REVISITING INTENSIVE RICE CULTIVATION IN IRRIGATED AREAS:

THE CASE OF TAMIL NADU, INDIA

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The Philippine Rice Research Institute (PhilRice) is a chartered government corporate entity under the Department of Agriculture. It was created through Executive Order 1061 on November 5, 1985 (as amended) to help develop high-yielding, cost-reducing, and environment-friendly technologies so farmers can produce enough rice for all Filipinos.

It accomplishes this mission through research, development, and extension work in its central and seven branch stations, coordinating with a network that includes 57 agencies and 70 seed centers strategically located nationwide.

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The International Rice Research Institute (IRRI) is the world's premier research organization dedicated to reducing poverty and hunger through rice science; improving the health and welfare of rice farmers and consumers; and protecting the rice-growing environment for future generations. IRRI is an independent, nonprofit, research and educational institute, founded in 1960 by the Ford and Rockefeller foundations with support from the Philippine government. The institute, headquartered in Los Baños, Philippines, has offices in 17 rice-growing countries in Asia and Africa, and more than 1,000 staff members.

Working with in-country partners, IRRI develops advanced rice varieties that yield more grain and better withstand pests and disease as well as flooding, drought, and other harmful effects of climate change. More than half of the rice area in Asia is planted to IRRI-bred varieties or their progenies. The institute develops new and improved methods and technologies that enable farmers to manage their farms profitably and sustainably, and recommends rice varieties and agricultural practices suitable to particular farm conditions as well as consumer preferences. IRRI assists national agricultural research and extension systems in formulating and implementing country rice sector strategies.

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PREFACE

In 1995, the International Rice Research Institute coordinated an international effort that looked into the causes of declining productivity trends in intensive irrigated rice systems in the Philippines, China, Indonesia, Thailand, Vietnam and India. A major feature of this study is the development of a database on input use, level of rice output, prices and detailed cost of rice production. In this study with the costs of producing rice in Central Luzon, Philippines were compared with those in Central Plain, Thailand; Mekong Delta, Vietnam; West Java, Indonesia; Tamil Nadu, India and Zhejiang, China. More than a decade has passed since then, and new government policies, as well as trade regimes, may have caused changes in relative prices. A cost structure of paddy production that is comparable across countries is in short supply. Thus, it is imperative to update the findings of the study.

Rice is intricately related to food security and international trade policies in major rice producing countries. As a result, the Philippine Rice Research Institute of the Department of Agriculture and the International Rice Research Institute, with the participation of the Philippine Council for Agriculture and Fisheries also of the Department of Agriculture jointly planned, designed and implemented a project entitled "Benchmarking the Philippine Rice Economy Relative to Major Rice–Producing Countries in Asia" . The Philippine government, through the Department of Agriculture, provided the full financial support for this undertaking.

The country monograph is one of the major outputs of this project. This monograph is intended for a general audience who would like to learn about the current status of rice production in Asian countries. It attempts to provide the most detailed information on rice farming in intensively cultivated irrigated rice areas of the major rice-producing countries in Asia. These countries include Indonesia, Philippines, Thailand, Vietnam, India and China. All of these countries are among the top 10 rice producers in the world. Data from each country were collected through interviews using electronic questionnaires, which included questions on paddy output, input use, cost of rice production for crop year 2013-14, as well as basic farm and household characteristics.

Each monograph contains a detailed description of each country's crop management practices, input use, labor using and labor-saving practices and various support and services provided by their government to enhance rice production. Given the impending implementation of the free trade agreement which is expected to increase the flow of rice trade among Asian rice bowls, these studies also evaluated the costs and profitability of producing paddy rice.

Results from this study can provide insights on how a country can further improve its competitiveness in rice production and marketing. We gain a perspective on the policies being implemented by our neighbors to make their respective rice industry competitive. By understanding the costs of producing and marketing rice amidst different government policy frameworks in major rice-producing countries, agricultural policymakers can make appropriate decisions on how to best position the country's interest in terms of rice food security. Policymakers and planners can use this information in crafting sustainable development programs for the rice industry.

Project Leaders

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We are also thankful to our country collaborators who helped facilitate our field work in each study site.

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ABSTRACT

This paper describes the rice production system in intensively cultivated and irrigated areas in Tamil Nadu, India, 15 years after the implementation of a project on reversing declining trends in productivity. Current production and marketing practices of farmers are described and compared with previous practices. The cost and profitability of farm production are examined and government policies that supported the local rice industry are identified. The study also determines the best practices and areas for improvement, which can guide practitioners of intensive rice cultivation in other countries. Farm surveys were conducted using structured electronic questionnaires. Purposive sampling was done, and 102 and 101 farmers in the 2013 *kuruvai* and *thaladi* seasons were interviewed. Results indicate that the 2013 yield was lower than that of 1999 because of growing water scarcity, declining nitrogen productivity, and stagnating labor productivity. On a positive note, good practices that could counter the yield reduction were observed—e.g., high adoption of good-quality inbred seeds and less dependence on pesticides. Mechanization of harvesting and threshing operations has also lessened labor cost, potentially reduced postharvest losses, and improved grain quality. The average cost of producing a metric ton of paddy in this area was US$200 in *kuruvai* and US$193 in *thaladi.* Results also show that, on average, an irrigated rice farmer in Tamil Nadu who belongs to a five-member household, owns land and capital, and uses his own and family labor, can generate an annual rice farm income just enough to keep them above the poverty line.

INTRODUCTION

India is the second largest rice-growing country in the world, producing 151.52 million t of paddy in 2012 from 43 million ha. It is also one of the leading rice exporters, trading 10.15 million t of basmati and non-basmati rice abroad in 2012-13 (AIREA, 2012a,b). India's ability to maintain its status as a rice exporter is remarkable, given its population of 1.24 billion, the second highest in the world. This is partly explained by the decline in annual per capita rice consumption from 74.5 kg in 1999 to 68.5 kg in 2009, leading to lower total domestic demand (GRiSP, 2013). Production growth in irrigated areas, which composed 48% of the country's rice harvested area, could have also contributed to its ability to export (TNAU, 2006). Nearly two-thirds of India's paddy production is grown in the irrigated environment. Hence, the country's capacity to sustain production in this environment will help feed its burgeoning population and maintain its status as a major exporter in the coming years.

