RICE PRODUCTION IN THE MIDST OF ECONOMIC DEVELOPMENT:

THE CASE OF JINHUA, ZHEJIANG, CHINA

Alice B. Mataia, Ma. Shiela D. Valencia, Ronell B. Malasa, Maria Belen A. Milanes, Flordeliza H. Bordey, Piedad F. Moya, Ding Xianghai, and Huang Xueping

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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.

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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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ABSTRACT

This report assesses the performance of rice production in intensely cultivated irrigated areas in Zhejiang, China, under a rapidly growing economy. In particular, farmers' rice production management and marketing practices were determined; rice productivity and profitability examined; government support and policies in the rice sector identified; and best farming practices significantly contributing to rice productivity growth documented. A structured electronic survey questionnaire was used in collecting data on 2013 production during the *early* (January to June) and *late* rice (July to December) cropping seasons. A quota sample of 100 farmers from five villages was set for personal interviews. Results show that yields were high across seasons, averaging 8.02 and 6.56 metric tons (t) ha^{-1} for *late* and *early rice*, respectively. However, yield was significantly higher by 1.46 t ha^{-1} in *late rice* because of the adoption of hybrid rice. Labor productivity was also high and this was attributed to direct seeding and use of machinery in major farm activities. In spite of this, average cost of producing rice was high: an average of US$308 t^{-1} for *early rice* and US$324 t^{-1} for *late rice*. As a result, profitability of rice farming was low.

The rise in land rent and wages led to high cost of land and labor, and the extensive use of fertilizers and pesticides likewise contributed to high production cost. This diminished the province's competitiveness in rice production. This could affect rice food security because farmers shift to the more profitable and higher value cash crops. Input productivity must thus be increased to reduce cost and improve rice competiveness if the province were to sustain its rice production and enhance its food security.

INTRODUCTION

Rice has been the most important food crop in China's agricultural economy because it is one of its main staples. It accounted for 29% of the country's total grain sown area and 35% of total grain production in 2000. However, its importance has declined considerably as its share of total calories has fallen from 38 to 30% since 1985 (GRiSP, 2013). China is the world's largest rice producer, accounting for nearly one-fourth of the global sown area and more than one-third (32-35%) of world rice production (Zhang, 2013). In addition, more than 90% of its rice-growing areas are irrigated, the rests are under rainfed conditions (IRRI, 2015). Rice yield (6.5 t ha^{-1}) in the country is also above the world average of only 4.3 t ha^{-1} (GRiSP, 2013).

In 2012, the rice area harvested accounted for 30.30 million ha with a yield of 6.74 t ha^{-1}. This translates into total paddy production of 204.29 million t or an equivalent of 143.00 million t of milled rice. Within the 1990-2011 period, area harvested has declined by 0.53% annually, but paddy production has increased by 0.08%, and this was attributed to the growth in yield by 0.71% (Table 1).

China's rice economy faces a number of challenges. Although annual per capita rice consumption declined from 79 kg in 2000 to 71 kg in 2012, the country remains the world's largest consumer of rice (Table 1). It has a population of 1.38 billion, the largest in the world, and growth rate increases annually by 0.62% (an equivalent of 9 million people every year). Declining rice area is likewise a major constraint to food security as paddy production is put under pressure with more land being used for economic and urban development. Equally, this raises the opportunity cost of land for rice farming. The increase in off-farm employment opportunities and the subsequent labor shortage in the rural areas (Li et al., 2013) also drive up wages, resulting in higher production and marketing costs in the whole rice supply chain (OECD-FAO, 2013). From 1985 to 2004, the cost of producing rice in China increased from US$34.17 to $43.83 t^{-1} for *early indica rice* and from US$34.30 to $44.20 t^{-1} for *late indica rice* (Jin et al., 2010). Labor and material inputs represent 46% and 54% of total cost, respectively. Subsequently, the higher cost exerts pressure on net farm income and lowers the competitiveness of rice production.

China also regularly imports and exports rice each year. In 2012, imports exceeded exports (Table 1). The pattern of growth in China's rice area and production is particularly important because the country accounts for a large share of the world's rice production and consumption. China's changes in net trade status could have substantial effects on global rice prices.

Table 1. Rice supply and demand, China, 2012.

Item	2012
China	
Area harvested (million ha)	30.30
Yield (t ha^{-1})	6.74
Paddy production (million t)	204.29
Milled rice production (million t)	143.00
Per capita rice consumption (kg yr^{-1})	70.90
Export (million t)	0.30
Import (million t)	2.40
Population (billion)	1.38
Annual growth (1990-2011)	
Area harvested (%)	-0.53
Paddy production (%)	0.08
Yield (%)	0.71
Zhejiang, 2011	
Area harvested (million ha)	0.89
Paddy production (million t)	6.49
Yield (t ha^{-1})	7.25

Sources: IRRI, 2013; USDA,2015

Alongside this background, this report aims to provide a better understanding of rice production in intensively cultivated and irrigated areas in China and its implications on the country's competitiveness. Specifically, this report 1) describes the rice production system in irrigated areas; 2) assesses crop management practices and technology use; 3) examines productivity and profitability of rice production; 4) identifies government program and policy support in rice; and 5) ascertains best practices and lessons that can be useful in improving the productivity and competitiveness of the country's rice farm sector.

METHODOLOGY

Survey area, sample size, and data collection

The study was conducted in Zhejiang Province, situated in the southeastern part of China. The province has subtropical monsoon climate and four distinct seasons. It is endowed with abundant sunshine, mild temperature (16-18 ^{o}C), and adequate annual precipitation of 1,100-1,900 mm. In 1995, the province has a total cultivated land of 1.62 million ha, 1.27 of which is irrigated and where double rice cropping has been practiced since the 1960s (Wang et al., 2004). The two main rice-cropping seasons are *early rice* (ER) and *late rice* (LR). Rice farming comprises relatively small-scale farms with an average size of 0.6 ha.

