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CHARACTERIZATION AND ECONOMIC ANALYSIS OF INTENSIVE CROPPING SYSTEMS IN RAINFED LOWLANDS OF ILOCOS NORTE, PHILIPPINES

By M. P. LUCAS†, S. PANDEY‡§, R. A. VILLANO‡, D. R. CULANAY† *and* S. R. OBIEN¶

†*Mariano Marcos State University, Batac 2906, Ilocos Norte, Philippines,* ‡*Social Sciences Division, International Rice Research Institute, PO Box 933, 1099 Manila, Philippines,* ¶*Philippine Rice Research Institute, Maligaya, Muñoz, Nueva Ecija 3111, Philippines*

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SUMMARY

Many farmers are intensifying production systems by applying greater amounts of inorganic fertilizers, irrigation and pesticides, especially to cash crops. Such intensified systems, even though economically profitable in the short run, may not be sustainable. This paper analyses the economics and sustainability of an intensified rainfed rice-based system in Ilocos Norte, Philippines. Farmers use high levels of inorganic fertilizers for cash crops such as sweet pepper, garlic and tomato. Although these crops generate high levels of income, the high input systems may not be sustainable in the long run due to adverse on-site and off-site effects. Preliminary estimates of total factor productivity that include on-site effects only, display no clear time trend. However, negative externalities created by high nitrate contamination of groundwater and high rates of pesticide usage could make the system unsustainable by adversely affecting human health and the environment.

INTRODUCTION

The reduction in sustainability of agricultural production systems, especially systems undergoing intensification, is a major concern for agricultural researchers and policymakers. As increasing population pressure and expanding markets put a greater demand on natural resources, ways to increase and sustain agricultural production assume greater importance. It is essential to understand the factors and processes that make production systems less sustainable so that appropriate interventions to enhance sustainability can be devised. The objectives of this paper are to present an economic analysis of the intensive rice–cash crop production system of Ilocos Norte, Philippines, and assess its likely sustainability.

The province of Ilocos Norte can be divided into four major regions, Northern Coastal, Central Lowlands, Southern Coastal and Eastern Interior (PPDO, 1995). Much of the agricultural activity in Ilocos Norte is concentrated in the

§Author to whom correspondence should be addressed. Email: spandey-irri@cgnet.com

Central Lowlands. Ilocos Norte has distinct wet (May–October) and dry (November–April) seasons. The mean annual rainfall of the province is more than 2060 mm, with most of the rains received during typhoons, which pass through the province several times a year.

The population of the province was about 0.5 million in 1994, with an estimated annual compound growth rate of 1.68%. The population density is around 140 persons km^{-2}. More than two-thirds of the population reside in the rural areas. The cropping intensity in 1980 was 1.5, with the average farm size being approximately 1 ha per family.

Rice is the most common crop in the lowlands during the rainy season. The annual cropped area of rice is 60 000 ha, of which about 40% is rainfed. In 1993, the province had a rice surplus of approximately 100 000 t. Other crops grown in the upland areas during the rainy season are maize, sugarcane and vegetables. Sugarcane is a major industrial crop, grown on approximately 32% of the agricultural area.

Cropping in the dry season is highly diversified. Farmers grow a range of cash crops, including tobacco, mungbean, garlic, onion, pepper and tomato. These dry-season crops are supported by groundwater irrigation. A well developed marketing system has facilitated the evolution of the highly intensified rice–cash crop production system.

Ilocos Norte has a good potential for livestock development, with nearly 47 000 ha of pasture area available in northern and eastern parts of the province. The road density is relatively high at 0.91 km road km^{-2}. The province is also rich in minerals such as copper and iron. Agro-processing, ceramics and handicrafts are the major industrial activities in the province. Overall the province is considered to have good potential for a diversified pattern of economic activities such as agricultural production, agro-processing, mineral extraction and livestock development.