Concerns have been raised on the sustainability of intensive rice cultivation in irrigated ecosystems. Cassman and Pingali (1995) warned about declining yield in plots with no fertilizer and in those with the "best recommended" fertilizer rate in long-term experiments of double rice cropping in the Philippines. Ali (1996), Huang and Rozelle (1995), Byerlee and Siddiq (1994), and Byerlee (1992) also provided evidences of stagnating productivity and declining soil fertility and resource-use efficiency in intensive rice and wheat areas of the Philippines, China, India, Bangladesh, Nepal, and Pakistan. The diminishing soil fertility was generally recognized as the main cause of stagnating productivity (Dobermann and Witt, 2004). From 1994 to 1999, the International Rice Research Institute spearheaded a project on "Reversing the Trends in Declining Productivity" (RTDP) in intensively cultivated irrigated rice systems through the application of site-specific nutrient management. Fifteen years after implementation, project sites in India were revisited to understand how the rice farming system in those areas have changed since the introduction of such technologies.

This paper aims to (1) describe the current rice production system and marketing practices of famers in irrigated areas of India and compare these with previous practices; (2) examine the cost and profitability of rice production; (3) identify government programs that support the local rice industry; and (4) determine best practices and areas for improvement that would benefit practitioners of intensive rice cultivation in other countries.

METHODOLOGY

Data Sources and Methods

The RTDP project had previously selected Tamil Nadu to represent a tropical climate and a rice-rice cropping system in India. One of the most important rice-producing states in India, Tamil Nadu has favorable soil and climatic conditions (Nagarajan et al., 2004). In 2011, it produced 10.34 million t of paddy from 2.06 million ha, with yield averaging 5.02 t ha^{-1}. Its rank as a rice-producing state dropped to sixth from being fifth in 2000 due to a slight decline in production and harvested area (previously 10.80 million t and 2.10 million ha). Rice production in Tamil Nadu is concentrated in the Cauvery Delta Zone, including Thanjavur District. The project sites of RTDP were located in Thanjavur and Aduthurai, where the Tamil Nadu Rice Research Institute (TNRRI) is situated (Dobermann et al., 2004; Nagarajan et al., 2004). For purposes of the current study, we visited nine villages within Thanjavur and Nagapattinam districts (Fig. 1). Although no sample village was located in Aduthurai, the selected villages surround TNRRI.

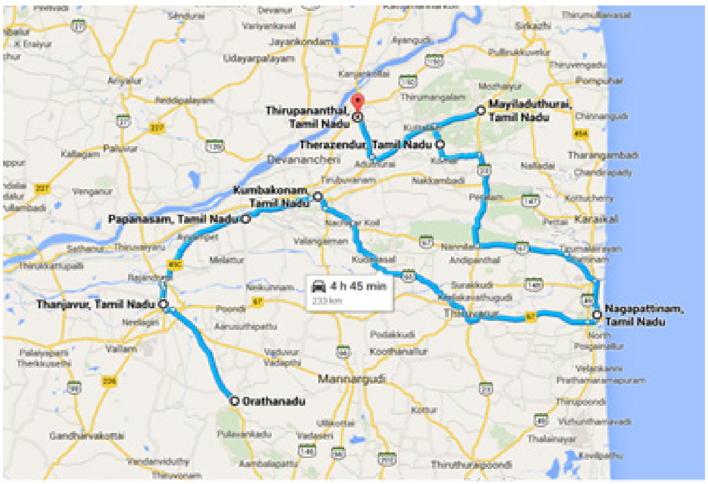

Fig. 1. Location of study sites (Source: www. google,maps.com).

Sampling procedure

Farm surveys were conducted during *kuruvai* (June to September 2013) and *thaladi* (October 2013 to February 2014) seasons using structured electronic questionnaires in MS Access format. Purposive sampling was done to get a quota sample of 100 respondents. As much as possible, farmers who participated in the RTDP project were traced and asked to become respondents. Some cannot be found and were replaced by farmers who met the following criteria: those living in the same villages, have at least 10 years of farming experience, and whose farms were irrigated and planted in 2013. Since the RTDP sample was small, about 25-30 farms located within a 15-20-km radius around TNRRI (Dobermann et al., 2004), the same criteria were used to get additional sample farmers for this study. A total of 102 respondents were interviewed during *kuruvai*. Unfortunately, only 94 of them were available for interview during *thaladi*. Data for seven replacements were gathered to complete the 101 respondents for the second season.

Data gathering through personal interview with farmers guided by a structured questionnaire and aided by a translator.

Analytical method

Data on yield, input use, crop management practices, and input and output prices were obtained during the interview. Basic demographic data of farmers and farm characteristics were also gathered. To construct the farm budget structure, costs of seeds, fertilizers, pesticides, hired labor, animal and machine rental, and fuel were considered. The value of operator, family, and exchange labor was imputed, and so was the value of land, using the average rent per hectare per season paid by those who did not own the land they cultivate. Average interest rate of savings was used to impute the interest cost of those who did not borrow capital. Other costs on irrigation, food, land tax, and transportation were also included. These were analyzed using frequency distribution and descriptive and inferential statistics**.**

Following Moya et al. (2004), partial factor productivity of nitrogen (N) and labor inputs was also analyzed. Nitrogen productivity was calculated by getting the ratio of kilogram grain output to kilogram N applied. Similarly, labor productivity was obtained by dividing total grain output by total mandays (1 manday = 8 h of work) employed in rice production for the whole cropping season.

Data Limitation

While the data in this study can provide insights about the status of irrigated rice production in Tamil Nadu, there are limitations that should be considered in the interpretation of results. First, the accuracy of the gathered information is subject to the farmers' ability to recall their production practices and expenditure in the previous season. Second, the reliability of the information also highly depends on the capability of the translators to accurately translate the responses of farmers from the local dialect to English. Finally, the information gathered only represent the rice production system in intensively cultivated and irrigated areas and results should not be construed to cover the entire state.

RESULTS & DISCUSSION

Demographic profile of farmers and farm characteristics

The 2013 study revealed that Tamil Nadu farmers were in their fifties, about a decade older than the batch of farmers under RTDP whose ages averaged 43 (Table 1). They have 10 years of education, similar to the educational attainment of the previous batch (Nagarajan et al., 2004). Rice farming in Tamil Nadu remained a patriarchal occupation, with 97% of the respondents being male. Households usually have five members. About half of them (47%) have attended rice production-related training since 2008, but only a few (28%) have joined farm organizations. An overwhelming majority (93%) of farmers owned the land they cultivate, but more than half still borrowed capital for rice production. Approximately 78% of the household's annual gross income came from rice farming.

Table 1. Demographic profile of farmers.

