummy variable for loan activity. The coefficients of loan for the fertilizer and pesticides allocation models are positively correlated. This supports the conjecture that households allocate more fertilizer and pesticide if they have access to credit. As expected, the model for labor allocation also indicates that households with more farm workers are likely to allot more workdays for every hectare of rice and corn plots.

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[22] Pairwise correlation analyses were done to test the association between the amount of pesticides purchase and number of days in off-farm work in different years. Using the full upland data set (n=521), and isolating the 2002 sample in the Tamlang site, correlation analysis results indicate that the number of workdays is negatively correlated (ρ=-0.18, n=133) to the amount purchased pesticides (at $\alpha = 0.05$).

The coefficients for *remote* in the fertilizer and pesticides equations are both negative which imply that households living further up into the primary forest areas have the tendency to purchase less fertilizer and pesticides. The point estimate for fertilizer is significant at the 5% test level, but the coefficient for pesticide is not significantly different from zero. The weaker point estimate for pesticide can be attributed to the fact that a large majority (86.4 %) of upland households do not use purchased pesticides for agricultural production.

The positive coefficients for the education of household head indicate that more educated households tend to apply more fertilizer and pesticides (significant at a 5% test level). However, in the case of labor allocation, we fail to reject the null hypothesis that farmers with different education levels allocate the same amount of labor per hectare of rice and corn.

The SUR estimates indicate that farmsize and the age of household head have no measurable correlation with the input allocation decisions of upland households. A possible explanation for this is that households use, more or less, a standard amount of input per unit of land cultivated to crops. The amounts of inputs applied per plot do not vary much despite the differences in farm size. The data also indicate that age differences of household heads are not correlated with the amount of inputs applied per hectare of rice and corn plots.

Table 4.6 Labor Supply, Agricultural Expansion and Asset Accumulation Choice Model 1995-2002

	Model 4.1			Model 4.2			Model 4.3		
	Offdays	Cleareda	Fert	Offdays	Cleareda	Fert	Offdays	Cleareda	Fert
Constant	17.687*	0.355*	6.801	15.912	-0.039	169.633*	30.856*	0.293*	-42.592*
	(8.366)	(0.094)	(20.002)	(26.807)	(0.301)	(63.352)	(10.293)	(0.116)	(24.595)
Indicator for 1997	16.293*	-0.199*	41.466*	16.871*	-0.195*	44.201*	17.165*	-0.193*	40.209*
	(5.998)	(0.068)	(14.340)	(6.041)	(0.068)	(14.277)	(6.023)	(0.068)	(14.392)
Indicator for 1999	0.105	-0.193*	27.090*	0.264	-0.192*	24.152*	0.452	-0.201*	21.699
	(6.090)	(0.069)	(14.560)	(6.158)	(0.069)	(14.552)	(6.151)	(0.069)	(14.698)
Indicator for 2002	11.694*	-0.228*	22.039*	11.499*	-0.231*	23.050*	11.656*	-0.226*	20.154
	(5.114)	(0.058)	(12.227)	(5.136)	(0.058)	(12.138)	(5.122)	(0.058)	(12.239)
Indicator of distance from lowland	-4.448	0.029	-31.976*	-6.012	-0.001	-20.952	-5.814	0.007	-23.887
(0 if < 30 min walk, 1 if ≥ 30 min)	(4.641)	(0.052)	(11.097)	(6.958)	(0.078)	(16.444)	(6.952)	(0.078)	(16.613)
Site	17.425*	0.007	-36.632*	14.983	0.312	-211.646*			
(0 if Tamlang, 1 if Marangas)	(4.859)	(0.055)	(11.616)	(24.778)	(0.279)	(58.556)			
Farmsize (ha)	3.332*	-0.010	7.054*	3.389*	-0.010	8.084*	3.447*	-0.009	7.972*
	(1.062)	(0.012)	(2.540)	(1.076)	(0.012)	(2.544)	(1.075)	(0.012)	(2.568)
Age (years)	-0.330*	-0.002	-0.321	-0.339*	-0.002	-0.466	-0.344*	-0.002	-0.405
	(0.146)	(0.002)	(0.350)	(0.149)	(0.002)	(0.353)	(0.149)	(0.002)	(0.356)
Education (years in school)	-0.656	-0.009	4.333*	-0.671	-0.008	4.541*	-0.678	-0.008	4.700*
	(0.770)	(0.009)	(1.841)	(0.777)	(0.009)	(1.837)	(0.777)	(0.009)	(1.858)
Number of workers	0.238	0.068*	4.531	0.350	0.070*	4.382	0.333	0.066*	4.627
	(1.551)	(0.018)	(3.709)	(1.556)	(0.017)	(3.678)	(1.556)	(0.017)	(3.719)
Indicator of carabao ownership	2.401	-0.001	56.789*	2.325	0.008	52.511*	1.988	0.006	55.870*
	(3.972)	(0.045)	(9.496)	(4.089)	(0.046)	(9.663)	(4.069)	(0.046)	(9.724)
Indicator of tenure security	6.009	-0.003	-14.140	5.626	-0.012	-16.797*	5.340	-0.020	-12.725
(1 if with CSC, 0 if no CSC)	(4.230)	(0.048)	(10.115)	(4.250)	(0.048)	(10.044)	(4.222)	(0.047)	(10.089)
R^2	0.08	0.07	0.15	0.09	0.08	0.17	0.09	0.08	0.16
Chi^2	48.15	37.29	93.91	49.98	44.99	110.4	49.70	42.53	96.23
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	521	521	521	521	521	521	521	521	521

Notes: 1. Values in parentheses are standard errors of parameter estimates.
2. * - indicates parameter estimate is significantly different from zero at $\alpha = 0.10$

Table 4.7 Agricultural Intensification and Input Allocation Choice Model 1995-2002

	Model 4.4			**Model 4.5**			**Model 4.6**		
	Labor (days/ha)	Fertilizer (kg/ha)	Pesticide (li/ha)	Labor (days/ha)	Fertilizer (kg/ha)	Pesticide (li/ha)	Labor (days/ha)	Fertilizer (kg/ha)	Pesticide (li/ha)
Constant	59.359	29.987*	0.088	-35.479	16.907	0.197	23.561	-1.574	0.088
	(36.952)	(11.624)	(0.059)	125.179	(39.221)	(0.197)	(48.284)	(15.128)	(0.076)
Indicator for 1997	20.993	24.157*	-0.189*	24.452	24.510*	-0.182*	25.710	24.116*	-0.185*
	(28.332)	(8.912)	(0.045)	(28.414)	(8.903)	(0.045)	(28.314)	(8.872)	(0.045)
Indicator for 1999	-11.057	-3.426	-0.092*	-13.265	-3.602	-0.081*	-12.707	-3.776	-0.082*
	(28.583)	(8.991)	(0.045)	(28.750)	(9.008)	(0.045)	(28.736)	(9.004)	(0.045)
Indicator for 2002	1.222	6.561	-0.052	3.838	7.528	-0.049	4.546	7.307	-0.051
	(24.110)	(7.584)	(0.038)	(24.065)	(7.540)	(0.038)	(24.031)	(7.529)	(0.038)
Indicator of remoteness	-4.522	-24.374*	-0.040	-1.514	-23.179*	-0.098*	-0.520	-23.490*	-0.100*
(0 if < 30 min walk, 1 if ≥ 30 min walk)	(21.793)	(6.856)	(0.035)	(32.285)	(10.116)	(0.051)	(32.234)	(10.100)	(0.051)
Site	-10.265	-16.561*	0.086*	59.133	-18.510	-0.109			
(0 if Tamlang, 1 if Marangas)	(20.944)	(6.588)	(0.033)	(115.679)	(36.245)	(0.182)			
Indicator of access to credit	-58.784*	30.703*	0.125*	-61.864*	30.540*	0.126*	-63.420*	31.027*	0.128*
(0 if no loan, 1 if with loan)	(23.895)	(7.517)	(0.038)	(23.973)	(7.511)	(0.038)	(23.785)	(7.452)	(0.037)
Farmsize (ha)	-6.250	-0.257	0.010	-5.556	0.565	0.013	-5.430	0.525	0.013
	(4.987)	(1.569)	(0.008)	(5.006)	(1.568)	(0.008)	(5.001)	(1.567)	(0.008)
Age (years)	0.421	-0.225	-0.0003	0.318	-0.340	-0.001	0.301	-0.335	-0.001
	(0.688)	(0.217)	(0.001)	(0.698)	(0.219)	(0.001)	(0.698)	(0.219)	(0.001)
Education (years in school)	-2.601	2.508*	0.019*	-2.458	2.554*	0.018*	-2.498	2.567*	0.018*
	(3.634)	(1.143)	(0.006)	(3.650)	(1.144)	(0.006)	(3.650)	(1.144)	(0.006)
Number of workers	37.249*	1.560	0.006	36.803*	1.669	0.008	36.678*	1.708	0.009
	(7.291)	(2.294)	(0.012)	(7.280)	(2.281)	(0.011)	(7.277)	(2.280)	(0.011)
R^2	0.07	0.12	0.09	0.08	0.14	0.11	0.08	0.14	0.11
Chi^2	38.76	69.52	50.15	45.75	81.67	67.60	45.56	81.47	67.26
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	521	521	521	521	521	521	521	521	521

Notes: 1. Values in parentheses are standard errors of parameter estimates.

2. * - indicates parameter estimate is significantly different from zero at $\alpha = 0.05$.

4.4.2.3 Elasticity Estimates

The sample mean of the explanatory variables were divided by the sample mean of the dependent variables to derive ratios. These are presented in Table 4.8 and allow us to see some of the trends. These ratios are also used in the computations of input elasticities from SUR estimates which are presented in Table 4.9.

Our data indicate that farm size is positively associated with the number of days in off-farm work (Table 4.9). Computed elasticities from the SUR estimates and sample means indicate that a 1% increase in farm size corresponds to an increase in off-farm work days of 0.3%, a decrease in cleared area by 0.1%, and an increase in fertilizer use by 0.3%. On the other hand, households headed by an older person might be expected to spend fewer days in off-farm work, expand less area and purchase less fertilizer.

A 1% increase in area of the upland landholding, on average, would indicate that farmers will have to increase the purchase of fertilizer by 0.64%. Our data also show that given that, an additional year in education would increase the purchase of fertilizer by 0.24%.

Table 4.8 Ratios of the Dependent X per Unit of Y and Labor Supply and Asset Accumulation Decisions Over Time

Item	Labor supply & asset accumulation decisions				
	1995	1997	1999	2002	All
<u>*Labor supply and asset accumulation decisions*</u>					
Off-farm work (days)					
Farmsize (ha)	0.15	0.07	0.09	0.07	0.08
Age of household head (years)	2.29	1.34	1.72	1.42	1.47
Education (years in school)	0.10	0.04	0.07	0.06	0.06
Number of workers	0.13	0.06	0.09	0.08	0.08
Cleared area (ha)					
Farmsize (ha)	6.89	12.75	10.53	11.33	10.00
Age of household head (years)	102.6	241.2	209.5	240.0	185.0
Education (years in school)	4.32	7.50	8.53	9.39	7.14
Number of workers	5.79	10.63	11.05	13.89	10.00
Fertilizer (kg)					
Farmsize (ha)	0.04	0.04	0.04	0.03	0.04
Age of household head (years)	0.57	0.69	0.88	0.69	0.69
Education (years in school)	0.57	0.69	0.88	0.69	0.69
Number of workers	0.03	0.03	0.05	0.04	0.04
<u>*Input allocation decisions*</u>					
Off-farm work (days)					
Farmsize (ha)	0.02	0.02	0.02	0.01	0.02
Age of household head (years)	0.32	0.31	0.37	0.30	0.32
Education (years in school)	0.01	0.01	0.01	0.01	0.01
Number of workers	0.02	0.01	0.02	0.02	0.02
Cleared area (ha)					
Farmsize (ha)	0.09	0.04	0.12	0.07	0.07
Age of household head (years)	1.36	0.84	2.36	1.57	1.38
Education (years in school)	0.06	0.03	0.10	0.06	0.05
Number of workers	0.08	0.04	0.12	0.09	0.07
Fertilizer (kg)					
Farmsize (ha)	15.88	408.00	18.87	16.19	20.37
Age of household head (years)	236.36	7720.0	375.5	342.9	376.8
Education (years in school)	9.94	240.00	15.28	13.41	14.54
Number of workers	13.33	340.00	19.81	19.84	20.37

Table 4.9 Elasticity Estimates from the SUR Fixed Effects Model

	Labor supply and asset accumulation decisions			Input allocation decisions		
	Off-farm workdays	Cleared area (ha)	Fertilizer (kg)	Labor (days/ha)	Fertilizer (kg/ha)	Pesticide (li/ha)
Farmsize (ha)	0.267	-0.100	0.280	-0.110	-0.003	0.210
Age of household head (years)	-0.486	-0.440	-0.227	0.134	-0.318	-0.107
Education (years in school)	-0.037	-0.062	2.993	-0.032	0.134	0.278
Number of workers	0.019	0.641	0.167	0.636	0.114	0.119

Note: Formula for elasticity: $\varepsilon = \hat{\beta} * \left(\frac{\overline{X}_i}{\overline{Y}} \right)$

4.4.3 Two-Way Tables

By grouping and classifying the upland sample on the basis of decisions to participate in off-farm employment and/or engage in agricultural expansion activities, we find that the proportions of upland households in different quadrants (see Table 4.1) have been changing over time. In 1995, the largest proportion of households (37%) was in Quadrant 4 (or Q4) where households engaged in both area expansion and off-farm work. The smallest proportion (19%) was in Q1 where they did not engage in either of these activities. However, in the years that followed, the largest proportion of households shifted to Q3 which indicates that the largest proportion of households engaged only in off-farm work and stayed away from forest degrading activities. The doubling of the proportions in Q3 corresponds to the halving of the proportions in Q4 which were cut to more than half to 14%, 13% and 18% in 1997, 1999 and 2002, respectively (Table 4.10). The proportions of households in Q2 also declined by at least 50% in the 1997, 1999 and 2002 samples. This implies that they have been pulling away from agricultural expansion in the forest lands and engaging in more off-farm work. The slightly higher proportion of households in Q1 in 1999 and 2002 indicates that some of the households shifted to allocating more resources towards on-farm agricultural production and other livelihood activities.

Table 4.10 Proportion of Households in the Four Quadrants of the Decision Matrix

Quadrant	1995	1997	1999	2002	All
% with agriculture only (1)	19	17	27	21	21
% with agriculture and expansion (2)	20	3	10	9	10
% with agriculture and off-farm (3)	24	67	50	52	48
% with agriculture, off-farm and expansion (4)	37	14	13	18	21
Total*	100	101	100	100	100

* Note: May exceed 100% due to rounding-off.

Tables 4.11 and 4.11 present the summary of the means of the variables sorted by quadrant. The identification of these variables is based on the specified variables in the jointly estimated regression models presented in Table 4.6, so as to facilitate cross examining the regression results from a different perspective.

4.4.3.1 Spatial Aspect

While the regression results in Table 4.6 do not show any link between the distance of upland residence to the lowlands and the number of workdays and forest clearing, the results of the matrix analysis show that in 1995, 1999 and 2002, there are larger proportions of households (25%, 33% and 28%, respectively) who are involved in *agricultural expansion only* who lived far from lowland farms. Their far distance from the lowlands in return brings them closer to the public forest lands which, to a certain extent, provides them with better access to expanding agricultural production on these lands.

On the other hand, among the four quadrants, Q3, on average, has the smallest proportion of households (14%) living far from the lowlands. This implies that most (86%) of the households engaged in off-farm work are residing closer (or less than 30 minutes of walk) to lowland farms. The remoteness of residence acts as a disincentive for upland households to supply off-farm labor to the lowlands.

In 1995, 1997 and 2002, Q1 has the largest proportions of households living remotely from the lowlands which might indicate that distance not only limits access to employment but also agricultural expansion as well. The overall proportion of the remote households in Q4 is, less than Q2 but greater than Q3 (Table 4.11). This indicate that there are more upland households living in the remote area who engaged in both expansion and off-farm work than those doing off-farm work only. But, as expected, there are more remote households doing agricultural expansion only than doing both off-farm work and expansion.

4.4.3.2 Age Effects

In terms of age, it was found that in 1995, 1999 and 2002, Q4 contains, on average, the youngest set of household heads. This pattern supports the regression results in Table 4.2 where age is positively correlated with the number of off-farm work and negatively correlated with the area of agricultural expansion. It appears here that the younger households prefer to engage in diversification and expansion. In contrast, older households appear to be less inclined to engaging in either activities, as exhibited by the presence of the oldest sets of households in Q1 in 1995, 1997 and 1999.

4.4.4.3 Human Capital

The decision matrix analysis results show that, on average, households specializing in off-farm employment have more years of schooling than those specializing in expansion only. This finding casts light on the regression results in Table 4.2 where the education of household head is not correlated with the number of workdays. The matrix analysis shows that average years in schooling in Q1 and Q4 is higher than in Q2 and Q3. Using this method of analysis, we are able to specifically identify the group of households engaging in off-farm work only and agricultural expansion only.

4.4.3.4 Property Rights

Consistent with the regression results in Table 4.6, no obvious patterns appear between variables of interest and the proportion of upland households with land tenure. This indicates that the issuance of property rights to upland households may not influence upland households' decision to engage in employment and/or reduce pressure on forest resources.

4.4.3.5 Landholding Size

The decision matrices for 1995, 1997 and 2000 indicate that, as expected, households who are mainly engaged in agricultural production have the largest average farm size. The average farm size in Q1 is the largest among the four quadrants. This supports the notion that larger farms could accommodate enough livelihood activities (mainly agricultural production) to meet the economic needs of the household. The amount of time devoted to on-farm agricultural production consequently limits the households' capacity to expand agricultural activities into the forest lands and also limits its engagement in off-farm employment.

In contrast, for 1995, 1999 and 2002, Q4 has the smallest farm size among the four quadrants. This implies that households who own smaller farms have the tendency to engage in both agricultural expansion and income diversification to satisfy their livelihood needs. Quadrants (2) and (3), where households engaged in only one of the two options (either expansion or diversification), have middle sized farms.

4.4.3.6 Labor Force

Consistent with the regression results in Table 4.2, the results of the decision matrix indicate that in 1995, 1999 and 2002, the group of households engaging in *expansion only* have more workers compared to those engaging in off-farm work only. The average for the full sample shows the highest average number of workers in Q2 and lowest in Q3. Larger upland households put more pressure on forest resources. Smaller households engage in off-farm work.

4.4.3.7 Capital Sourcing

The decision matrix for credit shows that, in 1995 and 1997, the working capital from credit sources was used by 33% of the households who engaged in expansion only. However, this changed in 1999 and 2002 since the proportion of households who borrowed money decreased to 11% and 0%, respectively. This shows a pattern where, upland households engaged in agriculture and forest clearing had a tremendous decline in availing credit in 1999 and 2002. While households engaged in agricultural production only appear to be most dependent on credit as a source of capital despite the abrupt decline in the average amount of loan between 1999 and 2002 (Table 4.12).

4.4.3.8 Farm Assets

The regression results in Table 4.2 show that ownership of an important farm asset, carabao, has no influence on the number of workdays and area of land cleared. However, results from the matrix analysis show that in 1997, 1999 and 2002, a greater proportion of households with *off-farm work only* have carabaos compared to the proportion of households engaged in *expansion only*. In 1997, none of the households who cleared forest owned a carabao while about 35% the households who engaged in off-farm work owned at least one carabao. This sheds light on the importance of carabao in the decision of upland households to engage in off-farm employment.

4.4.3.9 Household Income

In 1995, 1997 and 2002, households engaged in off-farm only had higher total income compared to those engaged in expansion only. Results from the decision matrix for the average total income for all years show that households who engaged in *expansion only* were the poorest among the four groups. This is consistent with the widely held view in the environment and development literature that upland households who practice slash and burn agriculture are the poorest of the poor. On the other hand, the group of households who decided not to engage in either expansion or employment is, on average, the group with the highest average income.

After the decision matrix analysis, case studies are used to corroborate some of the selected findings from the regression results. These are presented in the next section.