METHODS

Sustainability is defined, for the purpose of this paper, as an improvement in the productive performance of a system without depleting the natural resource base upon which future performance depends (Pandey and Hardaker, 1995). Unsustainability may result from on-site and/or off-site effects of agricultural landuse. On-site effects include adverse changes in the physical, chemical and biological properties of the soil–water–plant complex that reduce farm productivity. For example, in the intensified irrigated rice systems of tropical Asia, reduced availability of nutrients to plants due to changes in soil properties could lead to unsustainability (Cassman and Pingali, 1995). Off-site effects, which are also called externalities, refer to those effects that are not normally valued in the market place. Common examples are adverse health effects of ground water contamination and pesticide use, and damage to irrigation infrastructures due to soil erosion.

Two commonly used economic indicators of sustainability are trends in partial factor and total factor productivities. The partial factor productivity is defined as the average productivity of a factor of production. Total factor productivity (TFP) is defined as the ratio of the value of all outputs produced within a given time period (usually a year) to the value of all inputs applied during the same time period. TFP for time period '*t*' can thus be written as

$$\mathrm{TFP}_t = \mathrm{Q}_t/\mathrm{X}_t \tag{1}$$

where Q_t is the aggregate value of all outputs produced and X_t is the aggregate value of all inputs used for producing Q_t. Output and input prices are used as weights for aggregating physical quantities of various outputs and inputs, respectively.

Economists consider TFP to be a more meaningful concept than the partial factor productivity for assessing sustainability (Lynam and Herdt, 1989; Harrington, 1993). As all inputs and outputs are accounted for, a declining trend in TFP is an indicator of possible degradation of the resource base, or unsustainability. Although the definition requires the inclusion of all inputs and outputs, data limitations and valuation problems mean that only those inputs and outputs that can be measured easily and valued can be included. The 'externalities', such as environmental pollution, which are difficult to value are often excluded from TFP calculations. Similarly, changes in prices of inputs and outputs can affect TFP values over time, despite the use of methods that attempt to correct for such price effects (Rayner and Welham, 1995). Despite some of these practical limitations to calculating TFP, the trend in TFP (not its absolute value) is considered to be a useful indicator of (un)sustainability and has been widely used (Capalbo and Antle, 1988).

Following the method suggested by Rayner and Welham (1995), we used the Tornqvist–Theil method to calculate the TFP index. The Tornqvist–Theil method is considered to be theoretically superior to other methods since it is consistent with a flexible production function that does not arbitrarily constrain the substitution possibility between inputs. The input index $I(X)_t$ is computed as

$$I(X)_t = I(X)_{t-1} \exp\left[1/2 \sum_i (s_{it} + s_{it-1})(\ln x_{it} - \ln x_{it-1})\right] \tag{2}$$

where

x_{it} = quantity of input i in period t
s_{it} = share of input i to total cost in period t

$$s_{it} = \frac{w_{it}x_{it}}{\sum w_{kt}x_{kt}}; i, k = 1, \ldots n \tag{3}$$

w_{it}, w_{kt} = actual prices of inputs in period t.

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Similarly, the output index is computed as

$$I(Q)_t = I(Q)_{t-1} \exp\left[1/2 \sum_j (r_{jt} + r_{jt-1})(\ln q_{jt} - \ln q_{jt-1})\right] \tag{4}$$

where

q_{jt} = quantity of output j in period t
r_{jt} = share of output j to total revenue in period t

$$r_{jt} = \frac{p_{jt}q_{jt}}{\sum p_{it}q_{it}}; i,j = 1 \ldots m \tag{5}$$

p_{jt}, p_{it} = actual prices of outputs in period t.

Finally, the TFP index is obtained as the ratio of $I(Q)_t/I(X)_t$.

The computation of these indices follows the following procedure. For each year, all farm output and all inputs used for all farmers in the sample were included in the calculation. On the output side, provincial level data on yield and farm-gate prices for 1992–95 were used. As the cost of production data for individual crops for each year were not available at the provincial level, farm level data were used for this purpose. Different sources of data for output and inputs had to be used because the farm level data on outputs for 1991–93 were incomplete. In addition, TFP for 1991 could not be calculated because farm level data on input use for several crops were not collected. Indices of the value of outputs and inputs were subsequently obtained using Equations (2) and (4).