Item	Value (n=109)
Age (yr)	49.5
Education (yr)	10.0
Household size (no. of persons)	5.2
Sex (% male)	97.2
Tenure (% owner)	92.7
Organization (% member)	28.4
Training (% trained)	46.8
Capital (% borrower)	51.4
Rice income share (%)	78.2

The total area cultivated by respondents averaged 3.08 ha in *thaladi* and 3.33 ha in *kuruvai* (range was from 0.40 to 40.49 ha). Majority of the farmers, 62% in *thaladi* and 54% in *kuruvai*, tilled an area of 1-4 ha (Fig. 2). The one with the biggest farm size was operated by the Roman Catholic Church in Ammanpettai. Eight out of 10 farmers typically worked in one parcel. The current farm sizes were bigger than those in RTDP with a maximum of 32 ha and a median of 2.80 ha (Moya et al., 2004).

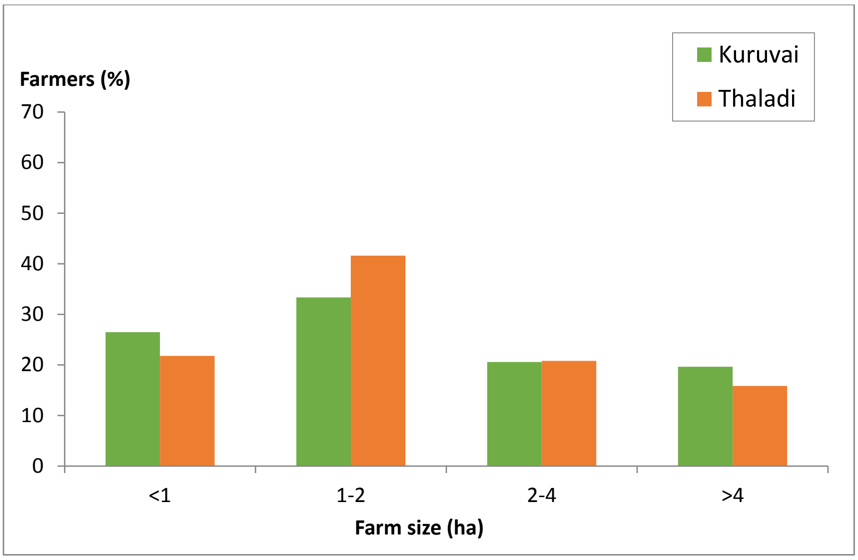

Fig. 2. Distribution of farm size, by season, Tamil Nadu, India, 2013.

For double rice crop, the two major rice-growing seasons in the Cauvery Delta Zone are *thaladi* and *kuruvai.* The former coincides with the monsoon and the latter coincides with the dry season. While the *thaladi* crop is commonly irrigated through the Cauvery river irrigation canal, the *kuruvai* crop has been increasingly irrigated through the use of bore wells. As before, pulses were still popularly grown in-between the two rice crops (Nagarajan et al., 2004).

About 80% of the farmers primarily used underground water for irrigation through bore wells (Fig. 3). Only 16% and 4% of farmers respectively indicated state irrigation canals and river/streams as their main source of irrigation water. Nearly 40% of the farmers who primarily used bore wells also mentioned state irrigation canals as a secondary water source. This reliance on groundwater for irrigation was already observed during the RTDP implementation (Nagarajan et al., 2004). However, its use may have intensified over the years because of the strictly regulated water release from the Cauvery River. The heavy dependence of farmers on groundwater for irrigation were driven by (1) a water dispute of Tamil Nadu with neighboring Karnataka State, leading to a limited water supply from the Cauvery River; and

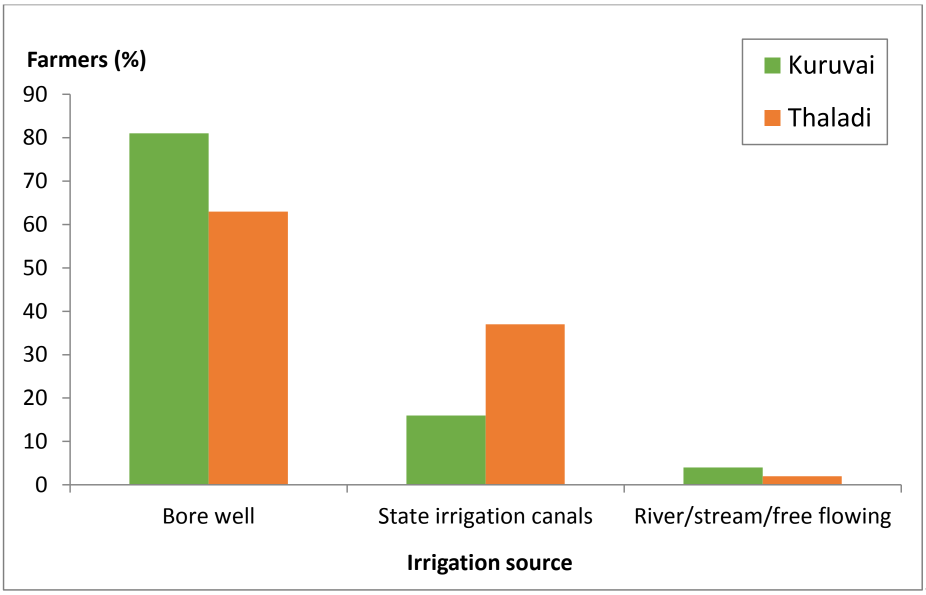

Fig. 3. Distribution of irrigation source, by season, Tamil Nadu, India, 2013.

(2) free electricity for agricultural purposes, which is used to power water pumps (Shah et al., 2007). Consequently, rice production in the area faced the problem of groundwater depletion and many farmers complained about insufficient water due to shortage of electricity.

Factor use and crop management

This section describes the input use of farmers and their crop management practices. This involves seed and variety, fertilizer, pesticides, and labor.

Variety, seed, and crop establishment

Medium- to long-duration rice cultivars (125-135 d) were often planted during *thaladi,* whereas early-maturing varieties (105-110 d) with high yield potential were regularly planted during *kuruvai*. Survey results (Table 2) indicate that CR 1009 and BPT 5204 were the most common varieties grown during *thaladi* (planted by 41% and 24% of sample farmers, respectively). The popularity of these two varieties is confirmed by the Rice Knowledge Management Portal (Thiyagarajan and Kalaiyarasi, 2011). CR 1009, a long-duration variety, was popular because of its resistance to brown planthoppers and high yield potential (TNAU, 2015). On the other hand, BPT 5204, a medium-maturing variety, was considered a fine variety, usually fetching a high price in the market.

Table 2. Common varieties planted (%), by season, Tamil Nadu, India, 2013.