Table 4.11 Summary of the Quadrant Means of Selected Variables 1

	1995	1997	1999	2002	All
Distance residence from the lowlands (0/1)					
Agriculture only (1)	0.39	0.35	0.19	0.29	0.29
Agriculture and expansion (2)	0.25	0.00	0.33	0.28	0.26
Agriculture and off-farm (3)	0.10	0.12	0.16	0.16	0.14
Agriculture, off-farm and expansion (4)	0.29	0.07	0.23	0.22	0.23
Age of household head (years)					
Agriculture only (1)	42	42	41	45	43
Agriculture and expansion (2)	39	33	40	54	44
Agriculture and off-farm (3)	41	38	40	42	40
Agriculture, off-farm and expansion (4)	36	38	38	39	38
Education of household head (years in school)					
Agriculture only (1)	2.5	0.8	2.0	3.0	2.3
Agriculture and expansion (2)	0.9	0.0	2.1	0.8	1.1
Agriculture and off-farm (3)	1.3	1.4	1.5	1.2	1.4
Agriculture, off-farm and expansion (4)	1.8	0.9	0.8	1.9	1.6
Land security (proportion with CSC)					
Agriculture only (1)	0.70	0.41	0.62	0.55	0.58
Agriculture and expansion (2)	0.67	1.00	0.60	0.56	0.63
Agriculture and off-farm (3)	0.83	0.46	0.52	0.50	0.53
Agriculture, off-farm and expansion (4)	0.69	0.36	0.62	0.69	0.64
Farmsize (ha)					
Agriculture only (1)	3.46	2.34	2.07	2.29	2.49
Agriculture and expansion (2)	2.38	1.36	1.83	2.19	2.17
Agriculture and off-farm (3)	2.70	2.07	2.06	2.06	2.14
Agriculture, off-farm and expansion (4)	2.26	1.66	1.76	1.71	1.94
Number of agricultural workers					
Agriculture only (1)	2.09	2.18	2.22	2.38	2.25
Agriculture and expansion (2)	2.25	1.33	2.67	2.89	2.48
Agriculture and off-farm (3)	2.07	1.53	1.92	2.47	2.06
Agriculture, off-farm and expansion (4)	2.31	2.07	1.92	2.72	2.37
Farmsize per worker					
Agriculture only (1)	1.9	1.4	1.1	1.1	1.3
Agriculture and expansion (2)	1.3	1.2	0.9	1.1	1.2
Agriculture and off-farm (3)	1.4	1.4	1.3	1.0	1.2
Agriculture, off-farm and expansion (4)	1.1	0.9	1.3	0.8	1.0
Credit (0/1)					
Agriculture only (1)	0.35	0.24	0.22	0.17	0.23
Agriculture and expansion (2)	0.33	0.33	0.11	0.00	0.19
Agriculture and off-farm (3)	0.21	0.24	0.16	0.11	0.16
Agriculture, off-farm and expansion (4)	0.11	0.14	0.23	0.14	0.14

Table 4.12 Summary of the Quadrant Means of Selected Variables 2

	1995	1997	1999	2002	All
Credit Amount (kg of rice)					
Agriculture only (1)	360	270	292	77	220
Agriculture and expansion (2)	111	167	26	0	63
Agriculture and off-farm (3)	36	181	98	33	87
Agriculture, off-farm and expansion (4)	41	27	101	13	37
Credit Amount (kg of rice no zeroes)					
Agriculture only (1)	1034	1146	1313	461	958
Agriculture and expansion (2)	332	500	231	0	338
Agriculture and off-farm (3)	173	469	612	313	529
Agriculture, off-farm and expansion (4)	370	192	436	91	267
Carabao (0/1)					
Agriculture only (1)	0.43	0.35	0.33	0.36	0.37
Agriculture and expansion (2)	0.38	0.00	0.22	0.28	0.30
Agriculture and off-farm (3)	0.38	0.34	0.42	0.36	0.37
Agriculture, off-farm and expansion (4)	0.24	0.36	0.46	0.33	0.31
Carabao (Number of Carabaos)					
Agriculture only (1)	0.52	0.35	0.48	0.55	0.50
Agriculture and expansion (2)	0.38	0.00	0.44	0.44	0.39
Agriculture and off-farm (3)	0.38	0.35	0.60	0.51	0.47
Agriculture, off-farm and expansion (4)	0.24	0.36	0.46	0.44	0.35
Carabao (Number of Carabaos no zeroes)					
Agriculture only (1)	1.2	1.0	1.4	1.5	1.4
Agriculture and expansion (2)	1.0	0.0	2.0	1.6	1.3
Agriculture and off-farm (3)	1.0	1.0	1.4	1.4	1.3
Agriculture, off-farm and expansion (4)	1.0	1.0	1.0	1.3	1.1
Total Income (kg of rice)					
Agriculture only (1)	4017	2097	1712	2291	2481
Agriculture and expansion (2)	1577	4509	2166	1426	1788
Agriculture and off-farm (3)	1810	2532	2481	1589	2050
Agriculture, off-farm and expansion (4)	2152	3190	2299	1430	2063
Income per capita (kg of rice)					
Agriculture only (1)	838	461	374	640	588
Agriculture and expansion (2)	365	826	487	636	501
Agriculture and off-farm (3)	492	681	553	353	498
Agriculture, off-farm and expansion (4)	578	637	829	303	524
Income per worker					
Agriculture only (1)	2177	1228	1004	1180	1354
Agriculture and expansion (2)	842	3842	1322	899	1108
Agriculture and off-farm (3)	953	1770	1428	829	1219
Agriculture, off-farm and expansion (4)	1000	1684	1652	669	1057

4.4.4 Case Studies

Five upland households were selected to serve as specific cases that might help further illuminate findings from the regressions and decision matrix study. The case studies are as follows:

1. Case 1 is studied in a more detailed manner than the others, with the goal of making it cut across the results of both regression and decision matrix analyses.
2. Cases 2 and 3 are used specifically to examine the regression results on labor supply and asset accumulation.
3. Cases 4 and 5 are used to illustrate household decisions regarding input allocation and access to working capital.

4.4.4.1 Case 1 – From Agriculture and Forestry to Agriculture and Off-Farm Work

Case 1 represents an upland household that prioritizes on-farm agricultural production. This household was observed four times. In all years it concentrated on producing annual and perennial crops, livestock, and occasionally engaging in off-farm work in the lowlands. It never reported expanding agricultural production into forest lands. Although there was no engagement in forest clearing activities, this household generated income from sale of products collected or hunted from the forest, such as Manila copal, fuelwood, honey and wild animals (e.g., wild boar, bats, birds).[21] Over time, returns from these non-timber forest products dramatically decreased from 1,309 kg

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[21] Sales of hunted wild animal products were reported mostly in 1995 and reported seldomly from 1997 to 2002, most likely because the 1995 survey contained a detailed sub-section on hunting practices.

of rice-equivalent income in 1995, to 183, 92 and 51 kg of rice respectively in 1997, 1999 and 2002. This income trend reinforces the idea that some upland households have been moving away from forest clearing activity and also from the collection and sale of forest products.

With the declining dependence on forest products over time, Case 1 compensated by intensifying agricultural production, on a farm that was relatively large (4.0 ha compared to the full upland sample average of about 2.2 ha). With agricultural intensification, the household increased the share of agricultural income to total household income (in real terms) from 0.75 in 1995 to 0.94, 0.99 and 0.95 in 1997, 1999 and 2002. Household real income per capita rose from 1,225 kg of rice in 1995 to 2,179 and 2,839 respectively in 1997 and 1999. However, this income declined dramatically in 2002 to 732 kg of rice. This pattern and level are similar to the average income trend in the full upland sample.

How did this household manage to intensify? This household initially increased production expenditures on variable inputs (primarily labor, fertilizer and pesticides) from 127 kg of rice worth of inputs in 1995 to 1,357 kg of rice in 1997 and then settled to 403 and 71 kg of rice in 1999 and 2002. The relatively large expenditure in 1997 initiated the shift from an agriculture and forestry income portfolio to an agriculture-dominant portfolio. In 1997 and 1999, the higher expenditure on variable inputs allowed this household to increase the income share of rice and corn from 0.35 in 1995 to 0.51 and 0.88 in 1997 and 1999. However, in 2002, the household did not produce rice and corn, preferring instead to cultivate other perennial crops (cassava and banana) and tree crops (coconut, cashew and mango) which have either a relatively higher value or permit value added processing (e.g., processing of banana and cassava as snack foods). Also in 2002, the household experienced the highest income from sale of livestock, i.e., chicken and swine, valued at 1,714 kg of rice-equivalents -- twice the level in previous years combined.

The household's upland agricultural activities in 2002 emphasized tree crops and livestock raising. These, in theory, are causing less harm (or might be friendly) to the fragile upland ecosystem compared to the cultivation of rice and corn. For this reason, this household might be aware of the consequences to the upland environment of annual crop cultivation.

While the household has not been expanding into forest areas, it appears to have been successful in accumulating carabao, which is believed to facilitate consumption smoothing. In all the observed years, the household always owned at least one carabao. In 1995 and 1997, it had one head of carabao but this increased to two and three heads in 1999 and 2002, respectively. Carabao is considered an important provider of draft power in farming operations, particularly in land preparation and hauling both farm inputs and produce. As a result, this increase in the number of heads of carabao might indicate that the household has further plans of intensifying on-farm agricultural production. Furthermore, in 2002, this household used carabao to engage in off-farm employment in the lowlands allowing a relatively higher wage compared to working without an assistance of carabao. One reason for participation in off-farm work is the location of the household residence (total travel time is less than 30 minutes walking to reach the lowland irrigated farms).

Although the household head did not have any formal education, the real income per capita of this household is in the top 16% of the 2002 sample and in the top 20% in the other sample years. Aside from agricultural production, another emerging contributor to its household income is off-farm employment in the adjacent lowlands. Although income share from off-farm work was only 0.01, 0.05, 0.00, and 0.04 in the respective sample years, in the latter part of 2002, this upland household was accepted as a tenant farmer on a lowland irrigated farm. Thus, this case serves as evidence that lowland irrigation development, which increases employment opportunities in the lowlands, has been attracting and/or pulling upland households, like Case 1, away from land degrading activities in the uplands into a more stable farming system in the lowlands.

4.4.4.2 Case 2 – A Shift From Agriculture to Off-Farm Work 1

Case 2 household was observed twice, first in 1995 and last in 2002. In 1995, the household did not engage in off-farm work instead relying on agricultural production on-farm and in the forest areas as main source of income. In 2002, the household head engaged in off-farm work (with his wife) working for a total of 56 days on lowland farms. This gave them a total off-farm wage income of P5,320 making income from off-farm work account for 69% of total household income in 2002. During the same year, income from sales of forest products (i.e., charcoal making) accounted for 28% while agricultural income (mainly from corn production) accounted for only 2% of the total income.

The above scenario illustrates an upland household's transformation from semi-subsistence agricultural production to off-farm work orientation. The household's area planted to rice and corn was reduced from 2.5 ha in 1995 to only 0.75 ha in 2002. There was also a reduction in the area of forest clearing by half (0.5 ha to 0.25 ha). This might indicate that part of the labor spent on forest clearing in 1995 was reallocated to off-farm work activities in 2002.

Some household characteristics that are consistent with the findings on off-farm employment participation include the following: (1) a below average farm size in 2002 (1.25 vs. 2.04 ha in 2002); (2) the residence was situated relatively close to the lowlands; and (3) a household head relatively younger than the average in that sample (32 vs. 43 in 2002). On the other hand, the continuation of forest clearing activities in 2002 might be linked to: (1) above average number workers (4.0 workers vs. 2.5 workers in 2002); and (2) below average farm size (1.25 vs. 2.04 ha in 2002).

4.4.4.3 Case 3 – A Shift from Agriculture to Off-Farm Work 2

Regression results indicate a shift from high forest dependence in forest areas to an increase in dependence in agriculture and off-farm work. Drawn from the balanced panel data set of 86 upland households observed in all rounds, Case 3 emerges as an upland household with one of the largest number of work days spent on lowland farms. In 2002, this household worked a total of 150 days on lowland irrigated fields receiving an average wage of 7.14 kg of rice per day. This is a large increase over the 9 days of work on rainfed lowland rice and corn fields reported in 1995 (and paid at an average of 4.55 kg of rice per day). With the increase in the number of workdays and increase in off-farm wage between these years, real income from off-farm work increased by more than 26 fold from about 41 kg of rice in 1995 to about 1,071 kg of rice in 2002. This scenario led the share of off-farm income in total household income to increase more than 28 fold from only 0.03 in 1995 to about 0.86 in 2002. This happened despite the household not owning a carabao. The household's strong participation in off-farm employment despite the absence of carabao is consistent with the regression results showing that, controlling for other factors, an absence of correlation between the number of work days and carabao ownership.

The dramatic increase in the dependence on off-farm employment was made possible by the reallocation of labor from on-farm agriculture and agricultural expansion into off-farm work in the lowlands between 1995 and 2002. In 1995, the share of income from agricultural production stood at 0.97. This high dependence on agricultural production was made possible by agricultural expansion, which entailed the clearing of 1.26 ha of public forest land which was planted to corn (1.01 ha) and rice (0.25 ha). The income shares of corn and rice were 0.86 and 0.02, respectively. In 2002, there was a significant reduction in the area allocated for corn production but rice production increased. Rice area increased to 1 ha while corn area was reduced to 0.13 ha. The area of forest clearing was reduced to 0.5 ha. Consequently, real income from corn decreased from 1,273 kg of rice-equivalents in 1995 to nearly zero in 2002 while real income from rice more than doubled from 36 kg of rice-equivalents in 1995 to 80 kg of rice-equivalents in 2002. Thus, Case 2 provides evidence of a pattern of decreasing dependence on forest resources and a shift to on-farm agriculture and off-farm employment in lowland irrigated farms. However, compared to the income portfolio of other households, Case 3's portfolio in 1995 and 2002 is focused only on on-farm agricultural production, agricultural expansion and off-farm employment. This household did not get income from forest products or other income sources.

In 2002, the household head was 32 years old, which is younger than the average farmer (43 years) in the 2002 sample. This supports the regression results presented in Table 4.6 which suggest that households with younger household heads are likely to spend more days in off-farm work than older ones.

Similar to Case 1, this household never had any formal education yet was able to participate in off-farm work. This supports the regression results that suggest that the years of education of household head and the number of off-farm work days are not strongly correlated. The household has insecure land tenure and this is also consistent with the regression patterns showing no strong association between land tenure and off-farm work.

4.4.4.4 Case 4 – Input Purchase Decision 1

Regression results on input allocation suggest that households who have access to credit are likely to apply greater amounts of fertilizer and pesticides. The results also imply that households with more years of formal education school would tend to use more fertilizer and pesticides per ha of rice or/and corn plot/s. Pairwise correlation between education and access to loans indicate that these two variables are positively associated with a correlation coefficient of 0.16 significant at the 1% test level. This implies that households with more years of education have slightly better access to loans than their counterparts with less education.

Case 4 is a household in which the head received two years of formal education. The household is residing relatively close to lowland farms. This household had a loan in 1995 but not in 2002. It purchased fertilizer and pesticides in 1995 but only fertilizer in 2002. The amount of labor per ha of rice and corn decreased from 57 days/ha in 1995 to only 8 days/ha in 2002. This decrease in labor allocation might have been offset by the increase in expenditures in variable inputs (from a real price equivalent of 254 kg or rice in 1995 to 646 kg of rice in 2002), which substituted labor.

This household cleared 1 ha of forest land in 1995 but did not clear any in 2002 and concentrated on agricultural production on farm and did some off-farm work on lowland farms. It earned a total of 206 kg of rice from off-farm work in 2002 which accounted for 6% of total real income of the household. The other 94% of income came from the sale of corn, banana and rootcrops. This household did not cultivate rice in 2002. It is also interesting to note that this household devoted 24 days to off-farm work in 2002 and none in 1995. The household owned a carabao and had an above average farm size of 4 ha.

The main pattern here is that this upland household, who did not participate in off-farm work during the rainfed year but did participate during the post irrigation year, has the following characteristics: (1) an upland household residing close to the lowlands; (2) increasing usage of agricultural chemicals while decreasing amounts of on-farm labor; (3) owning a relatively large upland farm; and (4) owning a draft animal. However, among these four items, only item (3) is consistent with the regression results from Model 4.1 which show that larger farms participate more in off-farm work.

4.4.4.5 Case 5 - Input purchase decision 2

The head of household for Case 5 did not have any formal education and was residing in a remote area which requires at least an hour of walk from the lowlands. This household, who was observed in 1995 and 2002, had never availed of any loan and never purchased any fertilizer and pesticides for farm production. This is consistent with the regression results in Table 4.6 which suggest education and distance are negatively associated with the purchase of fertilizer and pesticides, and access to credit is positively associated with the purchase of these inputs.

The patterns exhibited by Case 5 also support the regression results for the input allocation model which suggest that both distance and human capital matters when it comes to upland households' decisions to purchase inputs for their agricultural production or their use of credit. The full upland data set demonstrates a negative correlation (ρ = -0.14, significant at $\alpha = 0.01$) between the distance of the residence from the lowlands and access to credit which indicates that the further the household resides from the lowlands, the more limited the access to credit becomes. The data set also reveals a positive association (ρ = 0.15, significant at $\alpha = 0.01$) between education and access to credit which indicates that human capital matters if an upland household would like to borrow money.

4.5 Discussion and Findings

In the developing world, the problem of deforestation has long been associated with agricultural expansion in frontier areas (Barbier, 1997). In line with this view, this chapter presented a 10-year scenario wherein a group of upland households exhibited a decrease in agricultural expansion by participating in off-farm employment in the adjacent lowlands. This study centered on the factors that, in an empirical sense, contribute to the decrease as well as the increase in deforestation activities in the uplands.

Based on the results of regression, decision matrix and case study analyses, irrigation development in the lowland communities over time was seen to produce positive economic and environmental impacts on the adjacent upland communities. This positive economic impact appears to be sustained over time as reflected by the doubling and tripling of income from off-farm work in the years with lowland irrigation development compared to the year with no irrigation. The initial environmental gain, as exhibited by the decrease in deforestation activities in 1997, has also been sustained over time as observed in the statistically significant decrease in forest clearing activities in the years when the lowland irrigation facilities became operational. This sheds light on the question asked regarding the sustainability of initial gains by showing both a detailed and a concise picture of the sustainable positive economic and environmental off-site impacts of the shift to agricultural intensification in the lowlands over the 10-year period (Table 4.13).

From a broad overview of the impacts of lowland development, we list some of our specific findings based from the results of the analyses.

Finding 1. Lowland employment is economically beneficial for upland households. With agricultural intensification in the adjacent lowlands, off-farm employment became even more attractive for upland households with the increase in the average off-farm wages. Although the real off-farm wage is positively associated with the ownership of carabao, there are also households who have no carabao who engaged in off-farm employment (i.e., Case 3). Compared to income from agricultural production, incomes from off-farm work appear to have lower risk as exhibited by the increasing average income from off-farm work while all the other income sources have been decreasing through time. Another benefit from off-farm work is that upland households have the possibility of obtaining the excess amounts of pesticide inputs from their lowland employers which might be enough for their use on their smaller upland farms. For these reasons, we see a pattern of increasing dependence to off-farm employment of upland households as exhibited by the increasing income share of off-farm work to total household income over the years.

Table 4.13 Economic and Environmental Impacts on Upland Communities of the Adjacent Lowland Irrigation Development Over the 10-Year Cropping Period

	On-Farm	**Off-farm**	**Forest**
Economic impact	↓ Slightly decreasing dependence on agricultural production as income source. (Emphasis on tree crops)	↑ Increasing dependence in off-farm work sustained over time	↓ Forest clearing and forest products gathering reduced significantly
Environmental impact	↑ Slightly decreasing environmental degradation due to an emphasis on tree crop cultivation	↑ Pull away upland households from forest clearing	↑ Decrease pressure on forest resources giving more allowance to regenerate

Finding 2. Agricultural intensification on adjacent lowland farms leads to less agricultural expansion in the uplands. This is seen, over time, in the decrease in forest area cleared by upland households, the decrease in the proportion of households engaged in forest clearing and the decrease in the share of income from forest resources. Our

longitudinal analysis casts light onto the question of whether *initial environmental gains are sustained over time*. Based from the behavioral patterns in the 10-year data, we answer this question by *yes.*

Finding 3. The demand for lowland off-farm workers from upland farms can be sustained over time. The increase in the average off-farm wage over time appears to encourage upland household to participate in off-farm work. This is demonstrated by pattern of increasing proportion of households engaged in off-farm work and the increase in the number of days spent on off-farm work. There were also reported cases of an increasing number of households who were employed as full time farm laborers in the lowlands. The case of one upland farmer who turned into a tenant farmer in 2002 on a lowland irrigated rice farm, might serve as a success story of an increasing demand of upland labor into lowland irrigated farms. This might also indicate a potential for resettlement into the lowlands of upland households to somehow more permanently pull them away from an upland agriculture setting to a lowland agricultural setting.