Zhejiang is one of the major rice production areas in the southeastern region. In 2012, the area harvested (0.89 million ha) accounted for 2.98% of the country's total area harvested while its production (6.49 million t) accounted for 3.23% of national output. Zhejiang is the 11th largest rice-producing province in China, with its reported yield (7.25 t ha^{-1}) ranking 13th among the 30 largest rice producers (this was higher by 0.56 t ha^{-1} than the country's average) (Table 1). However, the decline in rice area in China has been mirrored in Zhejiang as the province became industrialized and agriculture has diversified. Since the mid-1980s, the province has become one of the fast-developing areas in China and off-farm employment of farmers has increased (Wang et al., 2004). Zhejiang was selected to represent the intensely cultivated rice areas in China because of its long history of double rice cropping. It was also a former site of IRRI's project on *Reversing Trends of Declining Productivity* (RTDP), which was conducted from 1995 to 1999 (Moya et al., 2004).

The survey areas were located in three towns of Jinhua City, the center of Zhejiang Province (Fig. 1). However, due to rapid economic and urban development in Jinhua District, some rice farms at the RTDP sites no longer exist as these were converted for cultivation of high-value crops and used for other purposes. Hence, these were replaced by areas under the same production system, with similar cropping pattern and soil type. Table 2 shows the sample survey areas with 3 townships and five villages specified. A quota sample of 100 farmers, equally distributed according to the number of villages, was interviewed for the farm household survey. The survey included the same farmers originally selected for the RTDP project. Nonetheless, farmers who shifted to planting of other crops were replaced. A new set of sample

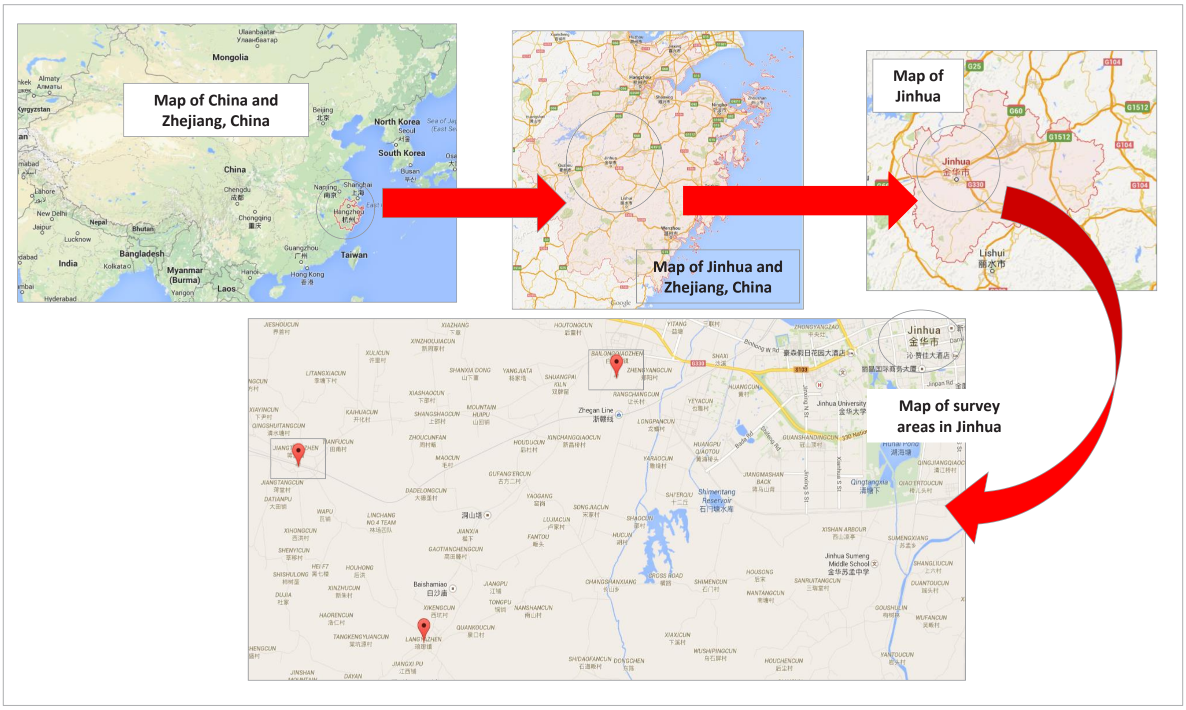


Fig. 1. Location of survey areas in Jinhua, Zhejiang, China
(Source: www.google.maps.com).

Table 2. Sample areas and corresponding number of sample farmers, Jinhua, Zhejiang.

Township	Sample village	Farmers (no.)
Lang-Ya	Xinzhu	20
	Baishalu	20
Jiangtang	Xihong	20
	Dongzhou	20
Bailongquiao	Xiayang	20
Total		**100**

farmers purposively selected by the respective village leader was included in the farm household survey to complete the 100 sample farmers. Farmers were selected using these criteria: farmers who live in the same village, have at least 10 years of rice farming experience, have an irrigated farm, and have a harvested crop in 2013. In addition, three sample farmers during the ER season, who were not available for interview in the LR season, were replaced using the established criteria.

Two separate surveys were conducted to capture data on the 2013 rice cropping seasons. The first survey covered the ER season and the second survey, the LR season. ER is mostly grown from early April to mid- or late July, and LR is planted from mid-July to late October. Primary data on farmers' socioeconomic characteristics, production practices, costs and yield, and the government's rice policy program were collected using an electronic survey questionnaire to expedite collection and encoding of data.

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

Data analysis

The two-season survey data were analyzed using descriptive statistics. The test of means was also utilized to determine significant differences between average yield, input use, and cost of production of ER and LR seasons. Cost-and-return analysis was also employed to determine profitability of rice production in the survey area. In addition, partial factor productivity (PFP) was used to measure farm-level productivity.

Data limitations

The survey data used in the analysis have some limitations, which could have potential impact on the findings. First, the data and information are based on farmer interviews about the 2013 harvested crop and data accuracy therefore depends on the farmers' ability to recall the exact amount of input use and corresponding prices. Second, there is a language barrier because the study proponents are not Chinese nationals. Third, interviews with farmers were conducted with the assistance of Chinese interpreters or translators, and data reliability is also dependent on how effectively the message in English was interpreted. Nevertheless, the dataset remains the most updated and useful source of information for assessing the performance of rice production in Zhejiang, China.