Sampling design

Monitoring of rice production practices in the study area was initiated in 1991 and the production systems of 50 selected farmers were monitored from 1991 to 1993. Data from 10 farmers for each of the five major cropping patterns were collected. These cropping patterns were rice–maize, rice–garlic, rice–mungbean, rice–sweet pepper and rice–tomato. Information on input–output from the parcel in which a particular cropping pattern was followed was collected from each farmer. The sampling design was changed in the wet season of 1994 to expand the sample size to 100 and to include data from all parcels cultivated by a farmer irrespective of the cropping pattern followed. This new sampling design permitted a more complete analysis of the farm household economy which was not possible with the earlier design. The results on economic characterization presented are, hence, based on data for 1994 and 1995 only. The farmers in the enhanced sample were distributed in the ten towns of Ilocos Norte: Badoc, Pinili, Currimao, Paoay, Batac, San Nicolas, Laoag City, Sarrat, Dingras and Bacarra. Data were collected using interview schedules which were pre-tested first to ensure their suitability.

RESULTS AND DISCUSSION

Land characteristics

Farmer classification of field characteristics has been found to correspond well with scientific classification (Talawar, 1996), indicating farmer classification as a rapid and cost-effective method of characterizing fields. Farmers in Ilocos Norte classified land into four categories depending on topography and drainage characteristics. *Bangkag* and *Tankig* fields are drought-prone fields in the upper part of the toposequence. Semi-*Lungog* fields are in the lower part of the toposequence and are partially prone to submergence. The bottom fields, called *Lungog*, are generally submergence-prone. Semi-*Lungog* is the most common land type, comprising about two-thirds of the area planted to rice (Table 1). The majority of the soil in the area is clay loam.

Farm size, tenure and cropping patterns

The average farm size of the sampled farmers is 1.1 ha. Almost 58% of the area is cultivated by tenants (Table 2). Land holdings are fragmented, with an average of three parcels per farm household and the average size of a parcel is 0.4 ha.

Almost all land is planted to rice in the rainy season, except for some upland fields that are not suitable for rice. A range of upland crops is grown in these fields. In the dry season, garlic, maize, mungbean and tomato are the four major crops, occupying over 75% of the area planted (Table 3). Although the area of sweet

Table 1. Area and percentage area by land type, Ilocos Norte, Philippines.

Land type	Area (ha)	%
Lungog	6.11	11
Semi-*Lungog*	35.33	66
Tangkig	1.95	4
Bangkag	9.84	19
Total	53.23	100

Table 2. Area and percentage rice area by tenure, Ilocos Norte, Philippines.

Tenure	Area (ha)	%
Tenant	30.76	58
Owner	9.88	18
Owner/tenant	12.59	24
Total	53.23	100

Table 3. Landuse in the dry season in Ilocos Norte, Philippines.

	1994		1995	
Activity	Area (ha)	% of total area	Area (ha)	% of total area
Garlic	13.10	23	10.90	19
Maize	12.42	22	9.99	18
Mungbean	10.12	18	10.02	18
Tomato	4.81	9	4.75	8
Sweet pepper	2.95	5	1.40	2
Others†	3.31	6	1.79	3
Fallow	9.89	17	17.94	32

†Other crops include tobacco, cowpea, vegetables and groundnuts.

pepper is only around 5%, it is an important source of cash income. The overall cropping intensity is around 180%.

Extent of mechanization

There is a trend towards increasing farm mechanization in Ilocos Norte. About 90% of the farmers own water pumps, 38% have hand tractors and 18% have rice threshers. Rental markets for these farm machines are well developed. Despite this, buffaloes are still the dominant source of draught power.

Economics of rice production

Rice is the main crop during the wet season. Modern rice varieties, including BPI Ri10 and various IR varieties, are the most common cultivars planted in the area. Traditional varieties of rice have almost disappeared.

Seedbed preparation for rice is usually done in June, using supplemental irrigation if rain is limiting. Groundwater is the source of supplemental irrigation. Most farmers have access to groundwater either using their own pumps or hiring a pump. Land preparation is done mostly using hand tractors and water buffaloes. Four- to five-week-old seedlings are transplanted in puddled soils in July–August.