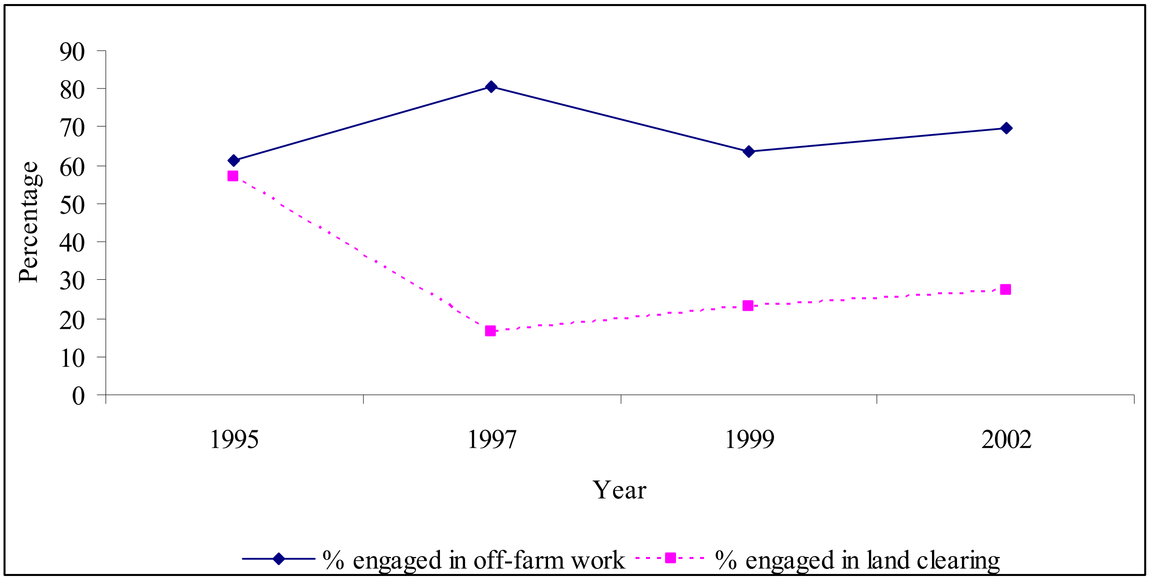

Figure 4.1 Proportion of Households with Off-farm Work and Those Who Engaged in Forest Clearing (1994 to 2003)

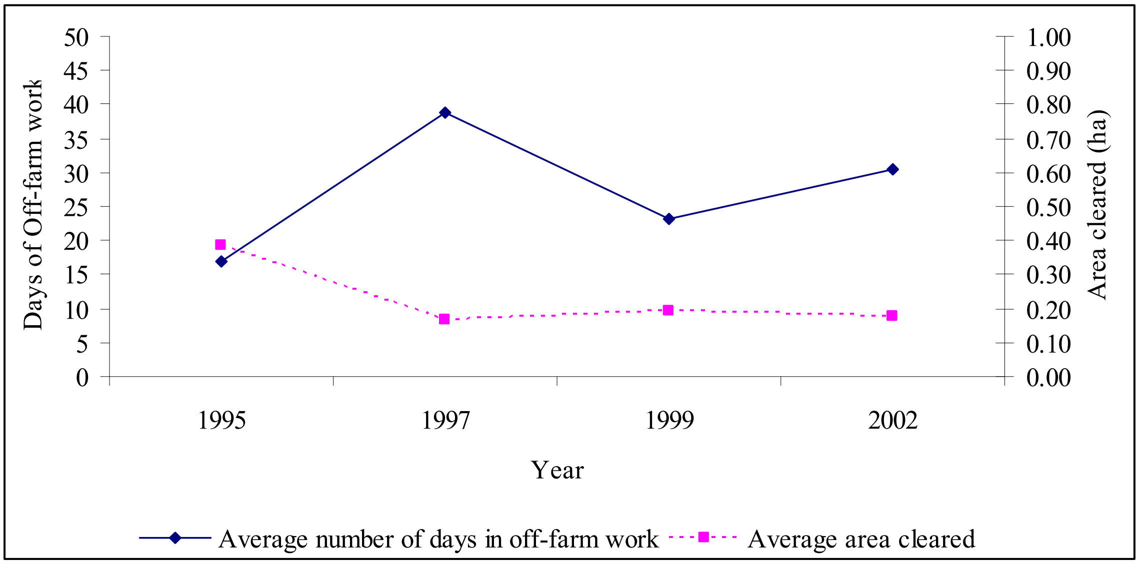

Figure 4.2 Average Number of Off-farm Work Days and Average Area Cleared (1994 to 2003)

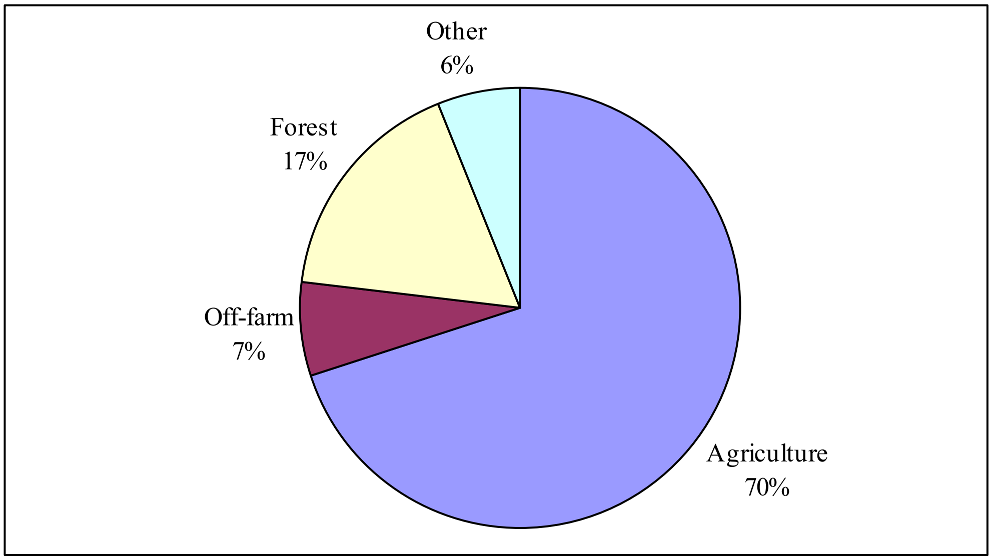

Figure 4.3 Distribution of Income by Sources in 1995 (n=121)

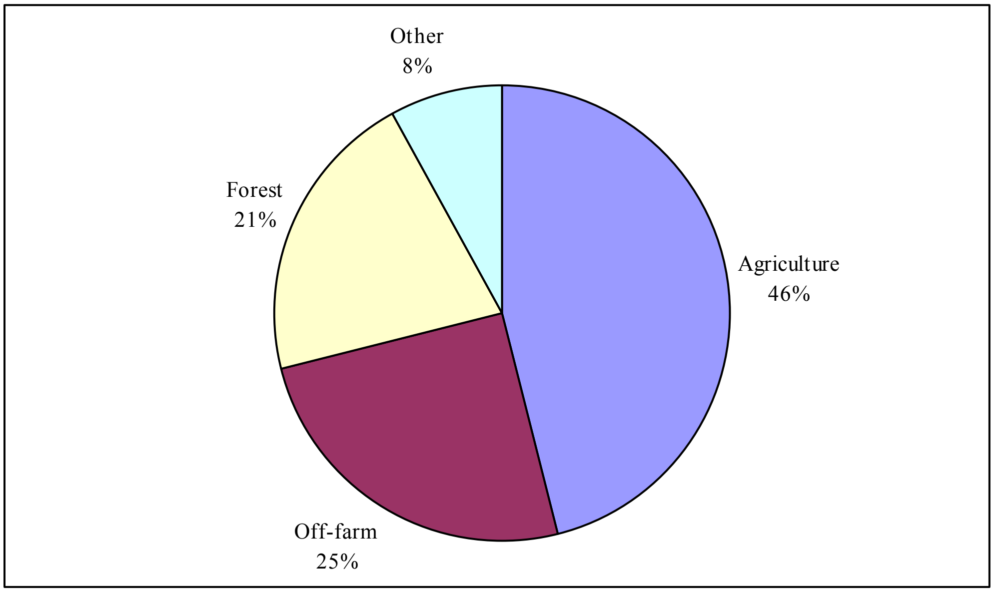

Figure 4.4 Distribution of Income by Sources in 1997 (n=102)

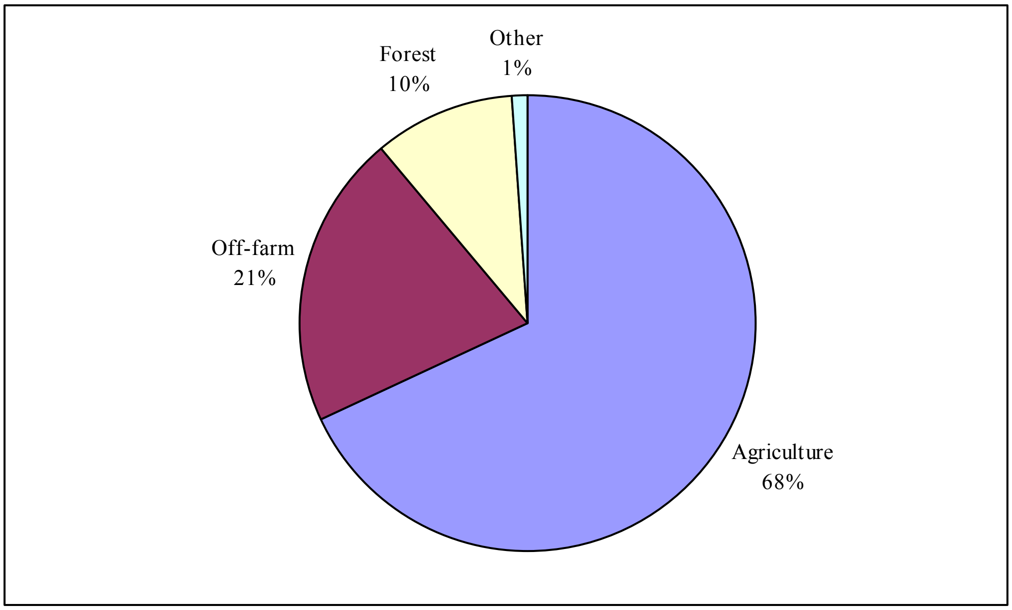

Figure 4.5 Distribution of Income by Sources in 1999 (n=99)

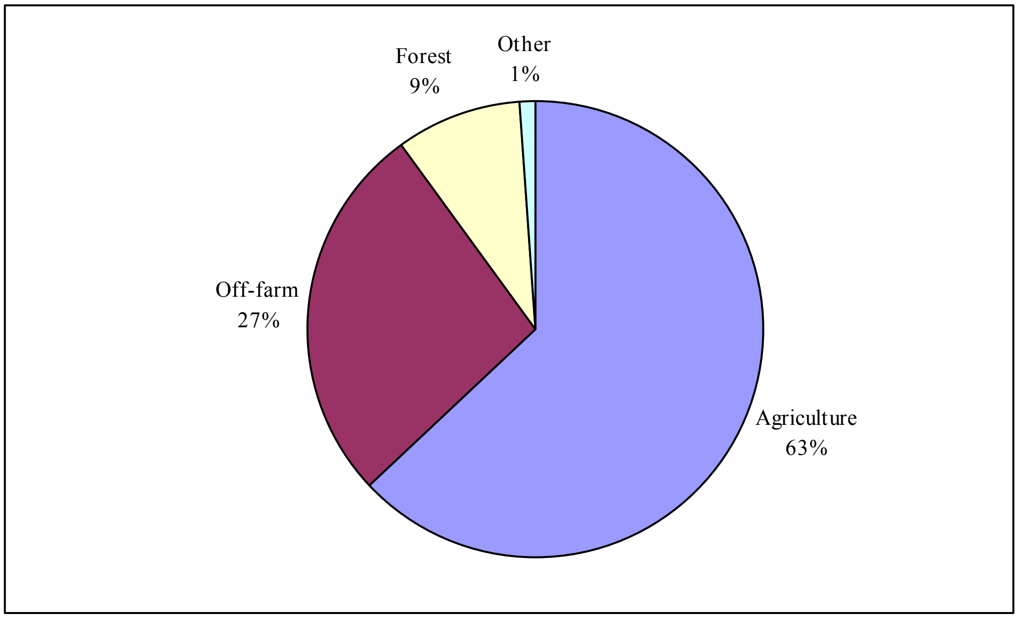

Figure 4.6 Distribution of Income by Sources in 2002 (n=199).

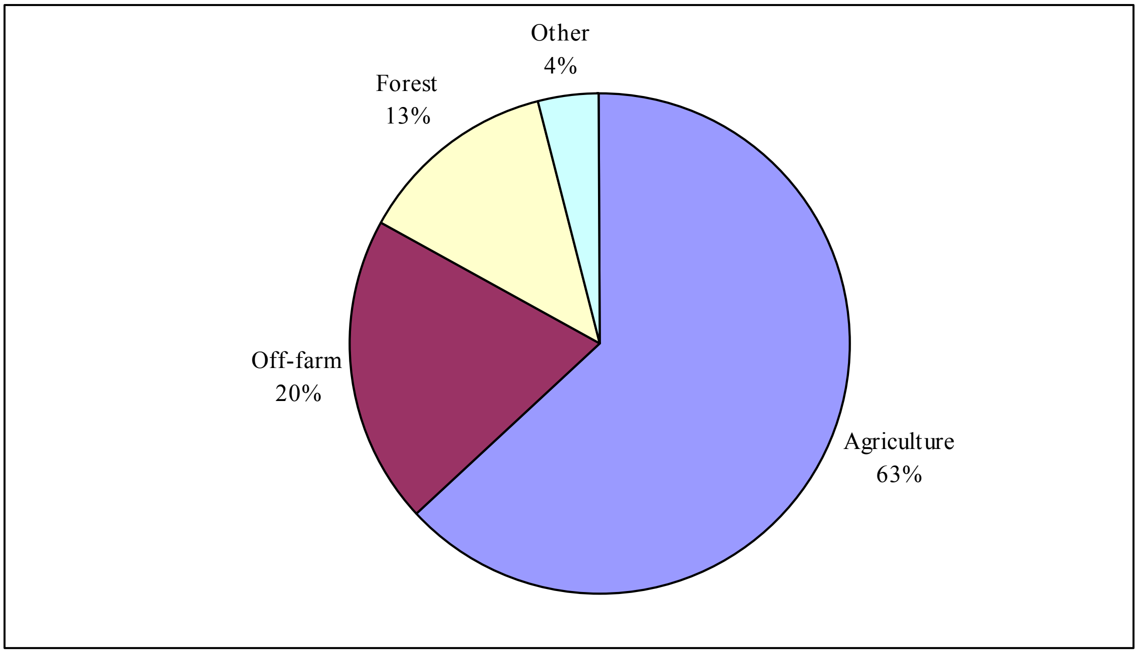

Figure 4.7 Distribution of Income by Sources for All Years (n=521)

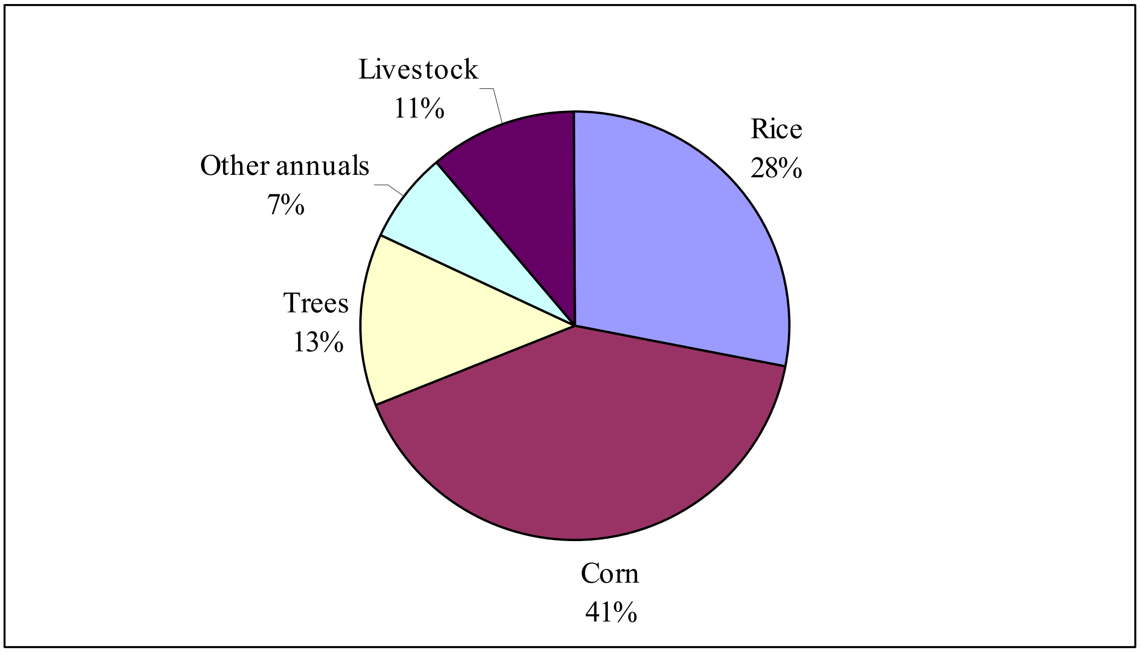

Figure 4.8 Distribution of Agricultural Income by Sources in 1995 (n=121)

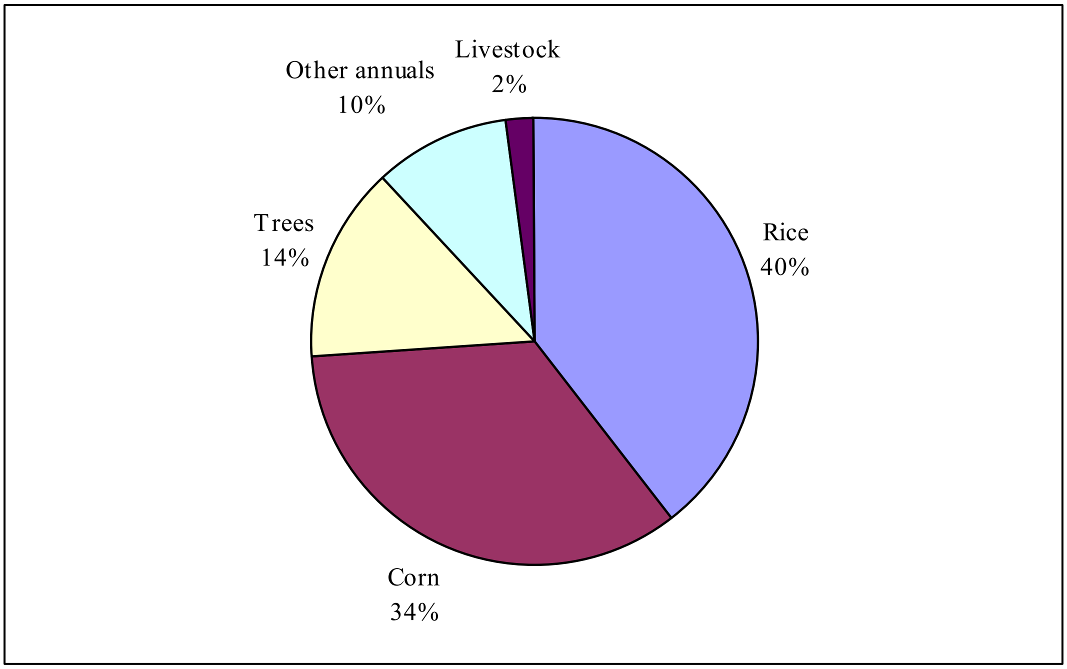

Figure 4.9 Distribution of Agricultural Income by Sources in 1997 (n=102).