Cost and return analysis

To determine profitability of rice production, gross returns, production cost, and net profit were analyzed. Gross return was derived by multiplying yield (in kg ha^{-1}) by farm gate price (in US\$ kg^{-1}). Production costs were divided into seed, fertilizer, pesticide, hired and family labor, power cost (animal, machine, fuel & oil), and other costs (irrigation, food, transportation, tax, land rent, interest on capital). Dawe (2006) states that costs of production are measured as cash paid out for inputs, labor, machine services; value of any paid in kind; and value of services provided by the farmer and his family (family labor and land). The cost of family labor (operator, family and exchange) was imputed by number of man-days multiplied by the corresponding daily wage rate, by farm operation. Wage rates in the survey areas varied, depending on the farm operation. In addition, since majority of the sample farmers used their own capital to finance production cost, interest on capital was imputed by multiplying the prevailing savings rate with cash expenditures consisting of paid-out costs of seed, fertilizer, chemicals, pre-harvest hired labor and power and assuming a loan period of 4 months.

On the other hand, net profit was computed by subtracting total production cost from gross returns. Yield, gross returns, and production cost were all calculated on a per-hectare basis. Simple averages were taken and converted into US$ using the exchange rate of RMB6.20=US$1 (IMF, 2015).

Partial factor productivity

Productivity measures how well an industry uses its resources. Partial factor productivity (PFP) refers to the productivity of a single input or the ratio of total output to a single input (Dawe 2004). This can be calculated by dividing total grain output by total amount of inputs used. In this study, PFP was measured for land, labor, and major nutrient (nitrogen fertilizer).

RESULTS & DISCUSSION

Socioeconomic and demographic characteristics

This portion describes the socioeconomic and demographic characteristics of sample rice farmers as well as features of their cultivated rice area. Specifically, it provides information on farmer's age, education, years in rice farming, rice income, and household farm assets.

Farmer characteristics

Table 3 summarizes the characteristics of sample farmers interviewed in the five villages of Jinhua, Zhejiang, China. An aging population of farmers was observed in this community— mean age was 55 years and age range was 41-70 years. Most of the farmers are male and have farming experience of not more than 35 years. Aside from farming, they also have off-farm employment (e.g., construction, carpentry, and factory/manufacturing) across Jinhua City. These farmers shuttle between cities during the off-season and return home to sow and harvest their crops during cropping season. Since more young Chinese people leave the rural community to engage in non-farm work in the cities, it is the elderly who are left behind to do the farming chores. Majority of the farmers have completed primary education (an average of 7 years in school), which corroborates the findings of Moya et al. (2004). However, this is lower than the government's requirement of at least 9 years of education[1].

Ninety-six percent of the respondents were members of an organization/association as cooperatives in China have rapidly developed since 1990 (Hu et al., 2006). The growth of farmer cooperatives has become a highlight in China's innovative management of its agricultural organizations and systems (MOA, 2011). From 2008 to 2013, 70% of the farmers have attended training courses related to rice production. Training is normally offered by agricultural input companies, national extension agencies, the township administration, and research institutions. The farmer interviewees said that most of the training they received was provided by cooperatives and agricultural input companies.

Farm household characteristics

On average, one household consisted of four members. According to the National Statistical Bureau of China (NSBC), household size was negatively correlated to income. In 2012, low-income households had

[1] In China, the government requires all school-age children to get at least 9 years of education (6-year primary education and 3-year secondary education) under the "Law on Nine-Year Compulsory Education" that took effect on July 1, 1986.

Table 3. Characteristics of farmer-respondents and farm household, Zhejiang, China, 2013.

Item	Value (n=100)
Age (yr)	54.0
Education (yr)	7.3
Household size (no. of persons)	3.7
Farming experience (yr)	35.0
Organization (% membership)	96.1
Training (% trained)	69.9
Share of rice income to total household income (%)	27.0

an average size of three, whereas the high-income households only had two. The relatively small size of Chinese households could be linked to the country's-one-child-per-household policy introduced in 1979.

Rice income, on the average, represented 27% of total household income. This means that non-rice income comprises the major share of total household income, making farm households less vulnerable to any fluctuations in income from rice farming. The computed per capita rice income was US$650 annually, which is above the annual per capita poverty threshold in Zhejiang, China (US$498 in 2012).

Farm characteristics

Table 4 shows that each sample farmer was cultivating an average farm size of 0.46 ha, divided into two (2.3) parcels with a mean size of around 0.2 ha per parcel. Farm size varied among regions because of differences in land quality. A typical farm is devoted to cultivation of rice and other high-value crops such as oilseed, vegetables, and ornamental trees. On average, farms in the survey areas are about 2.5 km away from the nearest market center and roads are commonly made of concrete.

Table 4. Farm characteristics, Zhejiang, China, 2013.

Item	Value (n=100)
Rice area cultivated (ha)	0.46
Rice parcels (no.)	2.3
Tenure (% ownership)	100.0
Source of irrigation	State irrigation canal
Road structure	Concrete
Distance in km from farm to market	2.5
Ownership of farm assets (%)	
No ownership	15.0
2-wheel tractor	30.0
4-wheel tractor	8.0
Thresher	2.0
Combine harvester-thresher	9.0
Pump	11.0
2-wheel tractor + 4-wheel tractor	2.0
2-wheel + combine HT + pump	1.0
2-wheel + pump	4.0

Generally, farmers "owned" the land they cultivate (Table 4). In China, the government owns the land as a collective, but farmers are given the right to use the land in the form of a contract. Under the Rural Land Contract Law, farmers have the right to transfer and exchange contracted land, and they have full control of production decisions. The law also allows family members to inherit the land rights during the contract period (Van Tongeren and Huang, 2004).

Most of the cultivated rice areas have access to state irrigation canals, where farmers do not pay any fee. Investment in irrigation was one of the major drivers of productivity growth in agriculture in China after the economic reforms. According to Wang (2000), irrigation has played a critical role in establishing the highly productive agronomic systems in China— the proportion of cultivated area under irrigation increased significantly from 18% in 1952 to about 50% of all cultivated areas in the early 1990s (NSBC, 2001).