Variety	*Kuruvai* (n=102)	*Thaladi* (n=101)
ADT 38	78.6	9.9
ADT 45	9.7	2.0
CO 51	6.8	0.0
ADT 43	1.9	9.9
CR 1009	1.0	40.6
ADT 46	1.0	3.0
BPT 5204	0.0	23.8
ADT 39	0.0	7.9
ADT 49	0.0	3.0

ADT38, a short-duration variety, was one of the most popular during *kuruvai.* Planted by 79% of the sample farmers (Thiyagarajan and Kalaiyarasi, 2011), it has good resistance to green leafhoppers, high tillering ability, and fine grain characteristics (TNAU, 2015). ADT 45 is another early-maturing variety commonly planted in this season.

The use of high quality seed (in the form of tagged inbred seed) was quite common in Tamil Nadu (Table 3). About 93% and 96% of sample farmers in *thaladi* and *kuruvai*, respectively, used tagged seed (i.e., certified or registered seed), which were usually bought from private companies or input dealers. Private companies were the seed source of 68% of sample farmers in *thaladi* and of 48% in *kuruvai.* Similarly, 12% and 38% of them bought seed from input dealers during the monsoon and dry seasons, respectively. The average price of certified seed in Tamil Nadu was US\$0.61 kg^{-1} (Rs 36 kg^{-1}) [1]. Hybrid rice varieties are far from being popularly adopted in this state.

[1] 1 US$ = 58.6 rupees (IMF 2015). This was also used in succeeding conversions.

Table 3. Seed class of varieties planted (%), by season, Tamil Nadu, India, 2013.

Class	*Kuruvai* (n=102)	*Thaladi* (n=101)
Hybrid	1.0	0.0
Certified and registered	96.1	93.1
Farmer's seed	2.9	6.9

Average seeding rate was 77 kg ha^{-1} during *thaladi* significantly higher 82 kg ha^{-1} in *kuruvai* (Table 4). In both seasons, 98 to 99% of farmers transplanted rice, which could explain the relatively lower seeding rate in this area. Nevertheless, the sample average was still higher than the recommended seeding rate of 40 kg ha^{-1} for medium-duration and 60 kg ha^{-1} for short-duration varieties (Thiyagarajan and Kalaiyarasi, 2011).

Although the mean seedling age at transplanting was about 27 to 28 days, the observed maximum age was 40 to 60 days. In fact, more than 50% of the sample farmers transplanted seedlings that were at least 30 days old. The relatively old seedling age at transplanting could have negatively affected the yield as the plant recovers from transplanting shock instead of preparing for the reproductive stage.

Mechanized transplanting of rice seedlings in Tamil Nadu.

Fertilizer and nutrient management

Farmers applied 107 and 105 kg ha^{-1} of N in *thaladi* and *kuruvai,* respectively; this difference was not significant (Table 4). Correspondingly, phosphorus (P) applications averaged 20 and 21 kg ha^{-1}, whereas mean potassium (K) applications were 37 and 33 kg ha^{-1}. As in N, P and K applications were not significantly different across seasons, implying that farmers did not maximize the higher yield potential yield that they could have achieved in the latter season. Rice is usually more responsive to fertilizers during the dry season and applying more of these can lead to higher yield.

The amounts of fertilizer applied were lower compared with recommended doses under RKMP (Thiyagarajan and Kalaiyarasi, 2011). Based on the findings of Moya et al. (2004), the current N rate was lower than those applied in the RTDP farms during the 1999 high-yielding season (113 kg ha^{-1}) but higher than those in the low-yielding season (92 kg ha^{-1}). On the other hand, current P rates did not differ much from previous applications of 20-24 kg ha^{-1}. The amount of applied K was slightly higher than previous applications (30 kg ha^{-1} in high-yielding season and 24 kg ha^{-1} in low-yielding season).

Table 4. Area and material inputs used in rice farming, by season, Tamil Nadu, India, 2013.

Item	*Kuruvai* (n=102)	*Thaladi* (n=101)	Difference	
Total area cultivated (ha)	3.33	3.08	0.2	ns
Seeds (kg ha^{-1})	82.2	76.6	5.6	*
N (kg ha^{-1})	105.0	107.2	-2.3	ns
P (kg ha^{-1})	20.7	19.7	0.9	ns
K (kg ha^{-1})	33.1	37.2	-4.1	ns
Insecticide (% of farmers)				
Monocrotophos	52.4	37.6		
Profenofos	11.7	17.8		
Demacron	0.0	4.0		
Carbofuran	2.9	4.0		
Permethryn	2.9	2.0		
Herbicide (% of farmers)				
Pretilachlor	25.2	25.7		
Metsulfuron methyl + chlorimurone	9.7	8.9		
Pyrazosulfuron ethyl	0.0	6.9		
Oxydiargyl	13.6	6.9		
Butachlor	3.9	4.0		

*indicates significance at 90% confidence level; ns=not significant.

Urea, diammonium phosphate (DAP), and muriate of potash (MOP) were the three most common inorganic fertilizers used in Tamil Nadu. All farmers applied urea and about 97% of respondents used DAP. About 86-87% used MOP in both seasons. Urea is popular in India because it is cheap (about US$102 t^{-1} or Rs 6000 t^{-1}. This was way lower than the world average price in 2013, which was US$340 t^{-1} (Index Mundi, 2015). Urea, being a controlled fertilizer in India, is sold at a government-fixed uniform sale price, while phosphatic and potassic fertilizers are sold at government-suggested maximum retail prices (GOIDOF, 2015). Among the three commonly applied fertilizers, DAP was the most expensive at US$401 t^{-1} (Rs 23,480 t^{-1}); MOP cost US$305 t^{-1} (Rs 17,900 t^{-1}).

Farmers also used biofertilizers such as neem cake and farmyard manure (FYM). Around 10% and 19% of them used neem cake as fertilizer in *thaladi* and *kuruvai* seasons, respectively. Neem cake is the by-product of oil extraction from the fruit-seed and can thus be used as fertilizer and systemic pesticide (Lim and Bottrell, 1994).

In addition to inorganic fertilizers, about 9% of farmers in *thaladi* and 15% in *kuruvai* also applied FYM. According to FAO-UN (2005), the use of FYM composed of cattle manure, compost, green manure, and others is the oldest and most widely practiced way of replenishing soil nutrients in India. However, use of FYM has apparently gone down substantially, considering that most Tamil Nadu farmers used FYM primarily in *kuruvai* during the RTDP implementation (Moya et al., 2004). The decrease in animal population could explain the declining use of FYM over the years. Farmers also incorporated rice straw in the soil. Around 18% and 37% of them practiced this in *thaladi* and *kuruvai*, respectively. Rice straw was used to supplement potassic fertilizers (TNRRI, 2014).