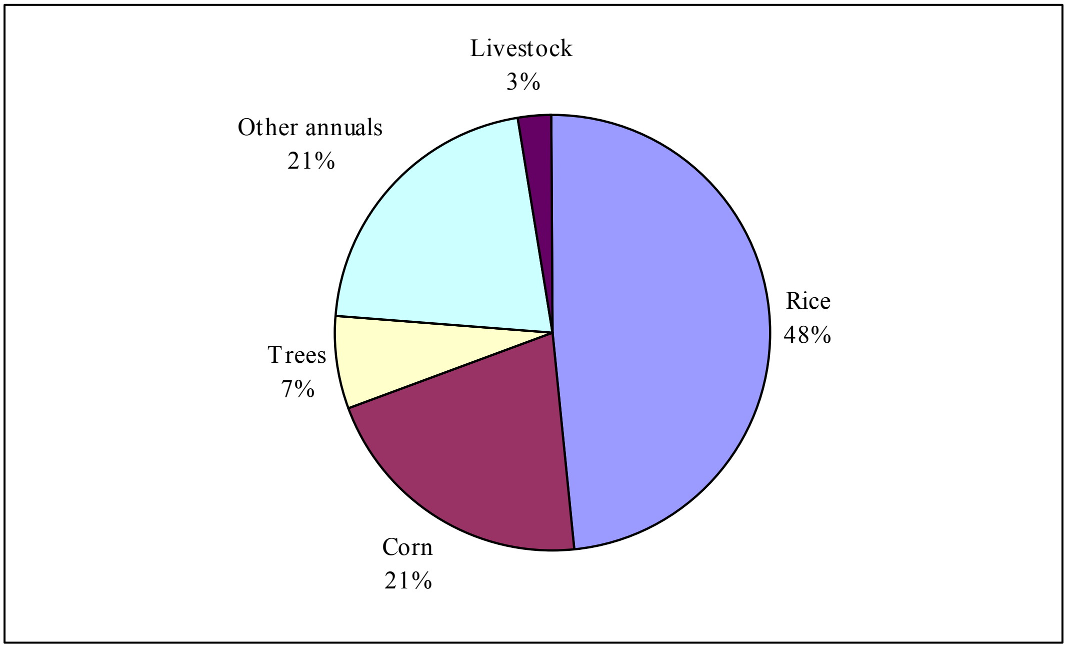

Figure 4.10 Distribution of Agricultural Income by Sources in 1999 (n=99).

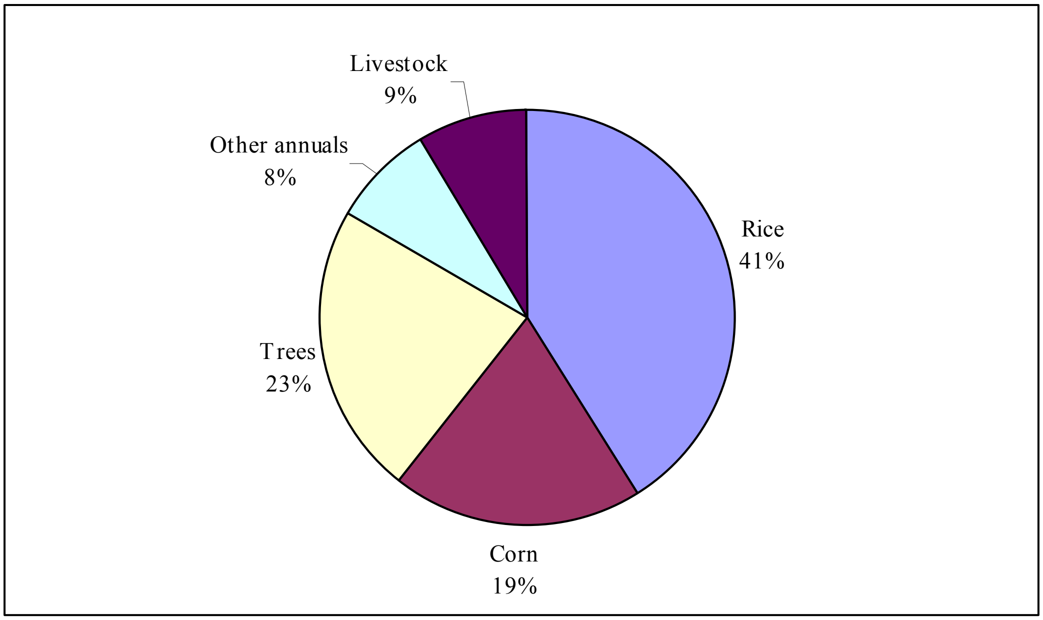

Figure 4.11 Distribution of Agricultural Income by Sources in 2002 (n=199)

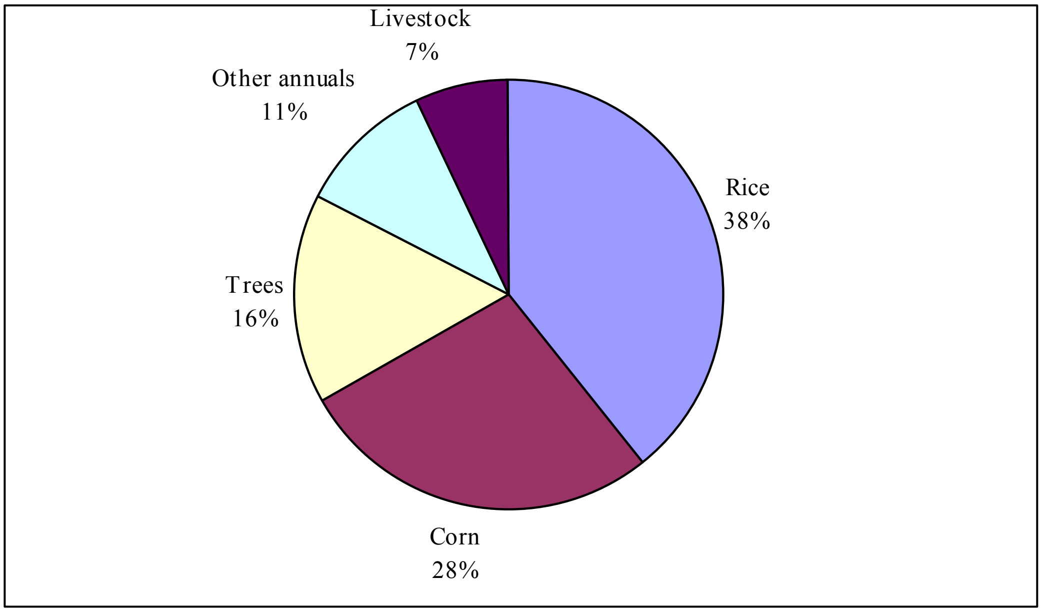

Figure 4.12 Distribution of Agricultural Income by Sources for All Years (n=521)

CHAPTER 5

INCOME INEQUALITY AND POVERTY IN THE STUDY COMMUNITIES

5.1 Overview

Irrigation development is an important factor for improving agricultural incomes and promoting rural wealth accumulation, particularly in the low-income tropics (Bhattarai, et al 2002). In developing countries, irrigation is considered a key determinant of poverty reduction since it contributes to land improvement, which in turn serves as an important vehicle for speeding up poverty reduction (Balisacan, 2001). However, despite its favorable impact on agricultural incomes and poverty alleviation, irrigation has been shown to exacerbate income disparity within irrigated farming communities (Bhattarai, et al 2002; Sampath 1990; Adriano, 1980). Irrigation systems, particularly the dam-type system (or gravity-diversion systems), bring greater inequality in the distribution of benefits across lowland farms as compared with groundwater or lift irrigation systems (Sampath, 1990; Shah, 1998; Shah, 2001). One reason is that rice farms most distant from the main water source (i.e., irrigation main canals) usually have the least security of water supply (Bromley, Taylor, and Parker, 1980; and Adriano, 1980). Another reason is that in such irrigated areas, larger landholdings frequently have more secure water supplies than smaller farms (Sampath, 1990; Bromley, Taylor, and Parker, 1980; Adriano, 1980). Past studies have highlighted situations where irrigation contributed to greater income inequality in rural areas of the humid tropics. Greater income inequality may perpetuate poverty and may also increase the tendency for governments to adopt policies and programs that reduce productive efficiency (Binswanger and Deininger, 1997). For these reasons, recipient communities of irrigation development might possibly be worse off in terms of income distribution. This conjecture motivates us to study the distributional impact of irrigation development in the low-income tropics.

Most studies on the distributional impact of irrigation development focus on the impact within the beneficiary lowland farming communities (Thapa, Otsuka and Barker, 1992; Adriano, 1980) and between lowland benefactors and the adjacent lowland non-benefactors (David, Cordova and Otsuka, 1994). Numerous studies have dealt with the distributional impact of irrigation at the aggregate level – between countries or between regions (Hussain and Wijerathna, 2004; Sampath, 1990; Ramasamy, et al. 1992). Most analysts use cross-country data sets observed at a point in time or household-level cross-sectional data sets. Although some studies on the distributional impact of irrigation development have used longitudinal data (Hossain, 2001), studies of this type remain scarce. Moreover, there is no study that we are aware of that addresses irrigation's off-site distributional impacts.

This study attempts to fill this gap in the literature using panel data from farm households in the southern district of Palawan, the Philippines. At the site, the operation of a pair of dam-type irrigation facilities has been found to have had economic and environmental impacts on adjacent non-irrigated upland communities. A number of studies conducted in the study sites have discussed the economic and environmental impacts of irrigation development but have largely ignored distributional impacts (e.g., Shively and Pagiola, 2004; Shively and Zelek, 2002; Shively and Martinez, 2001). Here, we focus our attention on income distribution in a pair of adjacent communities -- irrigated lowlands and rainfed uplands. This study evaluates the distributional impacts of irrigation defined in three ways: (1) within the beneficiary lowland community; (2) within the upland community adjacent to the lowland farms, where the main connection to irrigation has been through the local labor market; and (3) between these adjacent agricultural communities.

5.1.1 Background

High income inequality exists in many countries around the world, particularly in developing countries, including the Philippines. Balisacan and Fuwa (2003) argue that, over the last decade, the Philippines has been in a state of high income inequality and maldistribution of wealth. Although inequality is reported to be greater in urban areas, it is also evident in rural areas, especially in lowland agricultural communities situated near upland indigenous communities. This specific condition can be found in the southern district of the Philippine province of Palawan, where households in the lowland farming communities attain significantly higher income than households in the adjacent upland communities.[22] The high degree of inequality between these communities can be attributed to agronomic, cultural, and socio-economic factors. Most importantly, lowland

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[22] Real income per capita in the lowland communities in the four observed years in the pooled panel data set was higher than the adjacent upland communities (significant at $\alpha = 0.01$). Details of the pooled panel data set are discussed in the data section of this chapter.

farming conditions are more favorable and lowland farming systems are more modern, thus, outperforming the more traditional upland farming systems. Under these conditions, one might expect that any improvement in lowland farming conditions, such as irrigation, would further exacerbate income inequality between these communities.

Previous studies from the same location show that the upland communities are economically and environmentally connected to the adjacent lowland farms, due both to lowland off-farm employment (Shively and Martinez, 2001; Shively and Pagiola, 2004) and the reliance of lowland farms on upland watershed integrity (Shively, in press). Shively and Martinez (2001) confirm that lowland irrigation development is a useful strategy to improve the environmental conditions in the upland adjacent communities. This is due to the increase in the aggregate labor demand for work on lowland farms, which partly draws labor away from upland activities. This pattern also increases the number of off-farm employment days in upland households, which increases off-farm income, thereby reducing upland households' income dependence on destructive forest clearing and, in some instances, annual crop cultivation.

Studies have shown that irrigation brings economic and environmental benefits to the target lowland farming communities. However, the impact of irrigation on income distribution in the neighboring upland communities, which play a critical role in maintaining the health of the watershed, is a concern. For this reason, this study examines income distribution in the study communities which may be influenced by irrigation development.

In contrast to the studies highlighted in section 5.1, a study by David, Cordova and Otsuka (1994) (which was set in a different lowland area in the Philippines) found that income inequality was less pronounced in irrigated areas than in rainfed areas. This is consistent with the study results set in developing countries of Asia which suggest a better income distribution in irrigated farming communities than in rainfed areas (Bhattarai et al., 2002; Hossain et al., 2000). The current study extends previous cross-section research by using panel data. We study the income distribution patterns between and within the study communities in Palawan during the last eight years (1995-2002) where the lowland farms were transformed from rainfed to irrigated production.

Figure 5.1 is a schematic diagram showing the chain of events that underlie this study, where 1995 represents the condition with no irrigation in the lowlands and 1997, 1999 and 2002 are years in which lowland farms shifted to irrigated production. This study investigates how agricultural intensification in the lowland farming communities, over time, influenced the income distribution within these lowland communities, within the adjacent upland communities and between these communities. There are three possible types of distributional impact: (1) positive, i.e., a reduction in income equality; (2) negative, i.e., an increase in income inequality; and (3) no impact, i.e., no change in income inequality. It is important to note that income inequality could increase for one of three reasons: (i) both groups could become better off, but one group could become relatively better off (e.g., a rising tide lifts all boats, but lifts some boats relatively more); (ii) one group could become better off and the other could become worse off; and (iii) both groups could become worse off, but one group could become relatively worse off. Given these possibilities, a measure of inequality should not, in and of itself be considered a measure of welfare (Deaton, 1997). Accordingly, we also use poverty analysis to investigate the impact of irrigation on levels poverty at the study site.

To summarize, the overall finding of this study suggests an increase in income inequality in the study site over time as indicated by a six percentage point rise in the Gini coefficient for the pooled sample between 1995 (rainfed condition) and 2002 (condition with fully operational irrigation facilities). However, the lowland sub-sample indicates a reduction in income inequality over time, as exhibited by the fall of the Gini coefficient by six percentage points from 0.57 in 1995 to 0.51 in 2002 (see Table 5.1). In the uplands, income inequality rose by about four percentage points within the same period. These results are examined and discussed in detail in section 5.4.

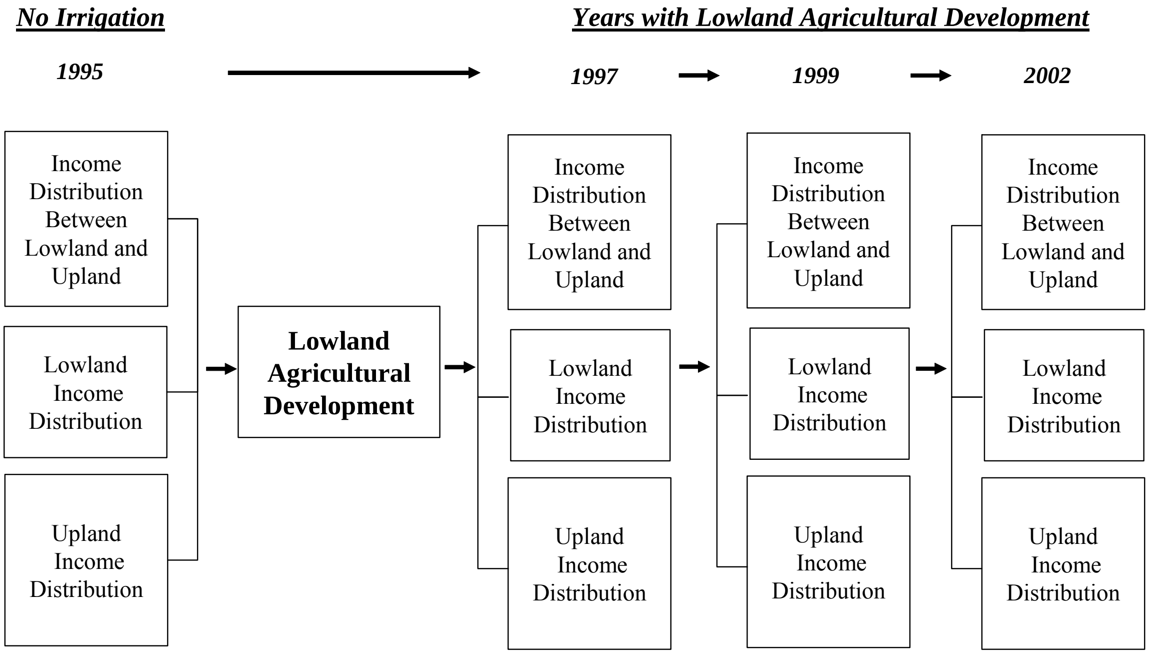

Figure 5.1 Framework of the Income Distribution Study

Table 5.1 Income Distribution and the Transformation of the Study Sites from Rainfed to Irrigated (1995 and 2002)

Sample	Gini for 1995	Gini for 2002	Income Distribution
Pooled Lowland and Upland	0.62	0.68	Widening
Lowland	0.57	0.51	Narrowing
Upland	0.54	0.58	Widening

5.1.2 Hypotheses

This analysis is motivated by two research questions: (1) Does irrigation development enhance or reduce income inequality? and (2) Is irrigation development an effective instrument for poverty alleviation?. Based on these questions, eight hypotheses can be formulated:

1. Income inequality in the study communities is worsened by irrigation development.
2. Irrigation development worsens income inequality within the lowlands.
3. Irrigation development in the lowlands worsens income inequality in the adjacent uplands.
4. Irrigation development in the lowlands improves the income distribution among large farms.
5. Uplands households' participation in off-farm employment in the lowlands reduces upland income inequality.
6. Irrigation development reduces poverty in the study communities.
7. Irrigation development reduces poverty in the lowlands.
8. Lowland irrigation development reduces poverty in the adjacent uplands.

5.1.3 Scope and Limitations of the Study

This chapter is mainly descriptive, and uses selected inequality indices to compare income distributions over time in the study communities. Of the selected inequality indices, we emphasize the use of the Gini-coefficient in the measurement of inequality. To compare and contrast income distribution between and within groups of households in the study communities, Gini-decomposition techniques are used. However, to explore possible explanations for observed change in inequality, selected regression results from Chapters 3 and 4 are used in conjunction with income inequality measurements. No regression analysis is conducted in this chapter. To address poverty concerns, the analysis relies on measuring the incidence of poverty in the study sites and decomposing selected poverty measures by specific categories of interest.

5.2 Methods

A number of authors have analyzed household surveys and calculated inequality measures using total income per household (Adriano 1980, Bhattarai, et al 2002). This study relies on real income per capita weighted by household size in the calculations of inequality measures. Income per capita is used instead of total income per household because it is difficult to provide meaning to household or family welfare without starting from the welfare of its members (Deaton, 1997). This approach is consistent with the method proposed in Yao (1999) and the methods discussed in Deaton (1997), Sadoulet and De Janvry (1995) and Coulter (1989). Computations were implemented using Stata version 8.2. Some inequality measures were also calculated using MS Excel.

A poverty analysis is also conducted to determine the possible impact of irrigation on poverty in the study communities. For this analysis, a group of standard poverty measures were selected and the poverty decomposition technique proposed by Foster, Greer and Thorbecke (1984) was adopted.

5.2.1 General Measures of Inequality

Income inequality can be measured in a number of ways. This study employs six widely-used inequality measures. All six measures rely on calculation using real income per capita weighted by household size.[23]

Before discussing the selected inequality measures, it is useful to first discuss the general properties of Lorenz curves. Lorenz curves are used here since they play a crucial role in characterizing the robustness of inequality measures (Atkinson, 1970). Lorenz curves are constructed from the Gini calculations, and plot the cumulative percentage of real income per capita (y-axis) against the cumulative percentage of individuals in a sample (x-axis) starting with the poorest individual (Figure 5.2). If any sample exhibited perfect income equality, the Lorenz curve would be the first diagonal line (or line of perfect equality), since any percentage of the population would receive the same percentage of total income. In the presence of inequality, the Lorenz curve appears similar to one of the three curves in Figure 5.2 where the area between the diagonal line and the Lorenz curve is the total area of inequality. Intuitively the further the Lorenz curve lies from the diagonal line, the higher is the degree of income inequality.

Each Lorenz curve in Figure 5.2 represents an income distribution in an observed cropping year. Such presentation allows us to see the existence of *Lorenz dominance* or *Lorenz crossings*. Lorenz dominance exists when two Lorenz curves, like Distributions A and C in Figure 5.2, do not cross. The upper curve, Distribution C, is considered as an unambiguously more egalitarian distribution, which shows a lower degree of inequality using any measure of inequality that respects the principle of transfers. Since

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[23] For a definition of real income, please see Section 5.3.

Distribution C is everywhere above Distribution A, the distribution corresponding to the former curve *Lorenz dominates* the income distribution in the latter curve (Deaton, 1997). On the other hand, when Lorenz curves cross, as exhibited by the crossing of Distributions B and C, neither distribution dominates.