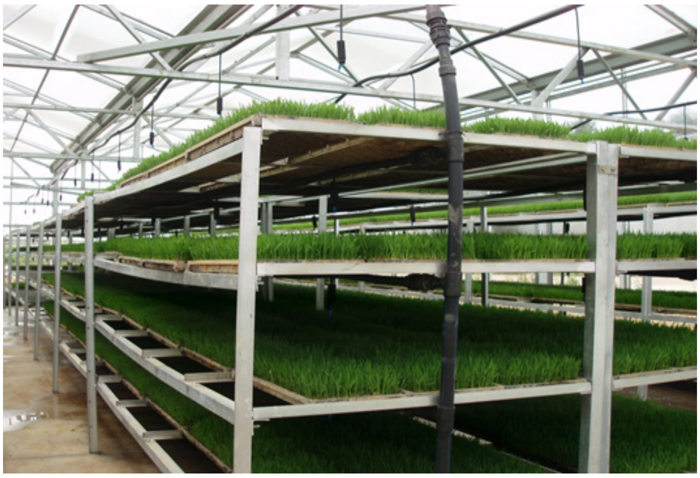
Majority of the sample farmers owned farm equipment: a big proportion (70%) owned an electric motor and some owned a two-wheel tractor (16%), a four-wheel tractor (4%), a thresher (1%), a combine harvester (2%), and individual pump (3%). Only 15% of the sample farmers did not own any farm assets. A few farmers owned several machines.

Factor use and crop management

The major factors used in rice production are land, labor, capital, seed, fertilizer, pesticide, machine, and irrigation. This section discusses these factors as well as the management practices of farmers in the survey areas during the two seasons.

Seed, variety, and crop establishment method

Table 5 shows the seed quality, variety, and crop establishment method used by sample farmers. The technologies and practices used in the ER and LR seasons were completely different. During ER, farmers typically planted inbred rice using manual direct seeding. In the 1990s, Zhejiang farmers started to shift from transplanting to direct seeding (Wang et al., 2004). Sixty-three percent used certified seed and 37% grew farmer's seed. Jinzhao 09 and Jinzhao 47 were the commonly used inbred rice varieties, with 43% of the farmers getting seed subsidy from the government. In contrast, hybrid rice was typically adopted during LR season when climate is more favorable. Majority of the farmers transplanted hybrid rice with 82% of them doing it manually and 10% using a mechanical transplanter. Hybrid rice is usually grown during LR because of its long growth duration. Seedlings are commonly transplanted 23−30 days after sowing. Only a few hybrid varieties were planted in this area, with Yongyou 9 being the most common. Majority (78%) of the farmers purchased hybrid seed from private companies and very few availed of it under the government seed subsidy program. Seed subsidy varied greatly between townships and villages, depending on their administration scheme. Key informants revealed that the government limits the number of varieties recommended for planting per season to only three per district to ensure high seed quality.



Left: Raising rice seedlings in tray for mechanized transplanting.
Right: A machine for rice transplanting in Jinhua, Zhejiang.

Table 5. Seed and crop establishment method used, Zhejiang, China, 2013.

Item	Early rice (n=100)	Late rice (n=100)
Crop establishment method (%)		
Transplanting	0	92
Manual	0	82
Mechanical	0	10
Direct seeding	100	8
Seed quality (%)		
Hybrid	0	100
Certified seed	63	0
Own-saved seed	37	0
Varieties (%)		
Jinzhao 47	50	0
Jinzhao 09	49	0
Xianyou	1	0
Yongyou 15	0	2
Yongyou 9	0	98
Seed acquisition (%)		
Free (government subsidy)	42	22
Bought	21	78
Own saved	37	0
Seed use and price		
Seed (kg ha^{-1})	109.7	13.8
Price (US$ kg^{-1})	0.84	12.33

In terms of seeding rate, farmers used an average of 110 kg ha^{-1} for inbred seed (under direct seeding) and only 14 kg ha^{-1} for hybrid seed. Prices also considerably differed between seed classes, US$0.84 and US$12.33 kg ha^{-1} for inbred and hybrid, respectively.

Fertilizer and nutrient management

Farmers in Zhejiang have applied high amounts of N fertilizer since the 1990s (Moya et al., 2004). The 2013 survey results confirmed this finding. Considerably higher fertilizer usage was observed in LR than in ER. Application rate was 198-29-110 kg NPK ha^{-1} in LR as opposed to 162-20-90 kg NPK ha^{-1} in ER (Table 6). This could be explained by the adoption of hybrid rice in LR, which is more responsive to fertilizer input. These rates were even higher than what Moya et al. (2004) found: 171-10-60 kg NPK ha^{-1} during the low-yielding season and 174-17-63 kg NPK ha^{-1} in the high-yielding season.

It was observed that farmers did not practice site-specific nutrient management (SSNM), which was one of the technologies introduced in the province in the last 15 years. Studies about SSNM conducted in Zhejiang showed that it is still possible to further decrease the level of NPK use with no adverse effect on yield (Wang et al., 2007). The farmers admitted not using SSNM as they relied more on the use of blanket fertilizer recommendations given by extension agents who visit their villages. This type of recommendation has minimum variability in terms of type and amount of fertilizers applied. Furthermore, the size of the area they cultivate was the basis for the recommended fertilizer rates.

Table 6. Fertilizer use and frequency of application, Zhejiang, China, 2013.

Item	Early rice (n=100)	Late rice (n=100)	Difference
NPK applied (kg ha^{-1})			
N	162.31	198.07	-36.76***
P	20.09	29.12	-9.03**
K	90.12	110.25	-20.13**
Frequency of application			
Average	2	3	
Minimum	2	1	
Maximum	4	5	
Farmers who applied (no.)	100	100	
Price of fertilizer (US$ kg^{-1})			
Potassium chloride (KCl)	0.51	0.56	
Urea (46-0-0)	0.37	0.35	
Complete (15-15-15)	0.60	0.63	

Note: ***, ** indicate significance at 99% and 95% confidence level, respectively.