On average, farmers applied fertilizers in four splits per season, including one in the seedbed (Table 5). More than 90% of the farmers applied fertilizer in the seed nursery and three out of four applied at least thrice in the main field per season. More frequent application of fertilizer is common in Tamil Nadu due to ample supply of labor and low wage rate in the area (Moya et al., 2004).

Table 5. Distribution of farmers, by frequency of fertilizer application and by season, Tamil Nadu, India, 2013.

Application	*Kuruvai* (n=102)		*Thaladi* (n=101)	
	Frequency	%	Frequency	%
Seed nursery				
None	10.0	9.8	4.0	4.0
Once	92.0	90.2	97.0	96.0
Main field				
None	1.0	1.0	0.0	0.0
Once	2.0	2.0	1.0	1.0
Twice	24.0	23.5	24.0	23.8
Thrice	60.0	58.8	66.0	65.3
Four times or more	15.0	14.7	11.0	10.9

Pesticide

Insecticides and herbicides were the common types of pesticides applied by Tamil Nadu rice farmers. About 69-75% of them applied insecticides and 62-66% applied herbicides in the main field in both seasons.

Nevertheless, only 22% applied insecticides in the seed nursery, while very few (2-4%) used herbicides in the seedbed.

Monocrotophos was the most commonly used active ingredient of insecticide with 38% and 52% of farmers applying this in *thaladi* and *kuruvai*, respectively. It was applied to primarily manage leaffolder incidence (Sivakumar et al., 1997). Profenofos is another popular insecticide in Tamil Nadu. About 18% and 12% of farmers used this in both seasons. Monocrotophos and profenofos belong to the organophosphate class of insecticide, which targets the nervous system of insect pests. However, monocrotophos is classified as highly toxic (FAO-UN, 1997) and profenofos moderately toxic (PANNA, 2014). The greater popularity of the former could be due to its lower price (US$9 L^{-1}). Profenofos cost US$10-12 L^{-1}. During *kuruvai*, 67% of farmers applied insecticides only once, while 9% applied twice or more (Table 6). On the other hand, 50% of the farmers applied once and 20% applied at least twice during *thaladi.*

Pretilachlor, the most commonly applied active ingredient of herbicide in Tamil Nadu, is primarily used against main annual grasses, broad-leaved weeds, and sedges (PIS, 2015). About 63% and 61% of farmers applied herbicide once in *kuruvai* and *thaladi*; only 1-3% applied at least twice. The price of pretilachlor was about US$8-9 L^{-1}.

Some farmers (30% in *kuruvai* and 28% in *thaladi*) also applied fungicides. Carbendazim was the most common. About 24-28% of the farmers applied fungicide once, while only 2-4% applied twice or more.

Table 6. Distribution of farmers, by frequency of pesticide application and by season, Tamil Nadu, India, 2013.

Application	*Kuruvai* (n=102)		*Thaladi* (n=101)	
	Frequency	%	Frequency	%
Insecticide				
Seed nursery				
None	80.0	78.4	79.0	78.2
Once	22.0	21.6	22.0	21.8
Main field				
None	25.0	24.5	31.0	30.7
Once	68.0	66.7	50.0	49.5
Twice	7.0	6.9	15.0	14.9
Thrice	2.0	2.0	4.0	4.0
Four times or more	0.0	0.0	1.0	1.0
Herbicide				
Seed nursery				
None	100.0	98.0	97.0	96.0
Once	2.0	2.0	4.0	4.0
Main field				
None	35.0	34.3	38.0	37.6
Once	64.0	62.7	62.0	61.4
Twice	3.0	2.9	1.0	1.0
Thrice	0.0	0.0	0.0	0.0
Four times or more	0.0	0.0	0.0	0.0
Fungicide				
Seed nursery				
None	100.0	98.0	98.0	97.0
Once	2.0	2.0	3.0	3.0
Main field				
None	71.0	69.6	74.0	73.3
Once	29.0	28.4	24.0	23.8
Twice	1.0	1.0	2.0	2.0
Thrice	1.0	1.0	1.0	1.0
Four times or more	0.0	0.0	1.0	1.0

On average, Tamil Nadu rice farmers applied pesticides twice per season (once for insecticide and once for herbicide). The use of varieties resistant to pests such as brown planthoppers and green leaffolders may have contributed to the low pesticide use in this area. No government support on the prices of pesticides was documented during the survey period.

Labor and mechanization

The labor input employed in rice farming per hectare, by type of labor and season, is shown in Table 7. Rice farming activities are divided into land preparation, crop establishment, crop care and maintenance,

Table 7. Labor inputs (man-days ha^{-1}) in rice farming, by type of labor and by season, Tamil Nadu, India, 2013.

Item	*Kuruvai* (n=102)	*Thaladi* (n=101)	Difference	
Total labor	78.3	77.4	0.9	ns
Land preparation	5.5	4.9	0.6	ns
Crop establishment	32.7	37.1	-4.4	**
Crop care and maintenance	37.5	32.7	4.8	ns
Harvesting and threshing	2.0	2.4	-0.4	**
Postharvest	0.6	0.2	0.4	***
Hired labor	67.3	70.2	2.9	
Land preparation	5.3	4.6	-0.7	ns
Crop establishment	32.4	36.7	4.3	**
Crop care and maintenance	27.0	26.3	-0.7	ns
Harvesting and threshing	2.0	2.4	0.4	*
Postharvest	0.6	0.2	-0.4	***
Operator, family, and exchange labors	11.0	7.2	-3.8	
Land preparation	0.1	0.3	0.2	**
Crop establishment	0.2	0.4	0.2	ns
Crop care and maintenance	10.5	6.4	-4.1	**
Harvesting and threshing	0.0	0.0	0.0	*
Postharvest	0.0	0.0	0.0	ns

*, **, *** indicate significance at 90%, 95%, and 99% confidence level, respectively; ns = not significant.

harvesting and threshing, and postharvest. Total labor is the sum of hired labor, and that of operator, family, and exchange (OFE) labor. Hired labor refers to workers who are employed and paid on a daily or contractual basis. On the other hand, the farmer himself, other members of the family, and exchange labor who performed farm activities comprise the OFE labor. These workers are not actually compensated for the tasks they do. However, OFE cost is imputed on the basis of the prevailing wage or contract rate per farm activity.

Hired labor was relatively higher in *thaladi,* with 70 md ha^{-1} as against 67 md ha^{-1} in *kuruvai*. In both seasons, labor inputs for crop establishment and crop care and maintenance had the largest share of total hired labor. The prevalence of manual transplanting explains the labor-intensiveness of crop establishment, which required 37 and 32 md ha^{-1} in *thaladi* and *kuruvai*, respectively. Labor for crop establishment was significantly higher in *thaladi* than in *kuruvai*. The high labor requirement for crop care and maintenance (e.g., fertilizer and pesticide application, weeding, and water control) results mainly from the popular practice of manual weeding.