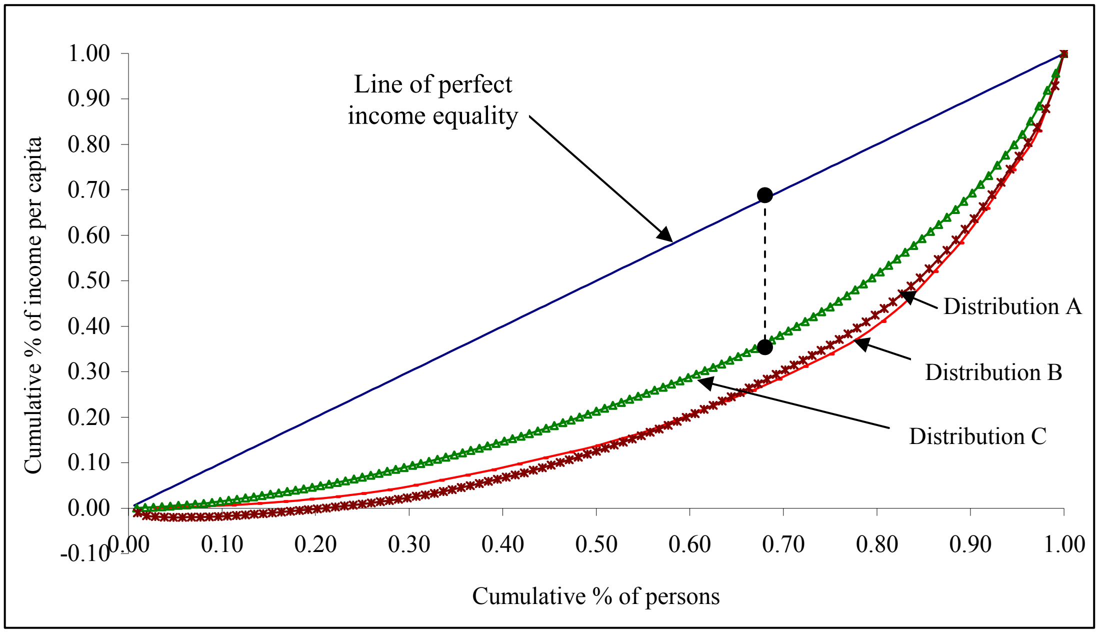

Figure 5.2 Graph of the Three Sample Lorenz Curves

The first three inequality measures for this chapter are derived from the Lorenz curve. These are the Relative Mean Deviation[24] (*RMD*), the Coefficient of Variation (*CV*), and the Gini-coefficient (*G*). The *RMD* is equal to the maximum vertical distance between the Lorenz curve and the diagonal of perfect equality. *RMD* is represented by the vertical dotted line in Figure 5.2. The average relative mean deviation for each sample is the sum of the absolute value of real income per capita relative deviations divided by the total number of individuals (*N*) in a sample:

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[24] The formula for this inequality measure is adopted from Schwartz and Winship (1980).

$$RMD = \sum_{i=1}^{N} \frac{|y_i - \bar{y}|}{N} \tag{5.1}$$

The second inequality measure is the coefficient of variation (*CV*). This can be computed by dividing the standard deviation of income $\sigma(y)$ of a sample by the mean income ($\bar{y}$) → $CV(y) = \frac{\sigma(y)}{\bar{y}}$. If we consider the Lorenz curve, the CV is equal to the standard deviation of the slope of the curve, namely:

$$CV = \sqrt{\sum_{i=1}^{n} \frac{(y_i - \bar{y})^2}{N / \bar{y}}} \tag{5.2}$$

The third measure is the Gini-coefficient (*G*) which is a measure of the extent to which income distribution among individuals deviates from a perfectly equal distribution. There are a number of ways to calculate *G*. For this chapter we elect to use the formula discussed in Yao (1999) where real income per capita is weighted by household size. The formula is

$$G = 1 - \sum_{i=1}^{I} p_i \left(2\sum_{k=1}^{i} Q_i - w_i \right) \quad where \quad Qi = \sum_{k=1}^{i} w_i \tag{5.4}$$

and where p_i is the relative share in the population frequency of household *i*, w_i is the income share of household *i*, and Q_i corresponds to the sum of the income shares, w_i. This formula for *G* also serves as the base formula for subsequent Gini-decomposition.

The fourth measure is the standard deviation of logs of income (S_L). This is also one of the most widely used inequality measures and relies on the formula:

$$S_L = \sqrt{\frac{\sum_{i=1}^{n}(\ln(y))^2 - \left(\sum_{i=1}^{n}\ln(y)\right)^2}{\frac{N}{N-1}}} \tag{5.3}$$

The fifth measure is the Theil index which ranges from 0 (complete equality) to *ln*N (complete inequality). The Theil index is:

$$T = \sum_{i=1}^{N}\left(\frac{y_i}{Y}\right)\ln\left(\frac{y_i/Y}{1/N}\right) \tag{5.5}$$

where Y is the total income of the sample and N represents the total number of individuals in the sample (Sadoulet and De Janvry, 1995).

The sixth measure is the Mean Log Deviation, also known as Theil's L index, which gives the standard deviation of log(y). This is included in the general entropy (GE) class measures of inequality, and from among this class is the most sensitive to changes at the bottom of the distribution. For this reason, a dramatic drop in income may drive an increase in measured inequality (Sadoulet and De Janvry, 1995). The Theil's L index is constructed as:

$$\textit{Theil's } L = \frac{1}{N}\sum_{i=1}^{N}\ln\left(\frac{\bar{y}}{y_i}\right). \tag{5.6}$$

Of the six inequality measures, this study focuses on using the Gini coefficient. This is because it satisfies the five major criteria of a good measure of income inequality, namely: *mean independence*, *population size independence*, *symmetry*, *Piguo-Dalton Transfer sensitivity* and *decomposability*. Gini's satisfaction of the criteria on population size independence is important for this study because unbalanced panel data are used.

The population size independence means that if the population were to change, the measure of inequality in the study sites should not change (World Bank, 2005).

5.2.2 Gini-decomposition Methods

An important feature of an inequality measure is the ability to decompose it. Inequality may be broken down by population groups, income sources or in other dimensions (Sadoulet and De Janvry, 1995). Although a number of publications point out that the Gini coefficient is difficult to compute and cannot be easily decomposed (Allison, 1978; Braun, 1988), a relatively recent publication (Yao, 1999) proposed a more straightforward method of Gini-decomposition using a spreadsheet. For this exercise, the computations for the decomposed Gini coefficients follow the method proposed in Yao (1999) and were verified using Stata version 8.2.

Figure 5.3 illustrates the two-tiered Gini-decomposition method adopted for this exercise. The decomposition process produces three components – *intra-class*, *inter-class* (or *between class*), and *overlapped*. Each component may take the value between zero and the total Gini-coefficient. The total of these three components is equal to the total Gini-coefficient. If the intra-class component is equal to zero, then there is no income inequality within each class or group. If the between class component is equal to zero, then the mean incomes of all classes or groups are identical. Also, when this component is small, then the inter-class income inequality is also small and vice versa. If the overlapped component is equal to zero, then the richest person in any low income class is not better off than the person with the lowest income in the high income class. For more details of the Gini-decomposition by population classes, see Yao (1999), Yao and Liu (1996) and Pyatt (1976). For details of the Gini-decomposition by income source, see Yao (1999) and Rao (1969).

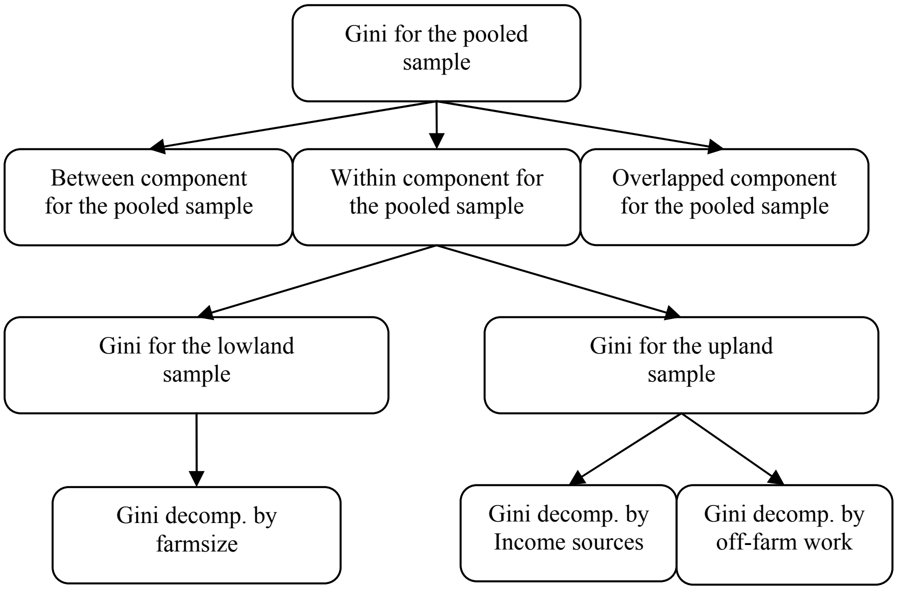

Figure 5.3 The Gini-decomposition Process (adapted from Yao (1999))

The method presented in Figure 5.3, above, shows the Gini-decomposition by different population groups and by income source. The three unbalanced panel data sets used for this study are decomposed as follows:

(1) pooled data set → by agro-ecosystem (lowland and upland)
(2) lowland data set → by the size of the landholding (small (< 3 ha) and large (≥3ha)
(3) upland data set → by off-farm employment (with and without employment)
→ by income source (agriculture, off-farm employment, forest products and other sources)

The first decomposition method is the decomposition by population class which is applied to items (1), (2) and (3) above. The pooled sample is decomposed by two classes of agro-ecosystems (*lowland* if residing in the lowlands and *upland* if residing in the uplands). The lowland sample is decomposed into two landholding size categories (*small* if farm size is less than 3 ha and *large* if 3 ha and above). The upland sample is decomposed by participation in off-farm employment (*with* and *without* off-farm employment). In the Gini-decomposition (G_{DC}) by population classes, we use the formula:

$$G_{DC} = 1 - \sum_{i=1}^{C} p_I \left(2\sum_{k=1}^{C} Q_I - w_I \right) \quad where \quad Q_I = \sum_{K=1}^{I} w_K \tag{5.7}$$

where C represents the number of population classes, w_I and p_I represent the income and population share of the Ith class ($I = 1, 2, \ldots, C$) in the population. The sums of p_I and w_I from 1 to I are both equal to unity. Q_I is the cumulative income share of source I.

The second type of decomposition method is implemented for the upland sample where the Gini-coefficient for real income per capita is decomposed by income sources ($\mathrm{G_{DS}}$).[25] To implement this we follow Equations 5.8 and 5.9.

$$G_{DS} = \sum_{h=1}^{H} w_h C_h \quad \text{where} \quad C_h = 1 - \sum_{i=1}^{N} p_i 2(Q_{ih} - w_{ih}) \tag{5.8}$$

$$Q_{ih} = \sum_{k=1}^{j} w_{ih} \tag{5.9}$$

where H represents the total number of income sources, w_h is the income share of source h, C_h is the concentration ratio of source h, and p_i is share of household i in the total

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[25] The Gini-decomposition by income class is only implemented for the upland sample due to the perceived importance of income source in these households.

number of individuals in the sample, w_{ih} is the income share of household *i* for source *h*, and Q_{ih} is the cumulative income share of household *i* for source *h*. Gini-decompositions by income source rely on the spreadsheet approach proposed by Yao (1999). This method of Gini coefficient calculation was used adopted by Fisher (2004).

5.2.3 Poverty Indices and Decomposition Technique

To date, a number of poverty measures have been used and proposed. For this study we elect to use only three major poverty measures, all of which have been included in the class of measures proposed by Foster, Greer and Thorbecke (1984). These three measures are *Headcount ratio*, *Poverty-gap ratio* and *Squared poverty gap ratio*. The definition and formulae for each poverty measurement are discussed below.

The *Headcount ratio (H)* is a measure of the prevalence of poverty which follows the formula

$$H = \frac{q_i}{N} \tag{5.10}$$

where q_i is the number of poor individuals and N is the number of individuals in the sample. Thus, the headcount ratio reflects the incidence of poverty by indicating the proportion of the individuals in a sample deemed to be poor, where poverty is defined by per capita relative to a poverty threshold.

The *Poverty-gap (PG) index* is a measure of poverty depth defined as

$$PG = H \cdot I, \quad where \quad I = \sum_{i=1}^{q} \frac{g_i}{qz} \tag{5.11}$$

where *I* is the Income Gap ratio, g_i is the income shortfall of household *i*, *z* is the absolute poverty line. In evaluating the impact of a developmental initiative on poverty alleviation, the poverty gap is considered a preferred measure since it is based on the aggregate poverty deficit of the poor relative to a given poverty line. For this study, we elect to use the absolute poverty line for the Province of Palawan (in income per capita) as reported by the Philippine National Statistics Coordinating Board.

The *Squared poverty gap* (P_2) measures the severity of poverty through the equation

$$P_2(y;z) = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{g_i}{z}\right)^2 \qquad (5.12)$$

This measure is advantageous for comparing policies which are intended for the poorest segment of the population. A disadvantage with P_2 is that it can be difficult to interpret (Ravallion, 1992). Equation 5.12 is transformed into Equation 5.13 which constitutes the formula for poverty decomposition by population class

$$P_\alpha(y;z) = \sum_{i=1}^{q}\frac{N_i}{N}P_\alpha\left(y^i;z\right) \qquad (5.13)$$

where $\frac{N_i}{N}$ is the population share of class *i*, and $\frac{N_i}{N}P_\alpha\left(y^i;z\right)$ is regarded as the total contribution of a class to overall poverty of the total sample. The decomposition in Equation 5.13 allows one to assess the effect of changes in subgroup poverty on total poverty both in quantitative and qualitative terms. For details regarding the poverty measures highlighted above and the poverty decomposition techniques, see Foster, Greer and Thorbecke (1984) and Ravallion (1992).

5.3 Data

The study of income distribution pivots on three unbalanced panel data sets that recorded household incomes in the frontier communities covering the cropping years from 1994 to 2003. The first unbalanced panel is a pooled data set consisting of 907 income data points observed in the years 1995, 1997, 1999 and 2002 in both lowland and upland communities. In this chapter, this is referred to as the *pooled sample*. The second unbalanced panel is a subset of the pooled data set consisting of 383 income data points for the observed lowland households (*lowland sample*). The third unbalanced panel is the subset of the pooled data set that contains 521 household income data points for upland households (*upland sample*). Different years have different number of observed households. The year 2002 is the largest pooled sample (n_h=333 and n_i=1832) while 1995 is the smallest (n_h=157 and n_i=789).

Table 5.2 The Three Unbalanced Panel Data Sets, 1995-2002

Year	Pooled sample		Lowland sample		Upland sample	
	Number of households	Number of individuals	Number of households	Number of individuals	Number of households	Number of individuals
1995	157	789	36	212	121	577
1997	214	1079	112	592	102	487
1999	203	971	104	507	99	464
2002	333	1832	134	743	199	1089
Total	907	4671	386	2054	521	2617

The analysis for this chapter uses real income per capita of the observed households in the study communities covering household incomes for the cropping year period from 1994 to 2003.[26] Real income per capita is expressed in the form of kg of rice equivalents. These rice equivalents are derived by deflating the nominal income per capita (including

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[26] Income per capita is total household income divided by the number of household members. The total income of an observed household consists of total cash income and the value of agricultural production retained for home consumption.

imputed values of retained rice for home consumption) by the average rice price in each particular year. Although we have consumer price indexes for the province of Palawan for the given period, we elect to use average prices of paddy rice as our deflator since the price of paddy rice is more localized and it accounts for a major portion of the household budget. Furthermore, it is the number one staple food in the sites (and in the country as well).

The pooled sample is composed of two classes of farm households, the lowland class and the upland class. In the Philippines, both of these classes belong to the low-income segment of the economy. Nevertheless, the lowland class is relatively better off. Lowland households derive most of their income from sale of agricultural crops, specifically commercial production of lowland rice using a relatively modern farming systems that includes mechanization and chemical pest control in a lowland environment. Upland households usually operate as semi-subsistence farmers along the forest margins they inhabit. Agricultural production is characterized by minimal inputs and use of traditional multi-crop plots which consequently give low yields. Commercial crop production in the uplands remains limited.

5.4 Results

Results of the distributional analysis are initially presented by decile and quintile. This is followed by the illustration of income distributions, over time, using Lorenz curves. The results of the distributional impact study are highlighted in the section on general inequality indeces and the decomposed Gini coefficients. This section concludes with poverty analysis.

5.4.1 Decile and Quintile Distributions

To give a general picture of real income per capita, Tables 5.3a and 5.3b present the decile and quintile distributions of the three samples from 1995 to 2002. The decile distribution for the pooled sample shows that, between 1995 and 2002, the income share of household members belonging to the lowest 10% of the distribution shrunk from 0.6% to 0.0% while those belonging to the highest 10% gained from 46.4% to 50.6%. This indicates that, between the start and the end of the study period, there was a regressive transfer of income wherein the poorest became poorer and the richest became richer.

A similar case of a regressive income transfer is observed in the upland sample, with the magnitude of transfer appearing greater. In the upland sample, the share of the poorest 10% shrunk from 1.0% to only 0.5% while the share of the richest 10% increased from 38.6% to 51.8%.

The lowland sample also exhibits a regressive pattern except that the magnitude of the transfer is much smaller. The share accruing to its poorest 10% shrunk from 0.6% to 0.5% while the share of its richest 10% slightly increased their share from 33.8% to 36.1% (Table 5.3).

Income inequality in the lowlands appears to have fallen over time. While the mean income per capita increased by 35% between 1995 and 2002 (from 1,931 kg of rice-equivalents to 2,604 kg of rice-equivalents), income distribution did not widen very much. This indicates that income gains were distributed in a relatively egalitarian pattern. In contrast, income inequality in the uplands appears to have worsened over time. Despite a 24% decrease in the mean per capita income between 1995 and 2002 (from 565 kg of rice-equivalents to 430 kg of rice-equivalents), income inequality increased considerably.

The quintile distribution for the lowland sample in Table 5.4 shows a pattern of improving income distribution in the lowlands following irrigation development. With the exception of the lowest quintile in 1999, the lowest, 2nd lowest, 3rd lowest and 4th lowest quintiles in all post irrigation years received higher income shares compared to the base year, 1995. The highest lowland quintile accounts for a smaller income share in the latter years. This indicates a pattern of improving income distribution in the lowland communities. This is consistent with the findings of Adriano (1980) and Bhattarai (2002) who found irrigation reduced income inequality. In the case of the lowland study communities, income distribution appears to have improved with irrigation development and this improvement has been sustained over time.

The upland sample exhibits an improvement in income distribution between 1995 and 1997 as exhibited by the increase in the income shares of the lowest quintiles and consequently lower income share by the highest quintile. However, it appears that this initial improvement in income distribution was not sustained over time. The income distribution in 1999 went back to the 1995 level and further worsened in 2002, while at the same time the mean real income per capita decreased to 430 kg of rice from a high of 689 kg of rice in 1999. The income share of the richest quintile increased by about 10 percentage points between 1999 and 2002.

In the case of the pooled sample, the quintile analysis indicates a worsening of income distribution in the study communities in the years following irrigation development. This is exhibited by the decrease in the income share of the lowest and 2nd lowest quintiles in 1997, 1999 and 2002 and a higher income share of the highest 20% of the households in the years with irrigation development. Thus, although irrigation development brought sustained improvement in the income distribution in the lowlands, initial improvement in the uplands was not sustained. Irrigation development has led to further widening of the income distribution in the study communities. However, the extent of this widening appears small, as shown by the slight increase in income the share of the highest 20% of the household respondents from 64.8% in 1995 to 66.4%, 65.7% and 70.7% in 1997, 1999 and 2002, respectively.

The average real income per capita appears higher during the post years irrigation years indicating that irrigation resulted in an improvement in the economic condition in the area. However, it appears from the above discussion that the rising tide did not lift all boats, since household members in the lowlands benefited more from irrigation development than households in the uplands. The adjacent uplands have been left further behind as a consequence of decreasing real incomes and a widening income gap within the upland communities.