All farmers in the area applied fertilizers, with greater frequency in LR than in ER. Farmers applied fertilizers in the main field one to five times in LR (average of three splits) and two to four times in ER (average of two splits). In addition, farmers traditionally applied fertilizer on the seedbed with a maximum of three applications. Some practiced basal application of fertilizer a day before direct seeding or transplanting. Across seasons, the most common fertilizers used by the farmers were urea (46-0-0), potassium chloride or KCl (0-0-60), complete (15-15-15), and CNH_3 (17-0-0). Only a very slight difference in the price of fertilizers in ER and LR was noted (Table 6).

Pesticide management

Because farmers in the survey areas did not consider rodents and golden snails as major pests, only herbicides, insecticides, and fungicides were commonly used. Majority of the farmers applied herbicides and insecticides, while about half used fungicides in both cropping seasons. Generally, they applied

Left: A tractor used in fertilizer application. Right: A fertilizer bin attached to the tractor.

several brands of pesticides: 12-19 for herbicides, 17-21 for insecticides, and 5-7 for fungicides (Table 7). Moreover, they usually mixed all types of pesticides per application. The most common herbicides used were penoxsulan butachlor and bensulfuron methyl; for insecticides, flubendiamide and imidacloprid were popular. However, one general observation was the greater number of farmers applying flubendiamide, abamectin, and imidacloprid in LR than in ER, a practice associated with the adoption of hybrid seed. Jiangangmycin and difenoconazole were the most common fungicides used across seasons (Table 8).

As with NPK fertilizers, farmers were also heavy users of pesticides. They extensively used insecticides, averaging twice in ER and ranging from one to four times of application. Usage was higher in LR, average of five applications and frequency range of 2 to 10 times. Across seasons, the number of applications for all types of pesticides was higher in LR as part of the management protocol for hybrid rice seed.

Table 7. Pesticide use, Zhejiang, China, 2013.

Item	Early rice	Late rice
Farmers who applied (%)		
Herbicide	100	98
Insecticide	97	100
Fungicide	43	48
Brands used (no.)		
Herbicide	12	19
Insecticide	17	21
Fungicide	5	7
Frequency of application		
Herbicide		
Av	1.3	1.8
Min	1	1
Max	2	4
Insecticide		
Av	2.1	5.1
Min	1	2
Max	4	10
Fungicide		
Av	0.5	0.8
Min	0	1
Max	3	3

Table 8. Most common pesticides used (%), by type and by season, Zhejiang, China, 2013.

Herbicide (n=100)		Insecticide (n=100)		Fungicide (n=100)	
Early rice*					
Penoxsulan Butachlor	61	Flubendiamide	49	Jiangangmycin	39
Zhibojing	26	Abamectin	28	Difenoconazole	17
Qianjin	25	Imidacloprid	26	-	-
Bensulfuron methyl	19	Fuge	21	-	-
Fenser	10	Chlorpyrifos	9	-	-
Late rice*					
Penoxsulan butachlor	49	Kang kuang	59	Jiangangmycin	34
Bensulfuron methyl	49	Imidacloprid	49	Difenoconazole	21
Zhibojing	14	Abamectin	39	-	-
Pretilachlor	14	Fuge	34	-	-
Clincher	10	Pymetrozine	10	-	-

* Greater than 100% due to multiple responses.

Labor and mechanization

Yang et al. (2013) reported the labor shortage in China's rural areas, particularly in the agriculture sector, the result of the rapid increase in rural non-farm employment and rural-to-urban migration. The government addressed labor concerns by promoting the use of machinery. Since 2004, machine ownership and rental have become popular in China (Yang et al., 2013). Farm mechanization through customized services specialized labor and use of large machinery has expanded.

Labor use

Table 9 shows labor input use (man-days [md] ha^{-1}) in rice production, by cropping season. The major farm operations were categorized into land preparation, crop establishment, crop care and maintenance, harvesting and threshing, and postharvest. The sources of labor were classified into hired and operator, family, and exchange (OFE) labor. Hired labor refers to workers paid on a daily basis or on a contract rate, whereas OFE refers to the farmer-operator himself, other family members, and exchange labor who are not paid for carrying out the farm operation. However, the cost of OFE labor was imputed on the basis of the prevailing daily wage rate or contract rate corresponding to the farm activity performed.

Labor in the area was primarily OFE labor, which comprises 80-86% of total labor input in rice production. This can be explained by the small farm size and limited supply of hired labor due to high off-farm employment opportunities. Hired labor input constituted only 14–20% of the total. Overall, rice production was found to be not highly labor-intensive, with only 20 md ha^{-1} in ER and 35 md ha^{-1} in LR. However, total labor use was significantly higher in LR as adoption of hybrid rice entailed more crop management activities.

Table 9. Labor input used (md ha^{-1}), by source and season, Zheijiang, 2013.

Item	Early rice (n=100)	Late rice (n=100)	Difference	
Hired labor	3.87	4.61	-0.73	**
Land preparation	1.19	1.48	-0.28	**
Crop establishment	0.10	1.91	-1.81	***
Crop care and maintenance	1.51	0.10	1.41	**
Harvesting and threshing	0.97	0.99	-0.02	ns
Postharvest	0.10	0.13	-0.03	ns
Operator, family and exchange labor	15.98	30.36	-14.37	***
Land preparation	2.92	3.76	-0.84	**
Crop establishment	2.02	14.58	-12.56	***
Crop care and maintenance	10.06	11.01	-0.96	**
Harvesting and threshing	0.03	0.01	0.02	ns
Postharvest	0.96	0.99	-0.03	ns
Total labor	19.86	34.96	-15.11	***
Land preparation	4.12	5.24	-1.13	**
Crop establishment	2.12	16.49	-14.37	***
Crop care and maintenance	11.57	11.11	0.46	ns
Harvesting and threshing	1.00	1.00	0.00	ns
Postharvest	1.06	1.12	-0.06	ns

Note: ns, ***,** indicate not significant and significance at 99% and 95% confidence level, respectively.