Chemical fertilizers are applied at a high rate of about 203 kg NPK ha^{-1} (Table 4). Fertilizers are applied in two applications, the first application being made two weeks after transplanting and the second about five weeks after transplanting. No basal application is made. The rate of application of insecticides and herbicides is low. Farmers do not perceive weeds as a major problem. Manual weeding is done whenever necessary.

Rice is harvested manually in late October. Threshing is done mostly with pedal-operated threshers. Harvesting and threshing are carried out as one activity, mostly on a contract basis, with the contractors receiving 20% of the output. Overall, rice production is based mainly on the use of hired labour, with family labour contributing about 20% of the total labour requirement.

Table 4. Average material and labour inputs for rice (1994–95), Ilocos Norte, Philippines.

Categories	Mean	s.d.
Material inputs		
Seed (kg ha^{-1})	109	72
Nitrogen (kg ha^{-1})	183	167
Phosphorus (kg ha^{-1})	42	53
Potassium (kg ha^{-1})	25	23
Insecticide (kg a.i. ha^{-1})	0.04	0.1
Herbicide (kg a.i. ha^{-1})	0.04	0.1
Fuel for land preparation (L ha^{-1})	6	21
Labour inputs (person-d ha^{-1})		
Land preparation	8	8
Crop establishment	35	26
Crop management†	10	12
Harvesting and threshing	42	30
Total labour	95	52

†Includes fertilizer and chemical application and weeding; a.i. = active ingredient.

In 1994–5 the average yield of rice was 3.7 t grain ha^{-1} (Table 5). Fertilizer is the major production cost and accounts for about 40% of the total cash spent. The costs of transplanting and harvesting are the other two major cost components. The return over the cash cost of rice production is US$636 ha^{-1}. If family labour

Table 5. Average grain yield, paid-out costs and returns for rice (1994–95), Ilocos Norte, Philippines.

Categories	Mean	s.d.
Yield (t ha^{-1})	3.7	1.9
Material costs (US$ ha^{-1})		
Seed	23	16
Fertilizer	141	122
Insecticide	6	12
Herbicide	1	2
Power for land preparation	37	40
Labour costs (US$ ha^{-1})		
Land preparation	5	14
Crop establishment	71	67
Crop management†	3	8
Harvesting and threshing	45	71
Total material costs (US$ ha^{-1})	185	
Total labour costs (US$ ha^{-1})	125	
Total costs (US$ ha^{-1})	310	
Gross returns (US$ ha^{-1})	946	
Returns above paid-out costs (US$ ha^{-1})	636	
Net returns‡ (US$ ha^{-1})	512	

†Includes fertilizer and chemical application and weeding; ‡net of cash and imputed cost of family-owned resources.

is valued at the market wage rate of US$4 d^{-1}, the net return from rice production drops to US$512 ha^{-1}. This is about 30% higher than in rainfed areas of Central Luzon.

Economics of dry season cash crops

Garlic, mungbean, sweet pepper, tomato and maize are the five major dry season crops and are grown using groundwater for irrigation. The average number of irrigations for various dry season crops ranges from 1 for mungbean to 16 for sweet pepper (Table 6). Sweet pepper is irrigated almost once a week.

Of the five major dry season crops, garlic is the most remunerative at US$1705 ha^{-1} (Table 7). Although sweet pepper is a profitable crop, it is also risky and

Table 6. Average number of irrigations for dry season crops, Ilocos Norte, Philippines.

Crop	Number of irrigations
Sweet pepper	16
Maize	4
Tomato	4
Garlic	3
Mungbean	1

Table 7. Costs and returns of different dry season crops (1994–95), Ilocos Norte, Philippines.

Categories	Maize	Garlic	Mungbean	Sweet pepper	Tomato
Number of fields	32	55	40	15	28
Material costs (US$ ha^{-1})					
Seed	62	635	41	66	89
Fertilizer	119	119	6	340	155
Insecticide	11	23	12	129	86
Herbicide	3	9	1	41	21
Power/fuel†	101	23	56	103	62
Labour costs (US$ ha^{-1})					
Land preparation	13		18	29	31
Crop establishment	14	87	19	69	66
Crop management‡	4	8	3	35	17
Irrigation	6	10	5	17	13
Weeding	3	42	3	43	10
Harvesting and threshing	50	34	66	126	81
Total material costs (US$ ha^{-1})	296	809	116	679	413
Total labour costs (US$ ha^{-1})	90	181	114	319	218
Total costs (US$ ha^{-1})	386	990	230	998	631
Gross returns (US$ ha^{-1})	1245	2695	465	2159	2128
Net returns (US$ ha^{-1})§	859	1705	235	1161	1497

†For land preparation and irrigation; ‡includes fertilizer and chemical application and weeding; §net of cash cost and imputed cost of family-owned resources.