Table 5.3 Percentage Distribution of Total Real Income per Capita by Income Decile (1995-2002)

Decile	1995			1997			1999			2002		
Group	Pooled	Lowland	Upland	Pooled	Lowland	Upland	Pooled	Lowland	Upland	Pooled	Lowland	Upland
Lowest decile	0.6	0.6	1.0	0.5	1.7	1.8	-0.9	-1.2	0.3	0.0	0.5	0.5
2nd decile	1.4	1.5	1.9	0.9	2.7	2.9	1.0	1.3	1.5	0.6	2.0	1.5
3rd decile	2.1	1.9	2.8	1.5	3.5	3.6	1.8	2.5	2.7	1.0	3.2	2.0
4th decile	2.5	3.6	3.6	2.1	4.6	4.8	2.6	3.6	3.7	1.5	4.1	2.8
5th decile	3.6	4.1	4.2	3.4	5.5	6.1	3.8	5.0	4.8	2.5	5.7	3.6
6th decile	5.2	7.4	6.1	5.4	7.2	8.3	5.5	7.4	6.4	4.4	8.5	4.5
7th decile	7.6	9.8	8.3	7.9	9.4	9.1	8.5	9.1	9.1	7.2	9.4	6.2
8th decile	12.3	10.3	13.3	11.9	13.8	12.0	12.1	14.0	12.5	12.1	13.2	9.7
9th decile	18.4	27.1	20.3	21.2	18.8	15.8	19.6	18.2	19.4	20.0	17.4	17.4
Highest decile	46.4	33.8	38.6	45.2	32.8	35.6	46.2	40.3	39.6	50.6	36.1	51.8
Total %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean income per capita (kg of rice)	878	1931	565	3132	5399	642	1199	1832	689	1305	2604	430

Source: Author's calculations

Table 5.4 Percentage Distribution of Total Real Income Per Capita by Income Quintile (1995-2002)

Quintile	1995			1997			1999			2002		
Group	Pooled	Lowland	Upland	Pooled	Lowland	Upland	Pooled	Lowland	Upland	Pooled	Lowland	Upland
Lowest quintile	2.0	2.1	2.9	1.4	4.4	4.8	0.1	0.1	1.8	0.6	2.5	2.0
2nd quintile	4.5	5.5	6.3	3.7	8.1	8.4	4.4	6.0	6.5	2.5	7.3	4.9
3rd quintile	8.9	11.5	10.3	8.8	12.7	14.4	9.3	12.4	11.2	6.9	14.2	8.1
4th quintile	19.8	20.1	21.7	19.8	23.2	21.0	20.6	23.1	21.6	19.3	22.6	15.9
Highest quintile	64.8	60.9	58.8	66.4	51.6	51.4	65.7	58.4	59.0	70.7	53.4	69.2
Total %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean income per capita (kg of rice)	878	1931	565	3132	5399	642	1199	1832	689	1305	2604	430

Source: Author's calculations

5.4.2. Lorenz Curves

Lorenz curves in Figure 5.4 illustrate the income distributions over time. For the pooled sample, curves for different years appear to cross, indicating the absence of Lorenz dominance between years. However, by deleting the Lorenz curves for 1995 and 1999, it appears that the 1997 distribution dominates the 2002 distribution. This indicates that, under any inequality measure, the income distribution in 1997 was more equal than in 2002.

The graph of the Lorenz curves for the lowland sample shown in Figure 5.5 also illustrates Lorenz dominance, but in this case, the 1997 distribution dominates the 1995 distribution. This is an unambiguous indicator that the lowland income distribution in 1997 was more equal than in 1995 (Figure 5.6). This also indicates a Pareto improvement between 1995 and 1997 in the lowlands since there was an increase in average real income per capita (significant at $\alpha = 0.01$). The distribution in 2002 crossed with the lower and upper ends of the distribution in 1995. However, it appears that the post irrigation year, 2002, had a more egalitarian distribution than during the rainfed year, 1995, since most of the middle part of the 2002 curve is above the 1995 curve. Also, although the distributions in 1999 and 1995 crossed at the 60% section of the x-axis, the Lorenz curves show that the lower half of the distribution in 1999 had more unequal income than the lower half in 1995. The upper 70% to 90% of the distribution in 1999 appears to be less unequal than that in 1995.

The Lorenz curves for the upland sample (Figure 5.6) indicate an initial reduction in income inequality in 1997. However, in 1999 and 2002, inequality returned to the 1995 level and in fact slightly increased (the Lorenz curves for the 1999 and 2002 sample are slightly below the 1995 level). This pattern might indicate a slight increase in upland income inequality in the years when the irrigation facilities became fully operational. Whether off-farm employment might be responsible for this pattern is explored in section 5.4.4 below.

5.4.3. General Inequality Indices

All inequality measures did not exhibit similar patterns of income distribution over time. The coefficients of variation, the Theil indexes and the mean log deviations for the pooled sample exhibit similar patterns indicating that the income distribution narrowed between 1995 and 1997, almost remained constant between 1997 and 1999, and widened between 1999 and 2002. On the other hand, the Gini coefficients for the pooled sample appear relatively stable compared to the abovementioned inequality measures.[28] The Gini coefficients for the pooled sample remained the same between 1995 and 1997, increased by four percentage points in 1999 and increased by another four percentage points in 2002. Considering the transformation of the sites from rainfed to irrigated conditions, it appears that the income distribution in the study sites widened over time.

In contrast to the pooled sample, where the Gini coefficients exhibit a different pattern than other inequality measures, in the lowland sample all the income inequality measures exhibit similar patterns (Table 5.5).[29] All these measures indicate a marked

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[28] This scenario is similar to the discussion in Braun (1988), where the Gini coefficient exhibited greater stability over long periods of time compared to other inequality measures. The Gini coefficient is more responsive to changes in income in the middle of the distribution than among the tails of the distribution (Allison, 1978).

[29] A large share of the income in the lowland sample comes from sale of lowland crops (i.e., rice and corn).

improvement in income distribution between 1995 (0% irrigated) and 1997 (50% irrigated). The income distribution worsened in 1999, with the full capacity operation of irrigation facilities. A possible reason for the increase in inequality in 1999 is the occurrence of an El Niño phenomenon in the cropping year of 1998-1999 wherein income variability increased as a consequence of several households incurring negative income per capita while a few households successfully mitigated the effects of the climatic disturbance allowing them to attain very high income from rice production.[30]

Regarding the upland sample, the calculated inequality indices do not exhibit any discernable pattern of narrowing or widening of income distribution over time (Table 5.5). However, the Gini coefficients in the four observed years are consistent with the results of the Theil indexes, the relative mean deviations and the coefficients of variation. Results show an initial improvement in income distribution between 1995 and 1997. But it appears that this initial gain was not sustained, as exhibited by the growing income disparity after 1997. The Gini coefficients increased from 0.43 in 1995 to 0.56 and 0.58 respectively in 1999 and 2002 indicating a widening income distribution in the years when irrigation facilities in the adjacent lowlands became fully operational.

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[30] El Niño is a period of prolonged drought caused by a large-scale oceanic warming that affects most of the tropical Pacific.

Table 5.5 Measures of Income Inequality in the Study Communities (1995-2002) [31]

Inequality Measures	1995	1997	1999	2002	All
Pooled Lowland and Upland Sample					
Relative mean deviation	0.47	0.46	0.48	0.53	0.52
Coefficient of variation	1.62	1.46	1.53	1.80	1.82
Standard deviation of logs	1.23	1.35	1.39	1.55	1.50
Gini coefficient	0.62	0.62	0.64	0.68	0.68
Theil index (GE(a), a = 1)	0.74	0.69	0.72	0.89	0.88
Mean Log Deviation (GE(a), a = 0)	0.75	0.82	0.71	1.01	0.97
Number of Households	157	214	203	333	907
Number of Individuals	789	1079	971	1832	4671
Lowland Sample					
Relative mean deviation	0.43	0.36	0.42	0.37	0.40
Coefficient of variation	1.26	1.02	1.28	1.17	1.28
Standard deviation of logs	1.13	0.85	1.10	0.96	1.09
Gini coefficient	0.57	0.46	0.58	0.51	0.55
Theil index (GE(a), a = 1)	0.58	0.38	0.57	0.47	0.54
Mean Log Deviation (GE(a), a = 0)	0.57	0.37	0.42	0.38	0.49
Number of Households	36	112	104	134	386
Number of Individuals	212	592	507	743	2054
Upland Sample					
Relative mean deviation	0.42	0.31	0.41	0.44	0.41
Coefficient of variation	1.20	0.94	1.32	1.73	1.34
Standard deviation of logs	1.10	0.85	1.29	1.17	1.18
Gini coefficient	0.54	0.43	0.56	0.58	0.55
Theil index (GE(a), a = 1)	0.52	0.32	0.57	0.67	0.56
Mean Log Deviation (GE(a), a = 0)	0.57	0.34	0.66	0.66	0.61
Number of Households	121	102	99	199	521
Number of Individuals	577	487	464	1089	2617

Source: Author's calculations

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[31] Measures of inequality were also computed using real income per capita of each household that are not weighted by household size. The patterns demonstrated using this approach are similar to the adopted approach.

5.4.4 Gini-decomposition Analyses

In the quantile analysis in 5.4.2, we observed that household members in the uplands have been lagging behind the lowlands. Furthermore, with the slight increase in inequality in the pooled sample they appear to be worse off in the years following irrigation development. However, one limitation of the quantile distribution analysis is that it can not capture *overlap* between the lowland and the upland sample. To address this problem, the Gini-decomposition method is used to capture the overlap component.

For the Gini-decomposition analysis, the three samples were decomposed by two classes. The pooled sample was decomposed by agro-ecosystem, the lowland sample by size of landholding, and the upland sample by participation in off-farm employment and by income source. The decomposition by class produced between, within and overlap components as well as the overall Gini coefficients of the respective classes. The decomposition by income sources for the upland sample produced a Gini concentration ratio for each income source.

5.4.4.1 Gini-decomposition for the Pooled Sample

Using the pooled sample, the Gini coefficients were decomposed by ecosystem. For all the observed years, the average real income per capita in the lowlands was significantly higher than in the uplands (Table 5.6). The level of statistical significance appears higher during the good and the average years compared to the rainfed condition and bad years.

The Gini-decomposition for the pooled sample shows that, in 1995 and 1997, the Gini coefficients were slightly higher in the lowlands. This pattern was reversed in 1999 and 2002 when the Gini coefficients were higher by 4% and 9% in the uplands, respectively (Table 5.6). This might indicate that the full operation of irrigation facilities improved the income distribution in the lowlands.

The between group component of the Gini coefficient indicates the mean difference of the real income per capita between individuals residing in the lowlands and in the uplands. The between group component accounts for the highest share of the Gini in 1995, 1997 and 2002. From 47% in 1995, the percentage contribution of this component rose to 59% in 1997, fell to 43% in 1999 and rose again to 63% in 2002 (Table 5.6). The relatively higher percentages in 1997 and 2002 of this component indicate a widening income disparity between the individuals in the lowlands and uplands in the good and the average post irrigation years.

The within group component indicates the contribution to income inequality within the two groups. The percentage contribution to Gini of this component was close to the between group component in 1995, 1997 and 1999 but not in 2002 (Table 5.6). This indicates that, from 1995 to 1999, income inequality within the groups was fairly high, contributing a relatively high amount of inequality to the overall Gini coefficient. However, in 2002, the income gap between the lowland and upland individuals markedly increased. This might have contributed to the reduction in the percentage contribution of within group component of the Gini for the pooled sample.

The overlap components were high in 1995 and in 1999 (corresponding to the rainfed year and the year in which a prolonged drought adversely affected irrigation operation). This indicates that crop failures due to lack of irrigation and bad climatic condition pulled down a number of lowland individuals to the point where their income per capita was similar to or was even lower than that of the upland individuals. On the other hand, during the good (1997) and average (2002) years, the overlap components were smaller. This indicates that there is probably a lower yield variability or production risk in the lowlands during the good and average years which reduces the overlap in income per capita.

Table 5.6 Decomposition by Site, Pooled Sample (1995-2002)

Gini-decomposition	1995		1997		1999		2002	
Component	Indice	%	Indice	%	Indice	%	Indice	%
Between	0.29	46.6	0.36	59.0	0.26	43.2	0.43	63.1
Overlap	0.07	11.2	0.00	0.5	0.07	11.8	0.03	3.8
Within	0.26	42.2	0.25	40.5	0.27	44.9	0.22	33.0
Total Gini	0.62	100.0	0.62	100.0	0.60	100.0	0.67	100.0
Decomposed Gini								
Gini for the uplands	0.54		0.43		0.56		0.58	
Gini for the lowlands	0.56		0.46		0.52		0.49	

Decomposition class	N	Ave	N	Ave	N	Ave	N	Ave
Real income per capita in the uplands	121	565	102	642	99	534	199	430
Real income per capita in the lowlands	36	1931	112	5399	104	1832	134	2604
t-statistic		5.75		8.57		5.31		9.26

Source: Author's calculation using Stata version 8.2

5.4.4.2 Gini-decomposition for the Lowland Sample

In general, farms in the lowlands are relatively flat making them favorable for agricultural intensification. This allows more advanced farming operations in the lowlands and with irrigation development, agricultural intensification advanced further. Lowland farms are larger compared to upland farms. Given the high difference between lowland and upland farms, separate Gini-decomposition exercises were done for these samples.

The Gini for the lowland sample was decomposed into two landholding size categories – *large* and *small*. We assume that large and small farms are affected differently by agricultural development. In the lowland sample, the average size of a lowland rice farm is 3 ha. In this exercise, a farm smaller than 3 ha is considered small while a farm that is 3 ha and above is considered large.

In contrast to the pooled sample, where the between group component of the Gini coefficient often gave the highest contribution to the total Gini, the within group component of the lowland sample gave the highest percentage contribution to the Gini in 1995, 1999 and 2002 (Table 5.7). This indicates that, within the two groups of small and large farms, there exists significant income inequality. The between group component in 1995 accounted for only 5% of the Gini but this increased to as much as eight fold in the years following irrigation development. This might indicate that irrigation development enhanced income inequality between these two groups. Furthermore, this rise in inequality corresponded to a reduction in the percentage contribution of the overlap component. Under rainfed condition, the overlap component accounted for about 41% of the Gini, but in the years following irrigation development, this fell to 15%, 21% and 22% in 1997, 1999 and 2002.

Table 5.7 Decomposition by Farm Size, Lowland Sample (1995-2002)

Gini-decomposition component	1995		1997		1999		2002	
	Indice	%	Indice	%	Indice	%	Indice	%
Between	0.03	5.0	0.20	44.0	0.10	18.6	0.17	31.6
Overlap	0.23	40.6	0.07	15.1	0.11	21.2	0.12	22.4
Within	0.31	54.4	0.19	40.9	0.31	60.2	0.24	46.1
Total Gini	0.56	100.0	0.46	100.0	0.52	100.0	0.49	100
Decomposed Gini								
Gini for small farms	0.65		0.35		0.50		0.43	
Gini for large farms	0.50		0.45		0.47		0.49	

Decomposition class	N	Ave	N	Ave	N	Ave	N	Ave
Real income per capita for small farms	11	3831	69	9658	83	4307	80	5485
Real income per capita for large farms	25	2059	43	6023	21	2145	54	2656
t-statistic		1.40		3.28		1.59		3.98

Source: Author's calculations

The decomposed lowland Gini coefficients for both large and small farms are lower in the years following irrigation development (Table 5.7). This might indicate that, over time, irrigation development has improved the income distribution in both large and small farms in the target lowland communities. Between 1995 and 1997, the decomposed Gini-coefficients fell for both small and large farms, but small farms had a relatively greater reduction in inequality. In 1999, with the occurrence of the climatic disturbance, smaller farms seemed to be more adversely affected with this group's Gini rising to 0.50. The Gini for large farms increased to 0.47. The analysis reveals that, in 2002 (considered as an average year for weather), small lowland farms had a more equal distribution of income than did large farms. This supports the initial claim that the income distribution benefit of irrigation development accrued more to small farms, which can be attributed to better production efficiency on smaller farms. This is supported by the results in Chapter 3 which presented empirical evidence that smaller farms were more technically efficient than larger farms. This can be attributed to the fact that smaller farms are relatively easier to manage therefore reducing yield variability thereby improving income distribution among small lowland farms. This is supported by the higher real income per capita on smaller farms in the years with irrigation development as indicated by the stronger levels of t-statistics in the post irrigation years (Table 5.7).

5.4.4.3 Gini-decomposition and Off-Farm Income Analyses for the Upland Sample

5.4.4.3.1 Gini-decomposition by class

Participation in off-farm work, over time, seems to have stabilized the upland income distribution. In 1995, the group with off-farm employment had slightly greater income inequality than those without employment. This scenario was reversed in 1997, wherein the off-farm work group had less inequality. In 1999, (considered a good year for the uplands), the Gini for both groups increased to 0.55 (Table 5.8). But in 2002, (a bad year in the uplands), the Gini coefficient of the group without off-farm income increased to 0.70 while those with off-farm work declined to 0.50. A possible explanation for this large inequality for non-off farm participants is that some of the households were able to specialize in generating income from other sources (e.g., handicrafts making) while some were not able to diversify, and depended mainly on on-farm production. So, despite significantly higher per capita income of the group without off-farm work, average income was pulled up by a few relatively richer upland households.

The group with off-farm work had a significantly lower income, but their income distribution was better. It seems that their off-farm employment provided them with lower income risk due to the cash inflow of fixed per work-day off-farm incomes. For this reason, the degree of income inequality for this group, while still high with a Gini coefficient of 0.50, is relatively lower than the non-off-farm group with a Gini of 0.70. It appears from Table 5.8 that, in the long run, the group with off-farm work is likely to have a better income distribution than households without off-farm work. This shows the importance of off-farm employment in helping reduce income inequality in the uplands.

Table 5.8 Decomposition by Off-Farm Work Participation, Upland Sample 1995-2002

Gini-decomposition Component	1995		1997		1999		2002	
	Indice	%	Indice	%	Indice	%	Indice	%
Between	0.06	11.1	0.04	9.0	0.07	12.5	0.08	14.2
Overlap	0.21	39.2	0.11	25.7	0.18	32.7	0.20	34.1
Within	0.27	49.7	0.28	65.4	0.31	54.9	0.30	51.7
Total Gini	0.54	100.0	0.43	100	0.56	100	0.58	100
Decomposed Gini								
Gini without off-farm	0.51		0.48		0.55		0.70	
Gini w/ off-farm	0.55		0.42		0.55		0.50	

Decomposition class	N	Ave	N	Ave	N	Ave	N	Ave
Real income per capita without off-farm work	47	597	20	516	36	403	60	639
Real income per capita with off-farm work	74	544	82	673	63	610	139	340
t-stat		0.41		-0.83		-1.45		2.09

Source: Author's calculations

5.4.4.3.2 Gini-decomposition by Income Source

The Gini coefficients for the upland sample in Table 5.5 may not demonstrate clear patterns of inequality reduction or enhancement over time. However, the results of the Gini-decomposition by income source cast light on how irrigation development in the adjacent lowlands contributed to improving income distribution in the uplands.

Data indicate that, among the four major sources of income in the uplands, the proportion of income per capita from off-farm work employment contributes the least to income inequality. This is exhibited by the values of the concentration ratios of off-farm income. These are lowest in 1995, 1997 and 2002 (Table 5.9).

The Gini-decomposition by income source allows the calculation of the Gini-coefficient for each source of income. Results in Table 5.9 show that the Gini coefficient for off-farm income declined from a high of 0.77 in 1995 to 0.50, 0.70 and 0.70 in 1997, 1999 and 2002, respectively. A possible reason for this decline is that irrigation development in the adjacent lowlands contributed to an increase in off-farm participation of upland households, allowing the entire sample to both increase the income share from off-farm work and increase mean real income from off-farm work (a factor of three times in the years following irrigation). This resulted in a narrowing of the off-farm work income distribution over time.

Despite the large Gini coefficients for income from forest products and other sources in all the years, their respective share in Gini-coefficient are always lower than agricultural income. This can be explained by their relatively small share in overall income. In 1999 and 2002, their shares in total income had declined, thus further reducing their share in the Gini coefficient. On the other hand, the share of agricultural income (composed of cash income and value of the retained rice crop for home consumption) in the Gini coefficient is always the highest because it represents the largest share of total income (at least 54%).

With agriculture getting at least 54% of the income share, it always has the largest share of the Gini coefficient. Since the ratio of income from off-farm work to total income has at least tripled in the years following irrigation development, its contribution to the Gini coefficient also tripled. However, despite the tripling of its contribution to the

Gini, the magnitude of contribution remains low compared to the contribution of agricultural production: the latter's contribution to the Gini coefficient increased in 1999 and 2002 (the years when lowland irrigation facilities became fully operational).