Farm mechanization

Major farm operations such as land preparation, harvesting, and threshing were highly mechanized. Land preparation activities from plowing, harrowing to leveling were commonly done with a four-wheel tractor and can be finished only 1 md ha^{-1}. On the other hand, cleaning and repair of dikes were manually done by the farmer operator and by other household members as well. Harvesting and threshing were performed with the use of a combine harvester and can be completed using only 1 md ha^{-1}. Other farm operations were also partly mechanized: more than half of the farmers adopted mechanical dryers, especially in ER, whereas the majority (97%) used electric motorcycles, tractors, or mini trucks to haul output from the farm to the house or any drying place (Table 10). The level of mechanization rose compared with what previous research had reported. Moya et al. (2004) found that, when power threshers were still used to thresh paddy, it took 8 md ha^{-1} to accomplish the task. Mechanizing rice farming has been part of China's long-term goals since the 1950s (Li, 2005; Wang, 2013). However, mechanization was done through custom-hiring, especially for major farm activities. The small farm size makes it impractical for farmers to own machines for land preparation, harvesting, and threshing. The Chinese government has recognized this and it came up with "socialized contract services as a solution to promote agricultural mechanization and resource conservation approaches for the small-scale farming system" (Wang, 2013).

A four-wheel tractor commonly used in land preparation.

Although China had already ventured into mechanical direct seeding, farmers still preferred manual direct seeding because of machine problems such as inaccurate "sowing rate" and "sowing leak" (Xu et al., 2011). Mechanized transplanting has better adoption rate, with 11% of farmers using transplanters (Table 10). The limited supply of farm labor motivated the farmers to slowly adopt mechanical transplanters.

Fertilizer and pesticide applications were largely done manually, and mostly by the farmer operators themselves (Table 10). However, key informants revealed that China is also planning to mechanize these crop care activities in the future and prototypes of this kind of machinery were already developed and were undergoing field testing in large farms. Table 9 shows that, in both seasons, crop care and maintenance was labor-intensive using 11 md ha^{-1}.

Wage rates

Wage rates in rice production activities were high in the area. Typically, wage rate differs on the basis of farm operation and gender. Wage rate was relatively higher in land preparation, crop establishment, and harvest and postharvest activities relative to other farm operations (Table 11). Likewise, it was higher for male than for female labor. A machine operator received the highest wage rate, at US$33 md^{-1}. On the

Table 10. Source of labor use and extent of mechanization in rice production, Zhejiang, China, 2013.

Activity	Early rice (n=100)				Late rice (n=100)			
	Source of power		*Source of labor*		*Source of power*		*Source of labor*	
	Manual	Mechanical	OFE*	Hired	Manual	Mechanical	OFE*	Hired
Land preparation								
Cleaning and repair of dikes	57	0	55	2	17	0	17	0
Rototilling/plowing/harrowing	4	96	13	87	0	99	17	83
Leveling*	13	0	13	1	35	20	38	17
Crop establishment								
Direct seeding	100	0	98	2	8	0	8	0
Transplanting	0	0	-	-	82	10	68	24
Pulling of seedlings	0	0	-	-	82	0	54	28
Hauling of seedlings	0	0	-	-	42	12	30	24
Replanting	4	0	4	0	9	0	9	0
Fertilizer and pest management								
Fertilizer	100	0	97	3	100	0	100	0
Herbicide	100	0	98	2	97	1	98	0
Insecticide	96	1	95	2	98	2	100	0
Fungicide	42	1	42	1	47	1	47	0
Monitoring								
Field	100	0	100	0	100	0	100	0
Seedbed	0	0	-	-	11	0	11	0
Water management								
Constructing canalets	0	0	0	0	17	0	17	0
Irrigating	98	2	97	3	95	5	100	0
Draining water in the field	83	0	82	1	72	0	72	0
Draining water in the seedbed	0	0	-	-	13	0	13	0
Harvest and postharvest								
Harvesting and threshing	3	97	4	96	0	100	2	98
Hauling	1	99	89	11	7	93	82	18
Drying	45	55	45	55	67	33	66	34

Table 11. Prevailing wage (US$ md^{-1}) and contract rate (US$ ha^{-1}),by season and gender, Zhejiang, 2013.

Activity	Early rice		Late rice	
	Male	Female	Male	Female
Land preparation				
Cleaning and repair of dikes	16.7	16. 7	16.7	16.7
Plowing	20.0	-	20.0	-
Leveling	20.0	-	20.0	-
Machine operator	33.3	-	33.3	-
Crop establishment				
Direct seeding	20.0	13.3	20.0	13.3
Transplanting	-	-	20.0	13.3
Hauling of seedlings	-	-	20.0	20.0
Pulling of seedlings	-	-	16.7	13.3
Replanting	16.7	-	16.7	-
Fertilizer and pest management	16.7	13.3	16.7	13.3
Water management				
Constructing canalets	-	-	16.7	16.7
Irrigating	16.7	13.3	16.7	13.3
Draining water in the field	16.7	-	16.7	-
Draining water in the seedbed	-	-	16.7	-
Monitoring				
Field	13.3	13.3	13.3	13.3
Seedbed	-	-	13.3	13.3
Harvest and postharvest				
Manual harvesting	20.0	-	20.0	-
Hauling (labor only)	16.7	-	16.7	13.3
Drying	16.7	13.3	16.7	13.3
Contract rates (US$ ha^{-1})				
Tractor (rototilling to leveling)	250-300			
Crop establishment (pulling, hauling, and transplanting)	675			
Mechanical transplanter (including seedlings)	263			
Combine harvester-thresher	250-300			
Mechanical dryer (US$ t^{-1})	27			

Note: '-' indicates not applicable.

other hand, the contract rate for tractor and combine harvester ranged from US$250 to 300 ha^{-1}; it was US$263 ha^{-1} for a mechanical transplanter (including seedlings). Contract rate was more expensive for manual transplanting with combined activities (pulling, hauling, and transplanting) at US$675 ha^{-1}. The fee for mechanical drying was US$27 t^{-1}.

Rice combine harvester in Jinhua, Zhejiang.

Farm financing

All farmer respondents used their own capital to finance their rice production activities. This implies that farmers have enough source of capital and have no need to borrow. The existence of other sources of income, aside from rice farming, reflects their ability to generate income that could be used to shoulder rice production expenses.