Table 8. Yield and input use in dry season crops (1994–95), Ilocos Norte, Philippines.

Categories	Maize	Garlic	Mungbean	Sweet pepper	Tomato
Number of fields	32	55	40	15	28
Yield (t ha^{-1})	4.1	0.9	0.61	4.5	37
Material inputs					
Seed (kg ha^{-1})	23	230	25	1.1	0.63
Nitrogen (kg ha^{-1})	129	138	6	342	107
Phosphorus (kg ha^{-1})	40	49	1	128	54
Potassium (kg ha^{-1})	39	51	0.64	81	99
Insecticide (kg a.i. ha^{-1})	0.13	0.15	0.12	1.98	0.08
Fungicide (kg a.i. ha^{-1})	0.05	0.28	0.04	2.7	0.7
Fuel† (L ha^{-1})	8	45	23	79	39
Labour inputs (person d ha^{-1})					
Land preparation	3		4	6	6
Crop establishment	5	31	7	25	23
Crop management‡	2	3	1	13	6
Irrigation	2	4	2	6	5
Weeding	1	15	1	15	3
Harvesting and threshing	18	12	24	45	29
Total labour	31	65	39	110	72

†For land preparation and irrigation; ‡includes fertilizer and chemical application and weeding.

labour-intensive and has a high cash requirement for inputs. Farmers apply over 500 kg of NPK ha^{-1} (Table 8), and insecticides and fungicides are applied at high rates. These factors may limit the area under sweet pepper.

Overall, the input usage in dry season crops (except for mungbean) is high (Table 8). In Ilocos Norte excess nitrogen has been found to move to deeper soil layers (Tripathi *et al.*, 1997), where it is prone to loss through leaching of nitrate into groundwater (Gumtang *et al.*, 1998) and/or emission of nitrous oxide into the atmosphere. Both these processes cause environmental pollution. Similarly, insecticides and fungicides used to protect these crops can have negative effects on human health. Farmers may not explicitly consider these costs in their calculations and hence adopt practices which may lead ultimately to the unsustainability of the production system.

Movement in farm-gate prices of dry season crops are presented in Fig. 1. The price of sweet pepper has a negative trend and this is probably a factor influencing the reduction in area under this crop in recent years. The price of garlic, although low in 1993, increased rapidly in 1994 and 1995. Even though the marketing system in the area is well-developed, the fluctuations in the farm gate prices of cash crops are considerable.

Farm income

The average agricultural income of a farm household is US$1626 (Table 9). More than 50% of this income is generated by dry season crops, which are also the major source of cash income. Thus, even in this rainfed rice area, rice is not the

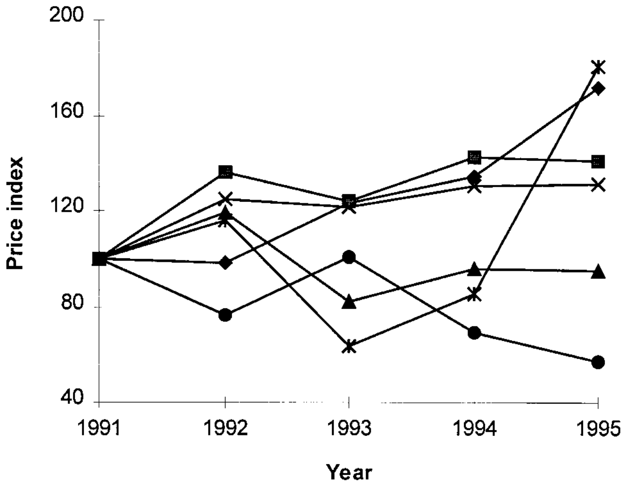

Fig. 1. Index of real farm-gate prices of major crops (garlic, —✳—; rice, —◆—; maize, —■—; mungbean,—×—; tomato, —▲—; sweet pepper, —●—), Ilocos Norte, Philippines. Base year = 1991. (Source: Bureau of Statistics, 1996.)