Table 5.9 Income Inequality Decomposition by Income Source, Upland Sample (1995-2002)

	Agricultural production	Off-farm employment	Forest products	Other sources	Total
1995 sample (n=121)					
Gini coefficient	0.56	0.77	0.86	0.85	0.54
Share in Gini coefficient	0.63	0.02	0.26	0.09	1.00
Concentration ratio (C_i)	0.52	0.24	0.65	0.64	---
Mean real income in kg of	1533	98	496	183	2310
rice per person	357	26	136	46	565
Share in total income (w_i)	0.66	0.04	0.21	0.08	1.00
w_iC_i	0.34	0.01	0.14	0.05	0.54
1997 sample (n=102)					
Gini coefficient	0.59	0.50	0.76	0.88	0.43
Share in Gini coefficient	0.64	0.07	0.20	0.10	1.00
Concentration ratio (C_i)	0.52	0.18	0.39	0.49	---
Mean real income in kg of	1397	420	565	226	2608
rice per person	334	120	141	47	642
Share in total income (w_i)	0.54	0.16	0.22	0.09	1.00
w_iC_i	0.28	0.03	0.09	0.04	0.43
1999 sample (n=99)					
Gini coefficient	0.61	0.70	0.83	0.98	0.56
Share in Gini coefficient	0.87	0.08	0.03	0.02	1.00
Concentration ratio (C_i)	0.61	0.34	0.26	0.80	---
Mean real income in kg of	1762	279	142	37	2219
rice per person	408	79	38	10	534
Share in total income (w_i)	0.79	0.13	0.06	0.02	1.00
w_iC_i	0.49	0.04	0.02	0.01	0.56
2002 sample (n=199)					
Gini coefficient	0.63	0.70	0.87	1.00	0.58
Share in Gini coefficient	0.70	0.15	0.08	0.07	1.00
Concentration ratio (C_i)	0.61	0.44	0.54	0.93	---
Mean real income in kg of	1138	343	140	73	1694
rice per person	261	78	32	58	430
Share in total income (w_i)	0.67	0.20	0.08	0.04	1.00
w_iC_i	0.41	0.09	0.04	0.04	0.58

Source: Author's calculations

5.4.4.3.3 Role of Off-farm Work Income in the Uplands

Off-farm income's low contribution to income inequality can be translated into a conjecture that off-farm income helps reduce income inequality in the uplands. There was greater upland participation in off-farm employment and higher income from this work. This conjecture is supported by the four pairs of Lorenz curves presented in Figure 5.7. The pair of curves for 1995 shows that, under rainfed conditions, it is not clear whether the income distribution for with and without off-farm work are different. However, in the post irrigation years, the pairs of Lorenz curves for 1997, 1999 and 2002 show clear signs that income inequality is lower with the existence off-farm work income.

The income inequality reducing effect of off-farm work is also exhibited by the income inequality measures for the upland sample grouped by with and without off-farm income (Table 5.10). All inequality measures are higher in the without off-farm work sample. This might indicate that off-farm income contributes to the reduction in income inequality in the uplands.[32] The percentage point difference of the Gini coefficients between the two samples indicate that off-farm incomes have already contributed to improving the income distribution even during the year without irrigation.[33] The years following irrigation development show that the contribution of off-farm income in reducing inequality had at least doubled and had been sustained over time. This scenario is revealed by the two percentage point difference between the two samples in 1995 and in 1997, 1999 and 2002, percentage point differences were 7%, 4% and 6%, respectively (Table 5.10).

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[32] This is similar to the finding of Fisher (2004) regarding the effect of forest income in Malawi.

[33] This casts light on the pair of Lorenz curves for 1995 in Figure 5.7.

Table 5.10 Inequality Measures for Upland Households Without Off-farm Income

Inequality Measure	1995	1997	1999	2002	All Years
Upland Sample with off-farm income					
Relative mean deviation	0.42	0.31	0.41	0.44	0.41
Coefficient of variation	1.20	0.94	1.32	1.73	1.34
Standard deviation of logs	1.10	0.85	1.29	1.17	1.18
Gini coefficient	0.54	0.43	0.56	0.58	0.55
Theil index (GE(a), a = 1)	0.52	0.32	0.57	0.67	0.56
Mean Log Deviation (GE(a), a = 0)	0.57	0.34	0.66	0.66	0.61
Upland Sample without off-farm income					
Relative mean deviation	0.43	0.36	0.45	0.49	0.46
Coefficient of variation	1.23	1.07	1.48	2.08	1.51
Standard deviation of logs	1.15	1.08	1.48	1.32	1.34
Gini coefficient	0.56	0.50	0.60	0.64	0.60
Theil index (GE(a), a = 1)	0.55	0.43	0.68	0.85	0.67
Mean Log Deviation (GE(a), a = 0)	0.62	0.47	0.83	0.82	0.75
Percentage point difference of the Gini coefficients between the two samples (%)	2	7	4	6	5
No. of Households	121	102	99	199	521
Population	577	487	464	1089	2617

5.4.5 Poverty Analysis

The poverty line used for this analysis was taken from the Poverty Statistics published by the Philippine National Statistics and Coordinating Board. This publication reports that, in 1997, the annual per capita poverty threshold in Palawan was P9,511 in nominal terms (NSCB, 2005). This absolute poverty line was computed from data of the Family Income and Expenditure Survey (conducted by the Philippine National Statistics Office every three years beginning 1994). The 1997 poverty line was chosen for use here since it corresponds to one of the four observed years in the study sites. The nominal provincial poverty line was deflated by the average price of paddy rice of P6.00 per kg in

1997 resulting in a poverty line of 1,585 kg of rice equivalents per person per year. This value is used as the absolute poverty line for all observed years.

5.4.5.1 General Poverty Indices

The municipalities in which the study sites are situated were among the lowest income municipalities in the country. Given that these sites are classified as rural areas in a frontier province, the observed households are considered poor. This is especially true of the upland households, who are regarded as the poorest of the poor.

With the setting of an absolute poverty line for the analysis, the different poverty indices of the three samples were calculated. These are presented in Table 5.11. Headcount ratios for the pooled sample indicate a very high incidence of poverty in the study sites. In 1997, the poverty incidence in the sites was 56%. This is about 24 percentage points higher than the poverty incidence of 32% reported by NSCB for the same year.

The headcount ratios for the pooled sample exhibit a pattern of lower poverty incidence in the years following irrigation development (Table 5.11). The poverty gaps per person also demonstrate a pattern of lower poverty depth in the years with irrigation development. This might indicate that irrigation has reduced the incidence and extent of poverty in the study sites.

With regard to the lowland sample, the headcount ratios show that the poverty incidence was highest in the year with no irrigation. The post irrigation years had lower incidences of poverty. In 1997, the headcount ratio for the lowland sample was 0.24, eight percentage points lower than the provincial headcount ratio of 0.32. The poverty gap per person also decreased to only 90 kg of rice equivalents – a seven fold reduction from 1995's 664 kg of rice equivalents. The low poverty gap units per capita in 1997 translates to a poverty gap ratio of only 0.06. The year 1997 was a favorable year for most of the observed lowland rice households, and was characterized by very low poverty incidence and very low poverty depth.

In 1999, which may be considered an unfavorable year for the lowlands, the lowland sample had a lower poverty incidence but a higher poverty depth. This can be attributed to the existence of negative income incurred by several lowland households, which increased the overall depth of poverty. Thus, although the percentage of lowland individuals who ranked as poor was relatively smaller, those poorest individuals fell very far below the poverty line. This is indicated by the poverty gap per capita of 668 kg of rice equivalents, which is slightly higher than 1995's 664 kg of rice equivalents.

In terms of the upland sample, the headcount ratios and the poverty gap ratio do not show clear patterns of decreasing poverty incidence or poverty depth in the adjacent uplands. In 1997, poverty incidence slightly increased while poverty gap ratio slightly decreased. This scenario was reversed in 1999. In 2002, there was a record high poverty incidence and poverty depth of 98% and 82%, respectively. This seems to indicate that the upland communities have become worse off in absolute terms.

Table 5.11 Poverty Indices for the Three Samples (1995-2002)

Poverty Index	1995	1997	1999	2002
Pooled				
Headcount ratio (%)	88.47	56.44	80.23	79.53
	797,977	571,462	880,340	1,754,816
Aggregate poverty gap (kg of rice-equivalents)				
Poverty gap per person (kg of rice-equivalents)	1,011	530	907	958
Poverty gap ratio (%)	63.80	33.41	57.20	60.43
Income gap ratio (%)	72.12	59.20	71.29	75.98
Watts index	150.12	68.37	124.49	153.12
Sen index	75.54	42.61	69.54	70.73
Thon index	81.54	53.15	78.40	80.98
Takayama index	49.07	29.67	49.89	51.97
Number of Households	157	214	203	333
Number of Individuals	789	1079	971	1832
Lowland				
Headcount ratio (%)	72.17	24.16	67.06	52.49
Aggregate poverty gap (kg of rice-equivalents)	140,837	53,159	338,602	336,518
Poverty gap per person (kg of rice-equivalents)	664	90	668	453
Poverty gap ratio (%)	41.91	5.66	42.13	28.57
Income gap ratio (%)	58.07	23.45	62.83	24.43
Watts index	75.61	7.99	65.52	40.46
Sen index	53.54	8.69	55.11	36.86
Thon index	61.93	10.69	64.69	46.48
Takayama index	34.62	5.33	39.07	25.11
Number of Households	36	112	104	134
Number of Individuals	212	592	507	743
Upland				
Headcount ratio (%)	94.45	95.69	94.61	97.98
Aggregate poverty gap (kg of rice-equivalents)	657,139	518,303	541,738	1,418,298
Poverty gap per person (kg of rice-equivalents)	1,139	1,064	1,168	1,302
Poverty gap ratio (%)	71.85	67.14	73.65	82.16
Income gap ratio (%)	76.06	70.16	77.85	83.86
Watts index	177.50	141.77	188.92	229.98
Sen index	82.73	78.06	83.48	90.33
Thon index	86.10	80.50	86.91	91.83
Takayama index	50.72	40.68	50.42	54.24
Number of Households	121	102	99	199
Number of Individuals	577	487	464	1089

5.4.5.2 Poverty Decomposition

We now turn to poverty decomposition for the upland sample. The general poverty indices from the full upland sample did not show a pattern of reduction in poverty incidence. This might suggest that the entire upland population did not benefit from the poverty-reducing benefit of irrigation development in the lowlands. Decomposing poverty by off-farm working class shows a pattern of a reduction in poverty share relative to population share of the with off-farm work group in the years following irrigation development (Table 5.12). During the year with no irrigation, the population share of 0.59 for upland individuals with off-farm work corresponded to a poverty share of 0.64 (using the squared poverty gap). In the years following irrigation development, particularly in 1997 and 1999, (considered as the average and the good years in the uplands), the poverty share measures were lower compared to the population shares. It was only in 2002, (considered a bad year in the uplands), when the poverty share was slightly higher than the population share. However, this scenario indicates that, during the post irrigation years, the poverty share of those with off-farm work was lower than for those without.

In 1995, the real mean income of the poorest group with off-farm work was lower by 100 kg rice equivalents than for their counterparts without off-farm work. This pattern was reversed in 1997 and 1999, indicating that the poorest of those with off-farm work were better off than the poorest with no off-farm employment. In 2002, although the group with off-farm work had a smaller mean income, the difference between the two groups was not as large as in 1995. Thus it appears that those with off-farm work remained better off in 2002 than those without.

Table 5.12 Decomposed Poverty Indices for the Upland Sample (1995-2002)

	1995		1997		1999		2002	
	no off	w/ off	no off	w/ off	no off	w/ off	no off	w/ off
Population share	0.40	0.59	0.22	0.78	0.37	0.63	0.28	0.72
Mean income	557	435	451	574	384	525	401	274
Mean income of the poor group	440	340	363	504	325	367	269	251
FGT Index								
Headcount	0.92	0.96	0.94	0.96	0.97	0.93	0.96	0.99
Poverty gap	0.67	0.75	0.72	0.66	0.78	0.71	0.80	0.83
Squared poverty gap	0.53	0.63	0.59	0.49	0.65	0.59	0.70	0.72
Poverty share								
Headcount	0.40	0.60	0.22	0.78	0.38	0.62	0.27	0.73
Poverty gap	0.38	0.62	0.24	0.76	0.39	0.61	0.27	0.73
Squared poverty gap	0.36	0.64	0.26	0.74	0.39	0.61	0.27	0.73
Poverty risk								
Headcount	0.98	1.02	0.98	1.01	1.03	0.98	0.98	1.01
Poverty gap	0.93	1.05	1.07	0.98	1.05	0.97	0.97	1.01
Squared poverty gap	0.90	1.07	1.14	0.96	1.07	0.96	0.98	1.01

5.5 Findings, Conclusions and Policy Implications

The results of this analysis point to the following findings regarding the hypotheses outlined at the start of the chapter.

1. Income inequality between lowland communities and adjacent upland communities in the sample increased with irrigation development.
2. Irrigation development led to a reduction in income inequality in the lowland farming communities studied here.
3. Lowland irrigation development increased income inequality in the adjacent upland communities.
4. In the lowlands, there was greater reduction of income inequality for the group with smaller farms.
5. Upland households' off-farm work reduces income inequality.

6. Irrigation development contributed to poverty alleviation in the entire group of individuals in the study communities.
7. Lowland irrigation development contributed to poverty alleviation in the lowland study communities.
8. Lowland irrigation development did not directly contribute to poverty alleviation of the entire group of upland households but only to the group who participated in lowland off-farm employment.

The major results are outlined in Table 5.13. Results from the pooled sample indicate that in the years following irrigation development income inequality increased while absolute poverty was reduced. This implies that although irrigation might not have led to a meaningful reduction in income inequality, it did alleviate poverty at the study site.

Results from the lowland sample reveal a reduction in income inequality and poverty incidence in the years following irrigation development. This indicates that, in the lowland study sites, irrigation development led to a narrowing of income distribution and alleviated poverty.

Using the full upland sample, the inequality and poverty measures suggest widening of income inequality and an increase in poverty incidence in the years with irrigation development in the adjacent lowlands. However, when the sample is decomposed into two upland population classes (with and without off-farm work), it appears that the group of upland households who participated in lowland off-farm work, over time, experienced more equal income and lower incidence of poverty. These patterns might logically indicate that the positive impacts of lowland irrigation development do not benefit both upland groups but instead are more concentrated on the group who were employed on lowland farms. Considering that irrigation development is mainly intended to benefit lowland farming communities, it is nevertheless significant that the distributional and poverty alleviating benefits of irrigation were channeled through off-farm employment and spilled over to some members of the adjacent upland communities.

Table 5.13 Summary Results of the Study

	Inequality		Poverty	
Pooled	↑		↓	
Lowland	↓		↓	
Upland	↑		↑	
	Without off-farm work	With off-farm work	Without off-farm work	With off-farm work
	↑	↓	↑	↓

Over time, it appears that irrigation development led to a sustained reduction in income inequality and incidence of poverty in the lowlands. This therefore extends previous research work where irrigation was mentioned as contributing to improving income distribution in the target lowland communities (Balisacan, 2001; Hussain and Wijerathna, 2004; Hossain, et al, 2000). This conjecture is found be true in the study sites during the favorable and average cropping years (in terms of weather). However, during an unfavorable year, the poverty gap ratio turned out to be higher than the rainfed year in the lowlands. This might indicate that the lowland households face greater income risk in the presence of irrigation. This suggests a need for the establishment of a mechanism that would help protect farmers from such risk or mitigate the consequences of the occurrence of a rice production shock (e.g., El Niño phenomenon). However, in developing countries, farmers are less protected in terms of crop production risk (i.e., weak crop insurance system). In this regard, the establishment of irrigation facilities in the low income tropics should be accompanied by a risk protection mechanism which might be incorporated in the institutional development component of agricultural development programs. If such mechanism is already in place, it should be supported and strengthened.

This study reveals a pattern of inequality and poverty in the uplands that might serve as evidence of the importance of off farm work in reducing income inequality and poverty. This pattern might indicate that off-farm employment of upland households, in the long run, is a very important channel to help upland household harvest the developmental benefits from irrigation development in the adjacent lowland communities. In this regard, there is a need to incorporate, say in rural development policies, incentives for upland households to participate in off-farm employment, particularly in areas where similar conditions exist. Such incentives might include investments in human capital (health and education) in the uplands, improvements in rural roads and infrastructure, and efforts to ensure fair and equitable wages for those engaged in off-farm employment.

The findings from this study are derived from comparisons of different inequality and poverty indices, calculated from a panel covering a ten year period and four different cropping years. It appears that this length of study might need to be extended to investigate if such reductions in income inequality and poverty have been sustained in the longer term. It is also interesting to note that we have used income data in the analysis of poverty in the study sites. The use of consumption data, which is not available from the study sites, would have enhanced our analysis of poverty in the study sites.