Postharvest and marketing practices

Generally, farmers sold dried paddy: 55% of them used mechanical dryers in ER and 32% used them in LR; the rest resorted to solar drying. Farmers sold all their ER produce to government-designated procurement grain centers at a specific support price. Centralized depots operated by China's official grain reserve corporation were the only authorized entity to purchase paddy at the support price. The support price is an incentive for farmers to grow ER as yield at this time is less than that in LR. According to Wang et al. (2004), the overall importance of ER decreased significantly because farmers preferred to grow more profitable cash crops or to leave the field idle instead.

The government used the procured paddy as buffer stock in cases of calamities. Key informants from the Jinhua Municipal Agricultural Technology Extension Service Center in Zhejiang also reported that the government also sold procured paddy to industrial factories for processing of monosodium glutamate or to aid military personnel and assist other countries. In contrast, 76% of the paddy produced in LR was sold to private traders, with 70% being delivered to market outlets such as those of paddy traders or rice millers. Farmers also retained 24% of the gross harvest for home consumption. During LR, the government did not give any support price and did not procure paddy. Paddy price is thus the prevailing market price, which is lower than paddy price in ER.

Yield and factor productivity

Yield

On average, yield was 6.56 t ha^{-1} in ER and 8.02 t ha^{-1} in LR; total yield was 14.58 t ha^{-1} for double crops. In dry-weight form, yield was 6.10 and 7.46 t ha^{-1} in ER and LR, respectively (Table 12). The significant yield difference between ER and LR can be partly explained by the 100% adoption of hybrid rice in LR and

Table 12. Yield and partial productivity of factor inputs, Zhejiang, 2013.

Item	Early rice (n=100)	Late rice (n=100)	Difference
Yield, fresh form (t ha^{-1})	6.56	8.02	-1.46 ***
Yield, dried form (t ha^{-1})	6.10	7.46	-1.34 ***
Labor (kg paddy/md)	351	232	119 ***
N (kg paddy/kg N)	43	40	3 ns

Note: ***, ** indicate 99% and 95% confidence level; ns means not significant.

the favorable climatic conditions. Mean yields obtained across seasons were also higher than those in Zhejiang RTDP sites during the 1999 high-yielding season (HYS) and low-yielding season (LYS), 5.71 and 6.71 t ha^{-1}, respectively. The yield improvement could be attributed to increasing productivity growth brought about by continuous R&D investment, particularly in hybrid rice technology development. The newly developed hybrid rice varieties can yield up to 13.5 t ha^{-1} (Li et al., 2009).

Similarly, yield in the area varied across farmers: range was from 2.86 to 10.37 t ha^{-1} in ER and from 5.37 to 11.22 t ha^{-1} in LR. Many farmers, however, have attained high yields in both seasons. In ER, 87% of the farmers have obtained yields of 5-7 t ha^{-1} and 11% have yields of 7-10 t ha^{-1}. On the other hand, two-thirds (68%) got yields of 7-9 t ha^{-1}; 13%, 9-11 t ha^{-1}; and 2%, above 11 t ha^{-1} in LR (Fig. 2).

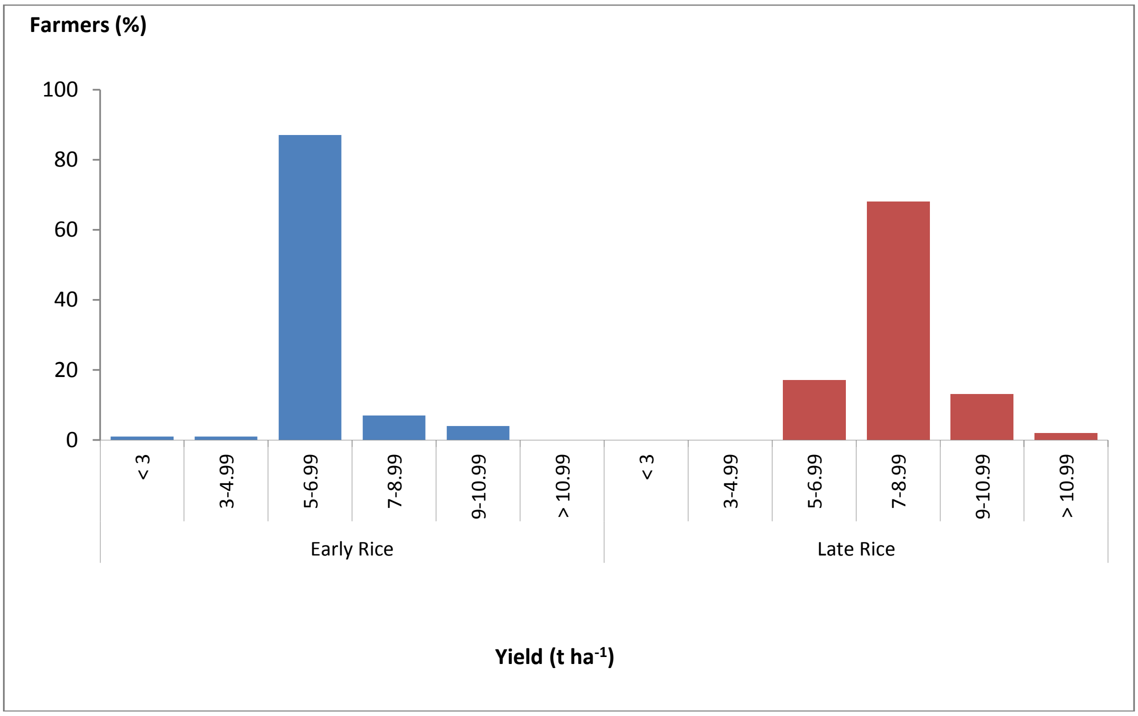


Fig. 2. Percentage distribution of farmers, by yield obtained in each season.

Factor productivity

The level of mechanization in the area increased. Most labor-intensive and major farm operations (such as land preparation, harvesting, and threshing) were completely mechanized and some activities (transplanting and drying) were partly mechanized. This development has augmented labor productivity in rice production. However, the estimated partial factor productivity of labor was significantly higher in ER at 351 kg paddy md^{-1} compared with 232 kg paddy md^{-1} in LR. The higher labor productivity in ER was due to the practice of direct seeding, which is a labor-saving technology. Likewise, land preparation during ER was purely mechanized unlike in LR where cleaning and repair of dikes were done manually by farmers.