Table 9. Mean farm income by sources (1994–95), Ilocos Norte, Philippines.

Source	Mean (US$)	s.d.
Rice	697	575
Dry season crops	861	684
Livestock	67	158
Total	1626	1002

primary source of income. Income from rice ranks second in terms of importance and together with cash crops accounts for almost 95% of the income of farm households.

Total factor productivity

The estimated input index, output index and TFP index are presented in Fig. 2. The input index increased over time but the output index rose after an initial decline in 1993. As a result, the initial decline in TFP was reversed. No clear trend in TFP was discernible from these estimates.

Lack of a clear pattern of a downward trend in TFP should not be taken to imply that the rice production system in Ilocos Norte is sustainable. First, the time period analysed was too short to separate any underlying long-term trend in TFP from random variations due to price and weather shocks (Fig. 1 and 3). A longer period of data is needed for detecting a trend. Second, and more importantly, the TFP estimates derived here do not capture the effects of externalities. Nitrate contamination of the ground water, negative impacts of pesticides on human health and environment, and possible depletion of groundwater are the major

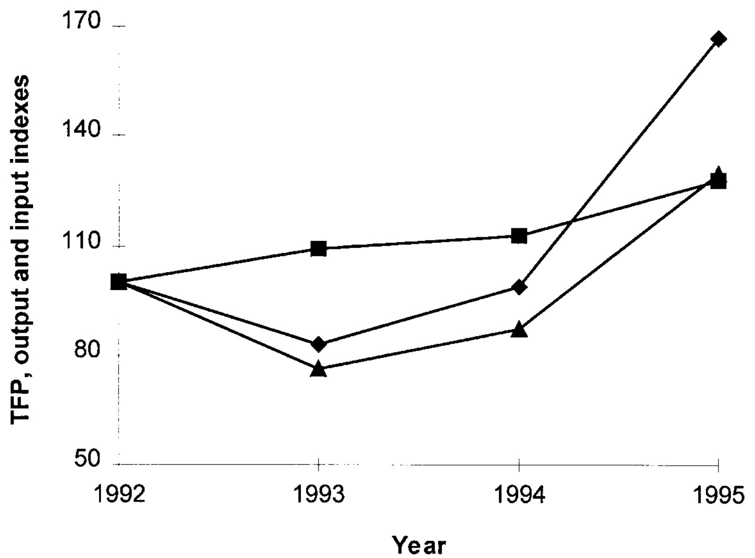

Fig. 2. Total factor productivity (TFP, —▲—), input indexes (—■—) and output indexes (—◆—) for Ilocos Norte, Philippines.

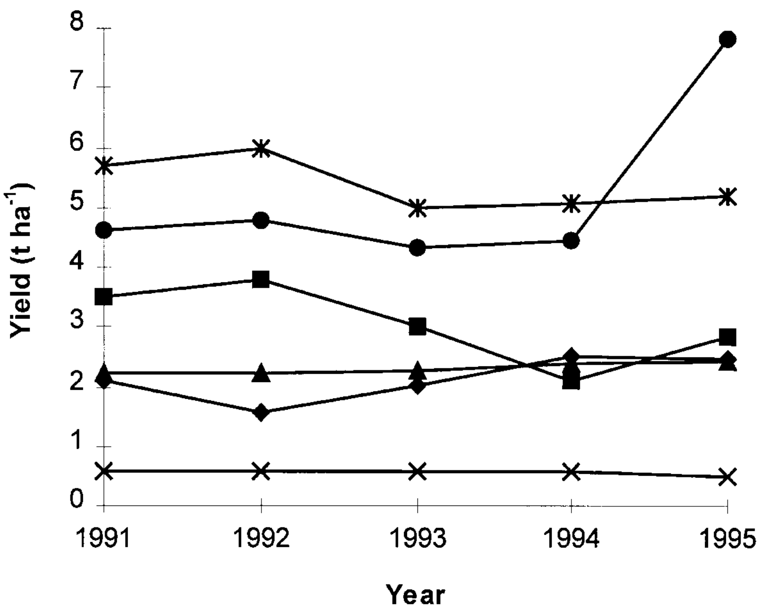

Fig. 3. Yields (t ha^{-1}) of major crops (tomato, —●—; sweet pepper, —✳—; maize, —■—; garlic, —▲—; rice, —◆—; mungbean,—×—) in Ilocos Norte, Philippines. (Source: Department of Agriculture, 1996.)