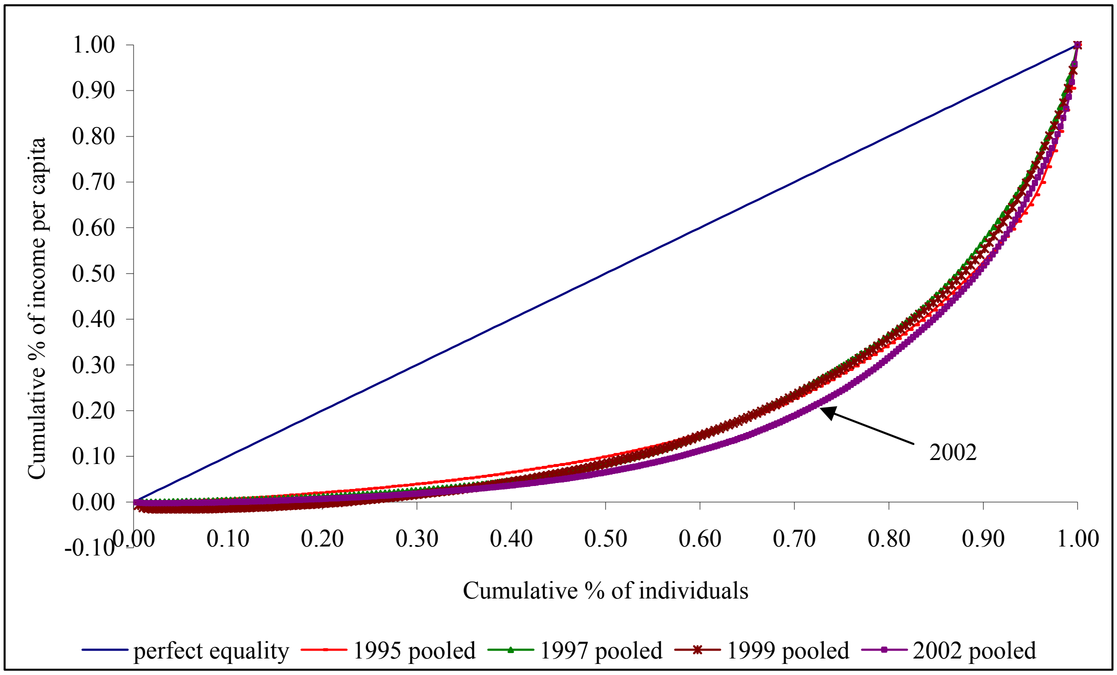

Figure 5.4 Lorenz Curves for the Pooled Sample

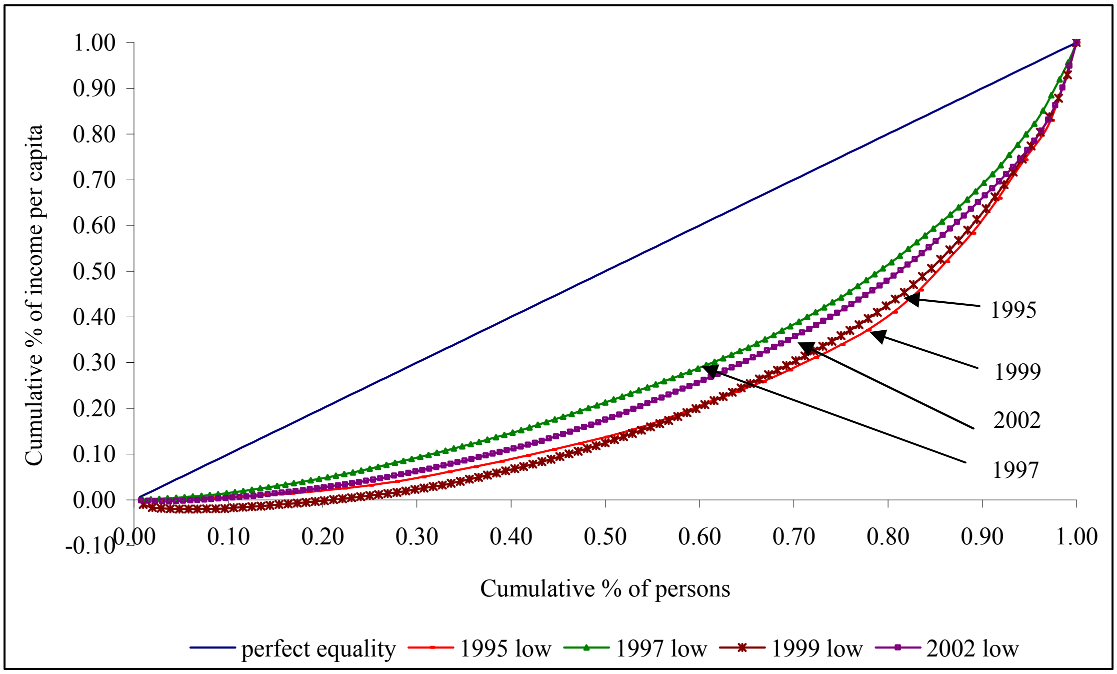

Figure 5.5 Lorenz Curves for the Lowland Sample

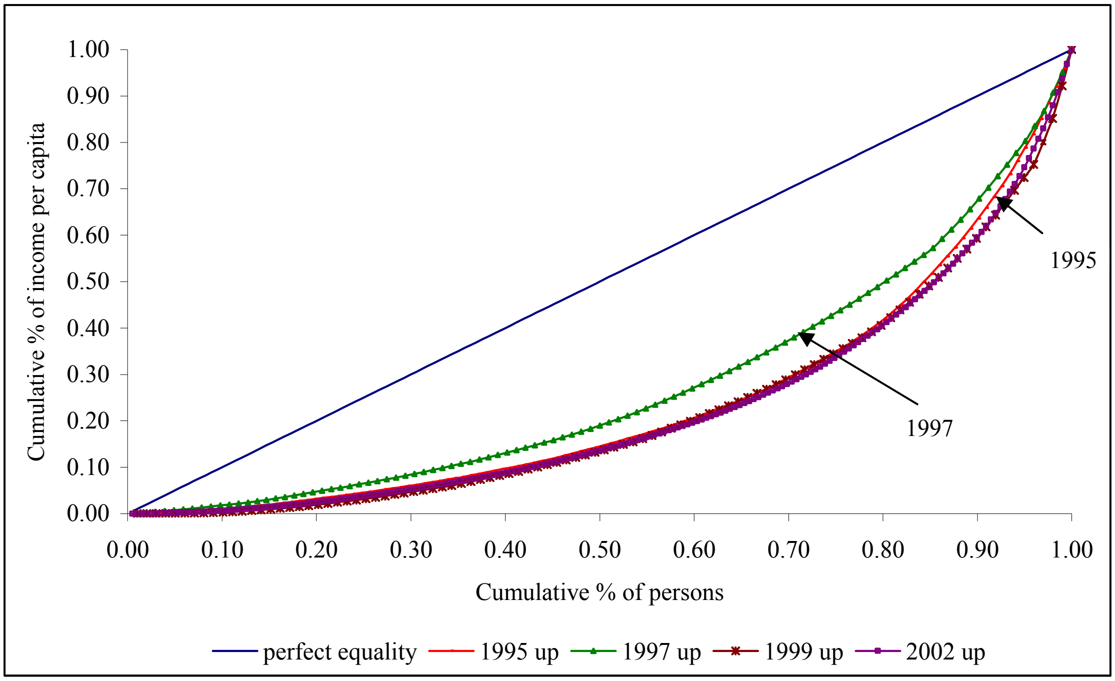

Figure 5.6 Lorenz Curves for the Full Upland Sample

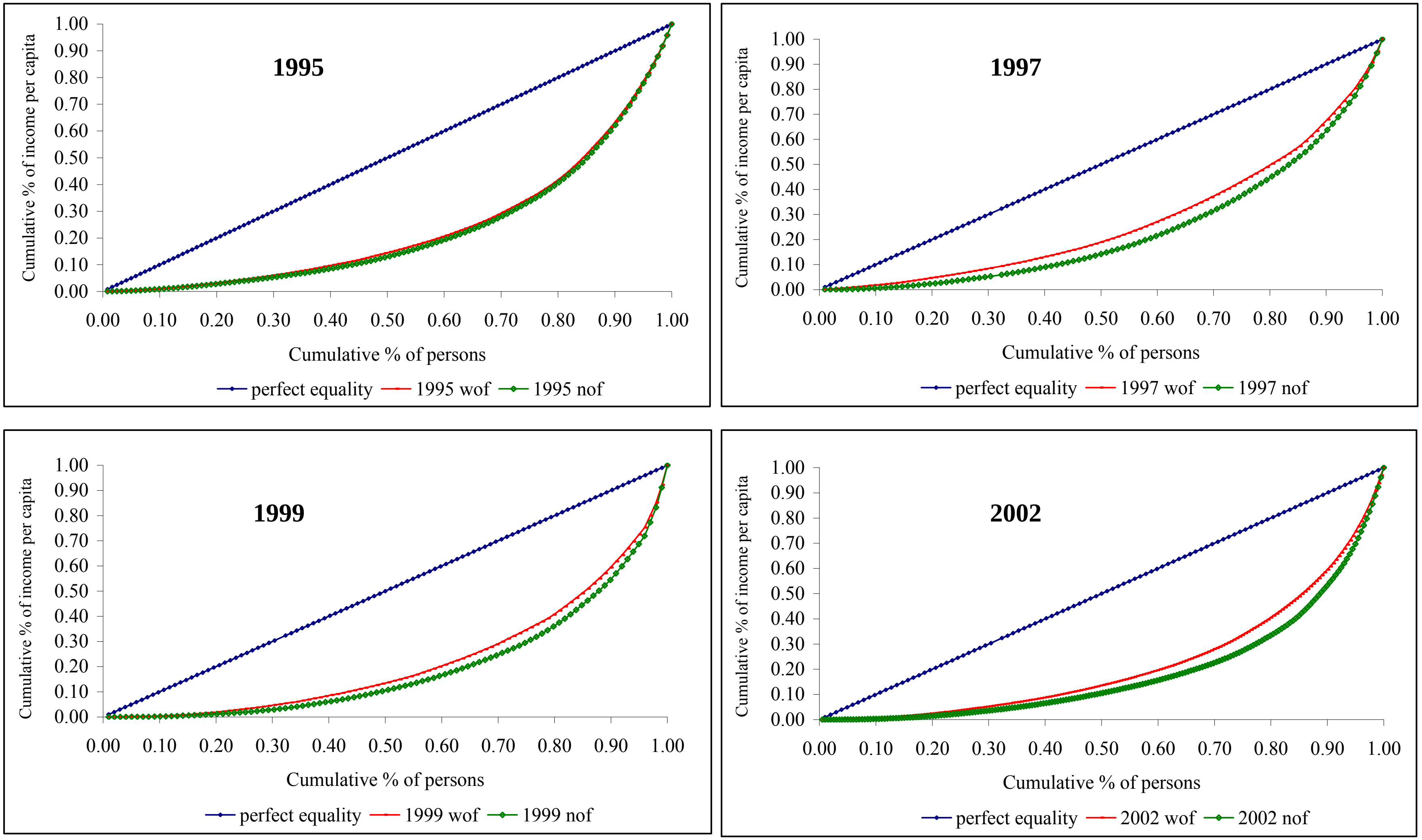

Figure 5.7 Lorenz Curves for the Two Upland Samples: With (*wof*) and Without Off-farm Income (*nof*), 1995-2002

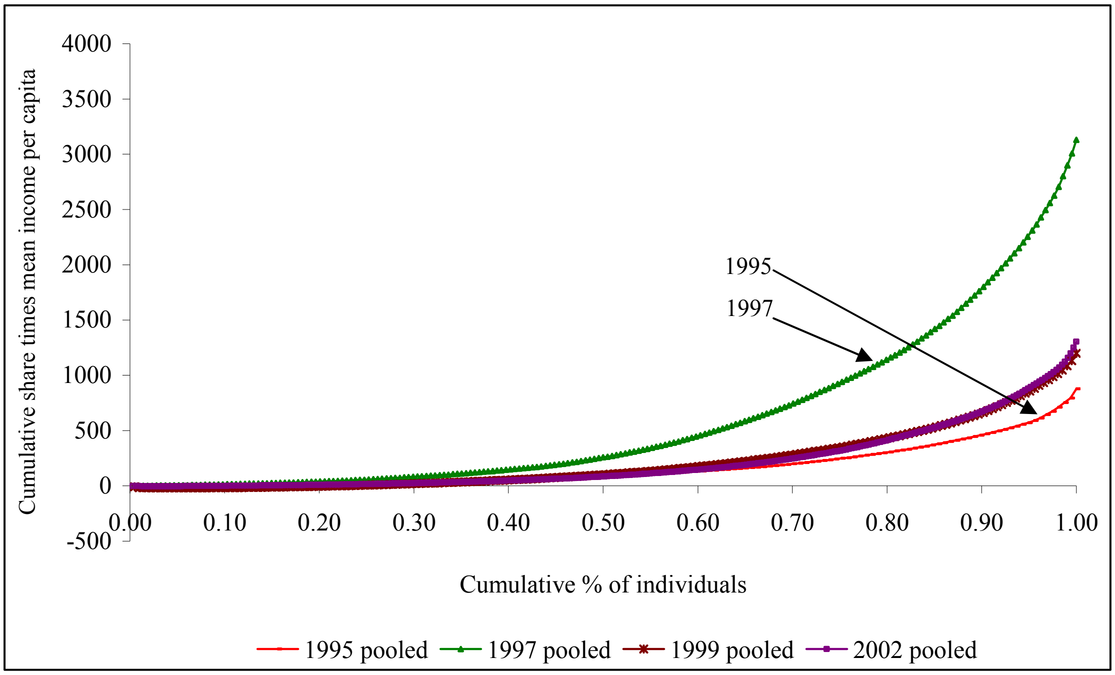

Figure 5.8. Generalized Lorenz Curves for the Pooled Sample, 1995 to 2002

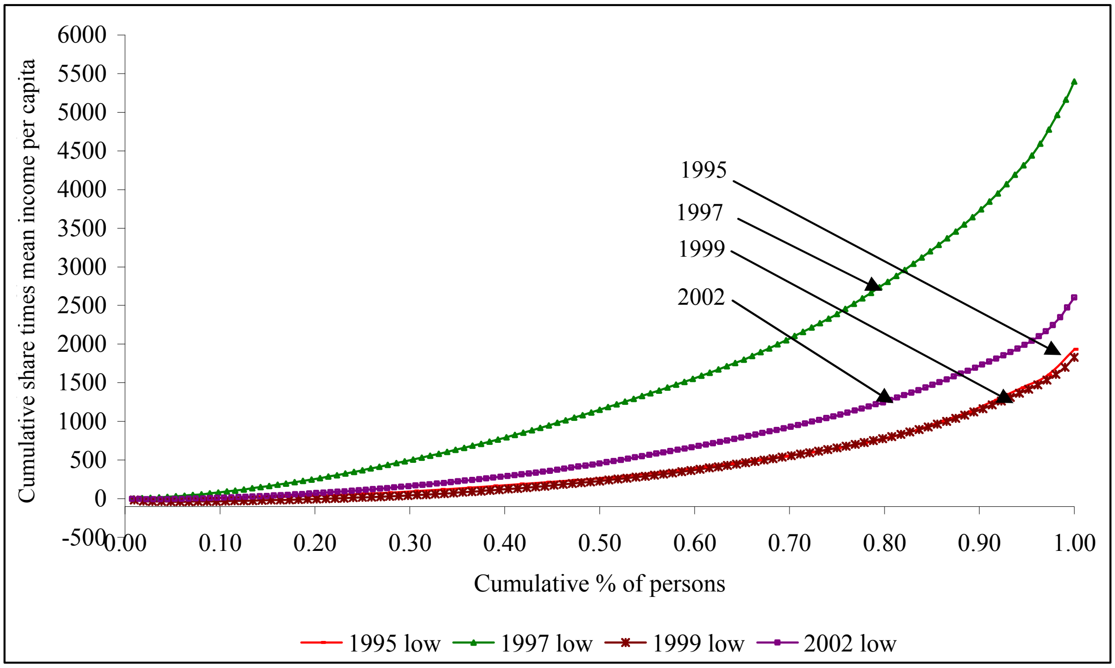

Figure 5.9 Generalized Lorenz Curves for the Lowland Sample, 1995 to 2002

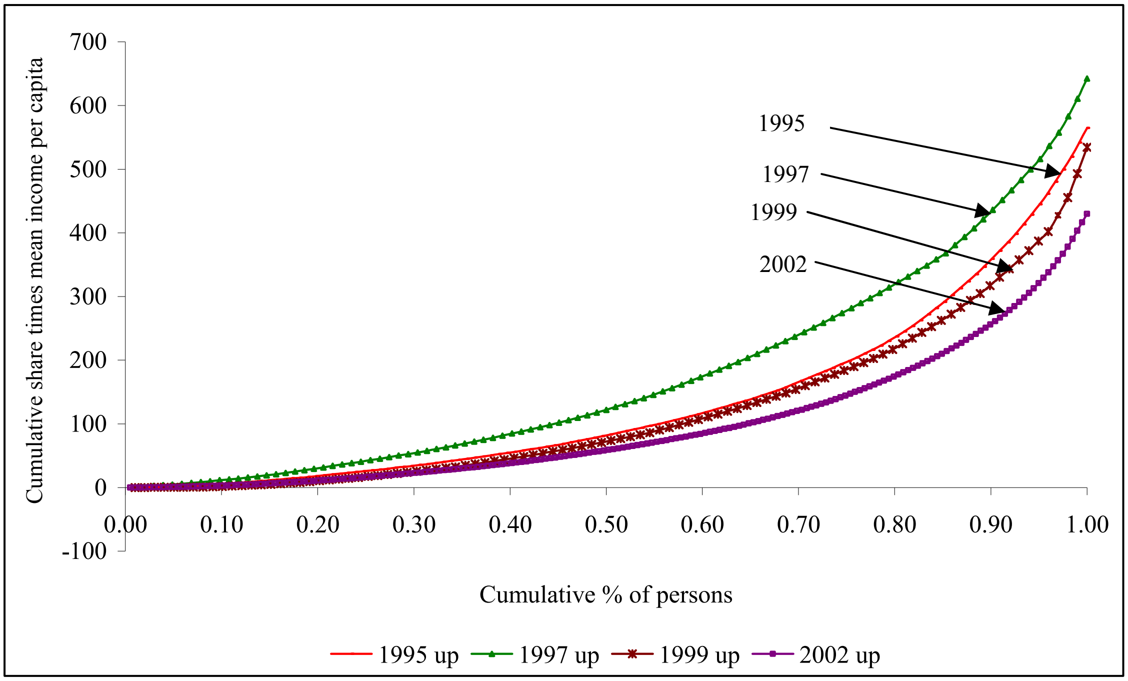

Figure 5.10 Generalized Lorenz Curves for the Upland Sample, 1995 to 2002.

CHAPTER 6

CONCLUSIONS AND POLICY IMPLICATIONS

6.1 Thesis Summary

This thesis examined the unfolding process of agricultural development in the low-income tropics using panel data collected over a 10-year period. A total of 386 lowland household and 521 upland household interviews were conducted in two adjacent agro-ecosystems – irrigated lowlands and rainfed uplands – in a frontier region of the Philippines. Irrigation development has been observed to provide economic and environmental benefits both on-site (lowland) and off-site (upland). The results suggest that irrigation, over time, led to an improved income distribution and lower poverty incidence in the study sites. In a nutshell, agricultural intensification in the lowland study sites, which has occurred through irrigation development, has been instrumental in achieving economic development and contributing to environmental conservation in the study sites. It appears that, despite the many reported set backs and issues in the operation of irrigation facilities in Asia, particularly in the Philippines (e.g., Levine, 1977; Bromley, 1982), investments and reinvestments in irrigation in the study sites have contributed to development at the study sites. The operation of two communal irrigation systems benefited households in the target lowland communities as well as a group of households in the adjacent uplands.

With irrigation in place, lowland farm households attained higher yields compared with rainfed production except during the survey year characterized by unfavorable climatic conditions (i.e., occurrence of El Niño). Chapter 3 described how higher technical efficiency ratings were observed in the years following irrigation development (except during the year with El Niño). Factors that were correlated with an increase in technical efficiency include household labor supply, security of land tenure, and level of mechanization. Factors associated with reduced efficiency include human capital (number of years of schooling) and age of the household head.

One obvious benefit from lowland irrigation in the study sites has been an increase in cropping intensity (usually from single to double cropping per year) which was found to lead to an increase in the overall demand for labor in a given cropping year. This resulted in higher employment opportunities in the lowlands and also helped to reduce pressure on the nearby upland ecosystem by providing upland households with a sustained, and at times increasing, level of off-farm employment. Thus, the increase in lowland employment opportunities spilled over into the adjacent uplands.

Participation of upland households in lowland off-farm work served as an important channel through which upland residents benefited from lowland irrigation. Results from the analysis of Chapters 4 and 5 indicate that upland households' participation in off-farm work provided important economic, environmental and distributional benefits in the intermediate term. These include (1) sustained employment opportunities providing greater incomes at lower risk; (2) a decrease of agricultural expansion into forest areas; (3) improved income distribution; and (4) decrease in poverty incidence. These benefits accrued, to a greater extent, to the group of upland households with off-farm work. The upland group without off-farm employment did not show such clear patterns of receiving benefits from irrigation development.

Overall, results show measurable benefits from irrigation development. One less favorable impact of irrigation development is that it has led to wider income inequality between lowland and upland communities. In terms of income, upland households, particularly those who were not able to engage in off-farm work were left behind. Economic growth in the lowlands did not lift up both communities. The lowlands became relatively better-off and the uplands became relatively worse-off in absolute terms. However, upland households with off-farm work were less worse off and in fact relatively better off in terms of poverty incidence than those with no off-farm work.

6.2 Policy Implications

Agricultural intensification in the lowlands resulted in an increase in aggregate labor demand. This and previous studies measured this increase in labor absorption in the lowlands (Shively and Martinez, 2001; Shively and Pagiola, 2004). Results have shown that the participation of upland households in off-farm employment contributed to a reduction in agricultural expansion in forest areas in the uplands, especially for some annual crops (e.g., corn). Our data also indicate a decrease in income dependence of upland households from activities with low returns such as annual crop production and sale of collected forest products (e.g., charcoal and Manila copal). The area planted to corn did not increase (and at times decreased). Environmental policies in areas with similar conditions should be cognizant of the strong role of off-farm work in altering labor allocation by upland households.

Based on the analysis conducted in this thesis, irrigation development in the lowland communities produced positive economic and environmental impacts on the adjacent upland communities. This positive economic impact appears to have been sustained over time, as reflected by the doubling and tripling of income from off-farm work in the years with lowland irrigation development (compared to the year with no irrigation). The initial environmental gain has also been sustained over time, as indicated by the statistically significant decrease in forest clearing activities in the years when the lowland irrigation facilities became operational. This sheds light on the potential sustainability of this form of economic development. We see a detailed and a concise picture of the positive on-site and off-site impacts of the shift to agricultural intensification in the lowlands over the 10-year period. We conclude that solutions to upland economic and environmental problems may rest with policies that focus on these indirect effects.

Considering that hand tractor ownership for lowland households contributes to higher yields and higher technical efficiency ratings, it appears that small scale mechanization should be supported. One support might be the extension of credit assistance to farmers for the acquisition of farm tractor. However, this should be carefully formulated and implemented since this might undermine employment gains for upland households.

6.3 Areas for Further Research

This thesis studied separately the impact of irrigation on income distribution, poverty and the environment using separate analyses. However, these three different aspects could be interconnected. Ravallion (1997) studies the link between poverty incidence and income inequality in 23 developing countries and suggests that higher income inequality reduces the impact of economic growth on absolute poverty. The Asian Development Bank recognizes poverty as a major cause for environmental degradation in its developing member countries. Applying these concerns to the conditions in the study sites would lead us to a new study that examines the link between income inequality, poverty and environmental degradation in a frontier region.

Since we have found that off-farm work is an important channel for lowland benefits to generate gains in the uplands, we might continue this line of inquiry by asking whether the upland households with off-farm workers, exposed to relatively modern technologies, *have more efficient agricultural production practices than households without off-farm work?* Perhaps this could be investigated using a stochastic production frontier analysis in the uplands. However, this might require additional upland data.

The parameter estimates from the stochastic frontier analysis with error decomposition were used in the expected profit model and gave reasonable results. However, the reason for the dramatically lower returns to scale of the SFA parameter estimates compared to OLS estimates might need more exploration. One explanation for observed outcomes might be the rigidity of the Cobb-Douglas functional form. In this regard, a further study that might provide the reason for the very low returns to scale value is by using a non-parametric approach (e.g., data envelopment analysis by Charnes et al, 1978; stochastic production frontier using local maximum likelihood estimation by Kumbhakar and Tsionas, 2002). Yet a third explanation might be departure from profit maximization as a motivating force in those households. Analysis that accommodates risk-aversion might shed additional light on the phenomena studied here.

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