Land preparation required only 5 md ha^{-1} in both seasons because of full mechanization; all farmers used either two- or four-wheel tractors in plowing and harrowing. The seasonal difference in hired labor for this activity was not statistically significant. Harvesting and threshing in Tamil Nadu are already mechanized, with virtually 100% of the farmers using combine harvesters. For these activities, farmers only need about 2 md ha^{-1}. Interviews of key informants revealed that the adoption of the combine harvester has been one of the major changes in rice farming in the area in the last 5 years. Though minimal, postharvest labor (e.g., for cleaning, blowing, and hauling) was significantly higher in *kuruvai*.

OFE labor accounted for only 9 and 14% of total labor input in both seasons. More OFE labor was required during *kuruvai* (11 md ha^{-1}) than in *thaladi* season (7 md ha^{-1}). Most of the OFE labor was spent on crop care and maintenance and was significantly higher during *kuruvai*. That devoted to land preparation was also found to be significantly lower in *thaladi.* As in Tamil Nadu, an increasing reliance on hired labor in rice production has been observed over the decades in other countries, particularly in the Philippines and other Southeast Asian economies (Hayami and Kikuchi, 2000). This could be partly explained by ageing farmers and increasing opportunity cost of family labor. The relatively bigger farm size in Tamil Nadu could have also contributed to the declining dependence on OFE labor.

The total labor input in rice production appeared to decline slightly. During RTDP implementation, average labor input in Thanjavur was 81 md ha^{-1} during 1998 *kuruvai* (Nagarajan et al., 2004). Based on the current survey, total labor input was only 77-78 md ha^{-1}. The reduction in labor input could be attributed to greater use of combine harvesters.

Transplanting and weeding were commonly done by women, while other activities that involve the use of machine or that require greater energy (e.g., land preparation, transporting seedlings, harvesting and threshing, hauling of input or output) were performed by men. Because of greater skills and power needed from male labor, a disparity in the prevailing daily wage rates was observed: about US$5-7 (Rs 300-400) for men and US$3-4 (Rs 150-250) for women. The male-female difference in wage rate was already common in Tamil Nadu, even during RTDP implementation, and this was one practice that did not change over time.

Women as manual transplanters in rice farming.

Aside from workers hired on a daily basis, some workers were asked to perform farm activities based on contracts. For land preparation, the common contract rate was US$63 ha^{-1} (Rs 3,705 ha^{-1}), which included payment for the operator and the machine rental. Similarly, the usual contract rate for harvesting and threshing that used a combine harvester was US$22-29 h^{-1} (Rs 1,300-1,700 h^{-1}). It commonly takes 3.5-5 h to harvest and thresh paddy from a hectare of land.

Rice combine harvesters in Tamil Nadu. (source: http://www.thehindu.com)

Credit and financing

Majority of Tamil Nadu farmers borrowed capital to finance their rice farming operation. About 54% and 55% of them borrowed capital during *thaladi* and *kuruvai* seasons, respectively. Interest rate per month was generally lower during *thaladi* (average of 0.61% and maximum of 3% per month). In *kuruvai*, average monthly interest rate was 0.70% and maximum was 5%. In both seasons, interest was 0% per month. This usually occurs when farmers borrow from cooperatives and pay within the prescribed time. About 48-49% of those who borrowed have zero interest on their loans. Other credit sources were private and government banks and private moneylenders. The latter charged the highest interest rate among various credit sources. Other loans required collateral in the form of jewelry.

Postharvest and marketing practices

Based on survey results, Tamil Nadu farmers usually sold their wet paddy right after harvest. Drying paddy before selling was not common, except when farmers were selling to direct procurement centers (DPCs) of the government. Hence, before the advent of the combine harvester, a common postharvest problem of farmers was the germination and fermentation of wet paddy. During those days, farmers used salt to prevent germination. Salt stress was found to inhibit final germination percentage, speed of germination, and germination energy percentage of indica rice varieties in Tamil Nadu (Anbumalarmathi and Mehta, 2013). However, the use of the combine harvester has hastened activities and significantly cut the time between threshing and selling of output. Because of this, farmers nowadays no longer use salt to prevent germination. This has also potentially cut postharvest losses.

As to marketing, buyers (traders or millers) directly picked up the output of more than 50% of farmers from their farm or a designated location. Paddy was commonly transported by lorry. The distance of the largest rice-based parcel to the nearest major market of inputs and/or output ranged from less than 1 km to 22 km. Results show that farm-to-market roads were mostly made of asphalt and concrete.

While all farmers sold paddy, 50% of them retained some amount for home consumption. About half sold paddy to private traders and millers and others sold to government DPC. The Tamil Nadu Civil Supplies Corporation has been procuring paddy in the Cauvery Delta Region under a decentralized procurement scheme since 2002. The state government of Tamil Nadu has adopted a decentralized system of procurement as per minimum support price and uniform specification fixed by the Government of India (TNCSC, 2014). The Corporation has become the sole agency of procurement on behalf of the Food Corporation of India. The paddy procured is hulled through its own and private modern rice mills. The decision on where to sell is sometimes affected by the type of varieties planted. Common varieties (CR 1009, TKM 9) were bought by the DPC, while fine varieties (ADT 43, ADT 45, BPT 5204) were bought by private traders.

An open cap storage of paddy rice.

Yield and partial factor productivity

Paddy yield was reported at field moisture content (MC), which was generally 18-24% during *kuruvai* and 14-20% in *thaladi*. Average yield in *thaladi* was 4.77 t ha^{-1}, which was slightly higher than *kuruvai*'s 4.71 t ha^{-1} (Table 8). The interseason difference, however, was not significant (Fig. 4).