types of externalities that can threaten sustainability of these intensive production systems. Hydrological monitoring in Ilocos Norte has shown that in several farm locations, nitrate contamination of the ground water is above the minimum safe value prescribed by the World Health Organization (Shrestha and Ladha, 1998).

For farmers not having alternative sources of water for household use, such a high concentration of nitrate could be a potential health hazard. Similarly, high rates of pesticide use could be hazardous as has been found in other locations (Pingali and Roger, 1995). If the rate of withdrawal of water for irrigation is more than the rate of recharge, ground water resources could be permanently depleted. In principle, the economic cost of health effects could be calculated as the sum of the potential loss of labour productivity and the cost of medical treatment using the method developed by Antle and Pingali (1994). However, the necessary data required are not currently available. Similarly, data on the rate of recharge and the hydrologic characteristics of the aquifer, which are needed to ascertain the sustainable level of withdrawal, are not available.

CONCLUDING REMARKS

The agricultural production system of Ilocos Norte can be characterized as commercialized and diversified. Farms are small, cropping intensity is high and the extent of mechanization is low but increasing. A combination of factors such as good access to regional and national markets, plentiful groundwater, fertile soils and favourable climatic conditions has led to the evolution of a dynamic agricultural sector with strong forward and backward linkages with the non-farm sector. Although a substantial proportion of the rice area is rainfed, yields are high because farmers have adopted modern varieties and they apply high levels of chemical fertilizers. Cash income generated by dry season crops seems to be a major factor in shaping the nature of rice production systems.

Intensification and commercialization of the agricultural production system, however, have increased the use of purchased inputs such as chemical fertilizers and pesticides. The high profitability of cash cropping has encouraged farmers to use high levels of these inputs. Although TFP estimates which capture only the on-site effects do not show any clear downward trend, adverse health effects associated with high nitrate contamination of groundwater and high rates of pesticide use could lead to unsustainability of these intensive systems. Groundwater depletion does not seem to be a problem so far in Ilocos Norte, but could also affect sustainability in the long term if it is increasingly exploited. A more complete analysis that captures all on-site and off-site effects for a longer period is needed to derive more definite conclusions regarding sustainability of the system under consideration. Unfortunately, long-term data on the resource base which are needed for such an analysis were not available. Collection of such data is a necessary first step for proper assessment of sustainability.

Assuming that the biophysical environment is conducive to intensification, rainfed rice production systems in other parts of Asia may also change over time and acquire the essential features of the production systems in Ilocos Norte. Production systems are likely to become more commercialized and diversified as access to markets improves. Availability of irrigation in the dry season will encourage the production of a range of cash crops which will be demanded increasingly by urban populations. Where drainage is not a major constraint, some degree of diversification may occur even in the rainy season. All these changes would mean an increasing use of inputs and increasing intensification. Such systems may not necessarily be sustainable if adequate precautions are not taken to minimize the adverse effects of intensification.

A challenge facing agricultural researchers is to develop technologies which ensure sustainability of such intensified systems. Unsustainability may originate not from rice but from other crops which require the use of high levels of inputs. For example, in Ilocos Norte, much of the groundwater contamination is believed to have originated from the dry season crops. If this is the case, improved rice production practices alone will not make the system sustainable. It will be essential for researchers to move from a focus on a specific commodity to the production system as a whole. Obviously, addressing the problems of sustainability in a diversified production system requires a much better understanding of the system-level interactions and a greater amount of multi-disciplinary research. Policy and institutional reforms may also be required to encourage the adoption of more sustainable practices.

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