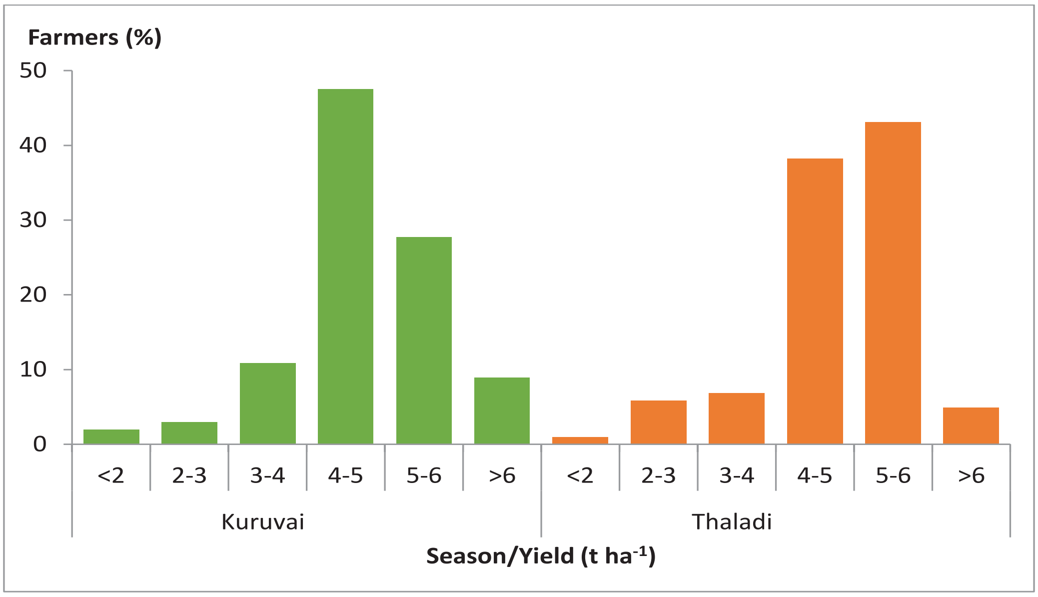

Fig. 4. Distribution of yield, by season, Tamil Nadu, India, 2013.

Table 8. Costs and returns of paddy production, by season, Tamil Nadu, India, 2013.

Item	Value		Difference		Cost share (%)	
	Kuruvai (n=102)	*Thaladi* (n=101)			*Kuruvai* (n=102)	*Thaladi* (n=101)
Returns						
Yield (t ha^{-1})	4.71	4.77	-0.06	ns		
Paddy price (US$ t^{-1})	244.2	233.8	10.5	**		
Gross revenue (US$ ha^{-1})	1,149.3	1,114.9	34.3	ns		
Costs (US$ ha^{-1})						
Seed	51.6	43.4	8.2	***	5.5	4.7
Fertilizer	95.2	96.1	-0.9	ns	10.1	10.4
Pesticide	21.5	25.3	-3.8	ns	2.3	2.7
Hired labor	279.9	249.7	30.2	*	29.7	27.1
Operator, family, & exchange labor	56.8	42.0	14.7	ns	6.0	4.6
Animal, machine, fuel & oil	181.5	193.2	-11.8	ns	19.2	21.0
Irrigation	11.9	12.7	-0.8	ns	1.3	1.4
Food	12.5	18.5	-6.0	***	1.3	2.0
Transportation	3.8	5.6	-1.7	*	0.4	0.6
Tax	2.8	2.6	0.2	ns	0.3	0.3
Land rent	202.4	209.9	-7.5	ns	21.5	22.8
Interest on capital	9.6	8.0	1.6	ns	1.0	0.9
Other inputs	13.7	14.3	-0.5	ns	1.5	1.5
Total cost (US$ ha^{-1})	943.2	921.2	22.0	ns		
Cost per unit (US$ mt^{-1})	200.4	193.1	7.3	ns		
Net income from rice farming (US$ ha^{-1})	206.1	193.7	12.4	ns		
Farmers' income (US$ ha^{-1}) [a]	474.8	453.6	21.2	ns		

*, **, *** indicate significance at 90%, 95%, and 99% confidence level, respectively; ns = not significant.

[a] Farmers' income is composed of net income from rice farming, returns of own labor, land, and capital.

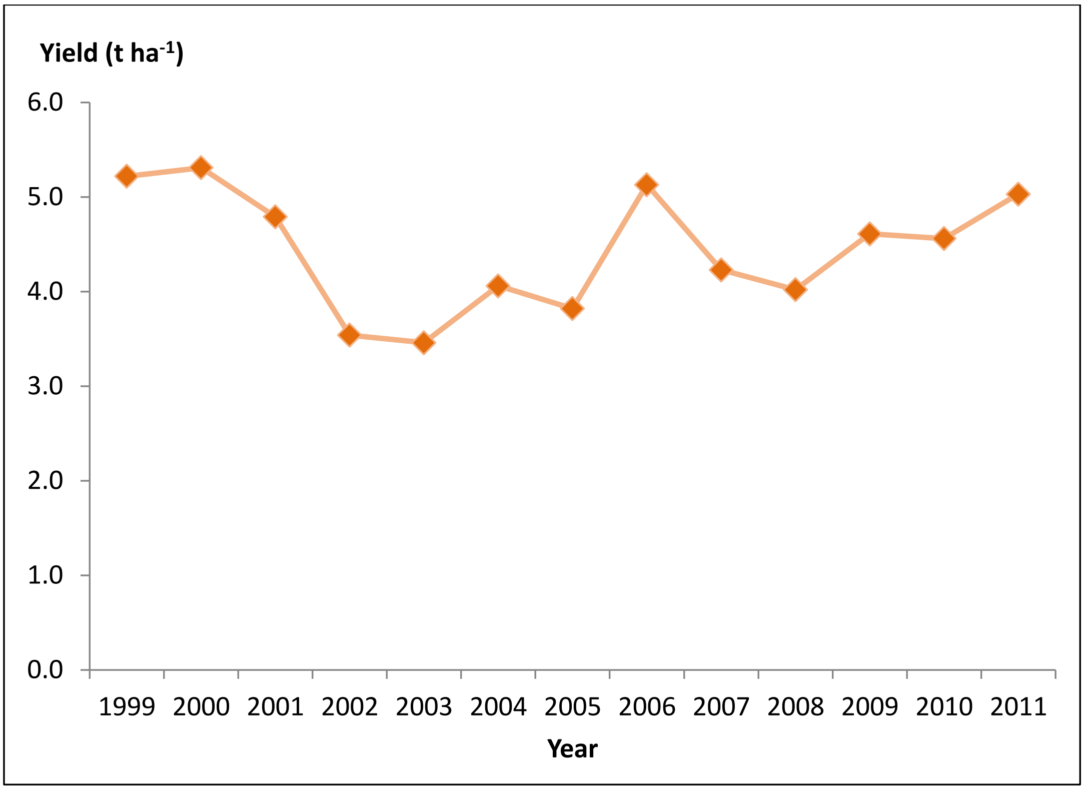

Fig. 5. Trends in rice yield in Tamil Nadu, all ecosystems, 1999-2011.

Using the midpoint of the reported MC as the initial level to convert yield to dry equivalent (14% MC) resulted in 4.3 t ha^{-1} in *kuruvai* and 4.6 t ha^{-1} in *thaladi*.

The mean dry yield in 2013 was slightly lower than the median yield in Thanjavur in the 1998 *kuruvai* crop, which was 5.2 t ha^{-1} (Nagarajan et al., 2004). It was also lower than the average yields observed during the high- and low-yielding seasons in Tamil Nadu RTDP farms (located mostly in Aduthurai) in 1999, which were 5.9 and 5.3 t ha^{-1}, respectively (Moya et al., 2004). The lower yield found in the 2013 survey was consistent with the general yield trend seen in Tamil Nadu from 1999 to 2011 (Fig. 5). In general, average yield in Tamil Nadu across production ecosystems declined substantially from 1999 to 2005. Although yield has recovered since then, the highest level achieved in 2000 was never reached in recent years.

Using fresh weight of paddy as basis, more farmers obtained yields between 5 and 6 t ha^{-1} in *thaladi* (43%) than in *kuruvai* (28%). In contrast, fewer farmers had yields between 4 and 5 t ha^{-1} in the former season (38%) than in the latter (48%). The lower yield achieved in *kuruvai* could be the result of water stress, noting that it coincides with the dry season and farmers relied more on pumped-out groundwater for irrigation. The lower amount of applied N could have also led to reduced yield in this season.

Nitrogen productivity was practically flat across seasons, at 45 kg grain per kg N. This level had gone down from 51 and 56 kg grain kg^{-1} N during the high- and low-yielding seasons reported in RTDP farms in 1999 (Moya et al., 2004). The insignificantly different N application across seasons indicates the inability of farmers to optimize N efficiency; they could have applied more N when the plant is more responsive (i.e., during the dry season). Water availability could be the main factor affecting their decision to apply N fertilizer.

Average labor productivity in 2013 was respectively measured at 62 and 60 kg grain md^{-1} during *thaladi* and *kuruvai*. The RTDP data showed that mean labor productivity in Thanjavur during 1998 *kuruvai* was 64 kg grain md^{-1} (Nagarajan et al., 2004). This means that labor productivity almost stagnated over time.

Although reduction in labor input due to mechanization of harvesting and threshing could have increased labor productivity, this has been countered by the reduction in yield.

Cost and profitability of rice production

Paddy prices were significantly higher during *kuruvai* perhaps because of the fine characteristics of rice varieties planted during this season (Table 8). Gross revenue per hectare during *kuruvai* was higher at US$1,149 compared with US$ 1,115 in *thaladi*, though this difference was not significant.

Total paddy production cost per hectare in *kuruvai* was US$943; it was US$921 in *thaladi*. In both seasons, hired labor cost contributed the largest share, at 30 and 27%. This expense was significantly bigger in the first season because of the higher cost of land preparation, crop care and maintenance, and postharvest activities. Land rent was next, with shares of 21 and 23%. Animal and machine rent, including spending for fuel and oil, contributed 19% in *kuruvai* and 21% in *thaladi.* Fertilizer and seeds had the respective share of 10% and 5% in each season, while OFE labor had a cost share of 5-6%. Pesticide had the minimal cost share of 2-3% because there was reduced application of this chemical. The cost of irrigation, food, transportation, land, tax, and interest on capital accounted for the rest.

The cost of producing a metric ton of paddy in Tamil Nadu was only US$200 (Rs 11,744) in *kuruvai* and US$193 (Rs 11,318) in *thaladi.* To compare with the estimated unit cost in 1999, land rent must be deducted from the current cost level since the former did not include this item. The 1999 cost must also be expressed in 2013 values using the consumer price index. Deducting land rent resulted in a per-metricton cost of US$157 (Rs 9,224) and US$149 (Rs 8,739) in *kuruvai* and *thaladi*, respectively. This is 29-36% higher than the cost recorded in 1999 (valued at 2013 prices), which was only US$115 t^{-1} (Rs 6,765). The increase can be mostly attributed to the increase in the price of inputs, particularly that of labor. Nevertheless, the slight decline in output did not help arrest the rise in cost per metric ton over time.

Net returns to rice farming in Tamil Nadu were US$206 ha^{-1} in *kuruvai* and US$194 ha^{-1} in *thaladi*, considering both paid-out and imputed costs. Nevertheless, in the situation when the farmer owns the land and capital used in rice farming and he does not pay for OFE labor, returns will double to US$475 ha^{-1} in *kuruvai* and US$454 ha^{-1} in *thaladi*. Thus, annual household income from rice would be around US$928 or US$186 per capita (assuming they have five members).

The 2011-12 annual per capita poverty threshold in the rural areas of Tamil Nadu was US$180 (Rs 10,560 yr^{-1} or Rs 880 mo^{-1}) (GOIPC, 2013). This shows that income from rice production, including returns to own land, capital, and labor will barely cover the basic needs of a five-member farming household—that is, farming households in intensively cultivated and irrigated areas that depend only on rice production for a living will, on average, be slightly above the poverty level.

SUMMARY & IMPLICATIONS

Yield in intensively cultivated and irrigated areas in Tamil Nadu was found to be lower than before, amidst rising problems of water scarcity, declining N productivity, and stagnating labor productivity. The diminishing N productivity in the area could stem from the inability of farmers to optimize the efficiency of fertilizer application (i.e., applying when plants are more responsive to fertilizers). In spite of mechanization, the yield decline resulted in decreasing labor productivity. These lead to further questions about the sustainability of rice production systems in intensively cultivated and irrigated areas.

Fortunately, good agricultural practices abound that could help counter the yield decline in the area. One is the high adoption of good-quality inbred seed. With popular use of high-quality seed, farmers only need to alter their crop management practices, particularly nutrient management, to fully harness the potential yield of varieties. Changing crop establishment practices, particularly transplanting of old seedlings, can also help improve yield.

Less pesticide application is also important as this reduces the risk of insects building pesticide resistance thereby lowering the incidence of pest outbreaks in the future. Moreover, the use of less pesticide is an advantage for Indian rice exports, especially if the country of destination is testing for pesticide residues.

The mechanization of harvesting and threshing has also improved the production process. Not only was labor cost reduced, farmers have potentially lowered postharvest losses. Grain quality improved by merely cutting the time between threshing and selling of produce.

In spite of the increase in production cost of paddy per metric ton, farmers in Tamil Nadu might still be one of the least-cost producers in Asia. This is important for the country to remain a major player in the world's rice export business. Unfortunately, this scenario will change if the decline in yield continues. The profitability of rice production in an intensively cultivated and irrigated ecosystem also showed that it is enough to lift a household of five members just above the poverty threshold. However, this may not hold true for farmers who rent land, borrow capital, and have limited OFE labor or for producers of a single rice crop per year. Hence, the generation of additional sources of income aside from rice farming could be an important strategy in alleviating poverty in the rural areas.

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