Partial productivity of N applied (ratio of yield to amount of N applied) across cropping seasons was low and almost the same, at 40 and 43 kg paddy per N kg in ER and LR, respectively. A previous study by Fan et al. (2011) reported that partial productivity of applied N has been halved for the last 30 years (on the basis of yearly data for grain yield and synthetic N consumption, NBSC, 1950-2010). The study also stated that nutrient use efficiency for rice was low, the consequence of excessive application of N fertilizer inputs and high nutrient loss. The productivity of N applied also suggests that farmers used more N fertilizer than what the rice crop requires, which failed to translate into additional yield.

Cost and profitability of rice production

Gross returns

Although yield was higher by 1.46 t ha^{-1} in LR than in ER, paddy price was higher in ER by US$80 t^{-1} due to the support price provided by the government. Thus, gross returns were not significantly different between two seasons at US$3,298 and US$3,364 (Table 13).

Cost of rice production

The total cost of producing paddy in Zhejiang was US$2,019 in ER and US$2,600 ha^{-1} in LR (Table 13). Total cost in LR was significantly higher than that in ER by about US$580 ha^{-1} because of hybrid rice, which requires more labor and material inputs. As shown in Table 13, the significant difference in cost can be attributed to the higher cost of hybrid seed, fertilizer, chemicals, and labor. Hybrid seed is more expensive than inbred seed despite the lower seeding rate. Likewise, the amounts of fertilizers and pesticides applied were comparatively higher, translating into higher cost of material inputs. Nevertheless, the significant yield advantage of LR was able to compensate for this cost difference. In terms of cost per metric ton, LR was comparatively higher at US$324 than ER at US$308. To be comparable, land rent must be deducted from the 2013 cost since this was excluded from the 1999 cost. Without the land rent, the cost of producing a ton of paddy in 2013 was US$206 in LR and US$238 in ER. These were significantly higher than US$107 t^{-1}, which was the reported cost in RTDP sites in 1999 (valued at 2013 prices using consumer price index). This means that the cost of producing rice has increased considerably in the last 15 years, and the change was attributed to changes in factor input use and cost such as extensive use of fertilizers and chemicals, rising wages, and opportunity cost of land, which resulted in high material input cost, labor cost, and land rent, respectively.

Among the different cost items, land rent, power (animal, machine, and fuel and oil), and family labor (operator, family, and exchange) represent the biggest share of the total cost. Land rent constituted the highest cost share (24-31%). The rising opportunity cost of land, attributed to rapid economic development in Zhejiang, resulted in high land rent. However, majority of the farmers own the land they cultivate through a land contract with the government; hence cost of land was only imputed using the prevailing land rent reported by farmers. Another cost component is power cost (machine, animal, and fuel and oil), which comprised the second largest cost share (20-25%). The power-intensive farm operations (land preparation, harvesting and threshing, transplanting, and drying of paddy), which were highly and partly mechanized and have been outsourced to custom service providers, caused an increase in the cost of machine and animal rental. On the other hand, the imputed unpaid family labor accounted for 16-20% of rice production cost. The high cost component of family labor reflected the rising wages and opportunity cost of farm labor in the area, owing to the increasing availability of off-farm employment in the industrial

Table 13. Costs and returns of rice production, Zhejiang, China, 2013.

Item	Value				Cost share (%)	
	Early rice	Late rice	Difference		Early rice	Late rice
Returns						
Yield (t ha^{-1})	6.56	8.02	-1.46	***		
Paddy price (US$ t^{-1})	500	420	80	***		
Gross revenue (US$ ha^{-1})	3,297.93	3,364.37	-66.45	ns		
Costs (US$ ha^{-1})						
Seed	83.99	168.49	-84.50	***	4.16	6.48
Fertilizer	278.13	349.85	-71.72	**	13.77	13.46
Chemicals	124.49	312.78	-188.28	***	6.17	12.03
Hired labor	69.39	93.79	-24.40	*	3.44	3.61
Operator, family, & exchange labor	316.55	514.97	-198.42	***	15.68	19.81
Animal, machine, fuel & oil	509.91	509.16	0.75	ns	25.25	19.59
Irrigation	0.00	0.00	0.00		0.00	0.00
Food	0.00	0.00	0.00		0.00	0.00
Transportation	6.35	20.10	-13.76	**	0.31	0.77
Tax	0.00	0.00	0.00		0.00	0.00
Land rent	626.25	626.25	0.00		31.01	24.09
Interest on capital	0.91	1.34	-0.43	***	0.04	0.05
Other inputs	3.28	2.87	0.41	*	0.16	0.11
Total cost (US$ ha^{-1})	2,019.25	2,599.60	-580.35	***		
Cost (US$ t^{-1})	307.90	324.16	-16.25			
Net income from rice farming (US$ ha^{-1})	1,278.68	764.78	513.90	***		
Farmers' income (US$ ha^{-1})	2,222.38	1,907.34	315.48	***		

Note: *, **, *** indicate significance at 90, 95, and 99% confidence levels, respectively.

and construction sectors. Other cost items such as fertilizer, chemicals, and seed were also significant contributors to the high cost of producing paddy in the area.

Net income

Net income from rice farming differed across cropping seasons. It was significantly higher in ER, by US$514 ha^{-1}, due to the high paddy support price received by farmers. The price subsidy from the government was intended to compensate for the rising production cost so that farmers could get a stable net income during ER. In addition, the relatively lower production cost has contributed to the bigger net profit obtained by farmers during this season. Nevertheless, without the price subsidy, the net return in ER was smaller at US$735 ha^{-1}. In the absence of the support price in ER, net return was almost the same as that in LR.

Overall, net income from ER was higher compared with those from the RTDP sites in 1999 at US$987 ha^{-1}. In contrast, net income from LR (US$765 ha^{-1}) was lower than the 1999 net income in the RTDP sites mainly because of relatively higher production cost.

In terms of returns actually received by farmers who own land and capital and use unpaid family labor, their net income increased by 149% (from US$765 to US$1,907) in LR and by 74% (from US$1,279 to US$2,222) in ER. Without price support, net returns to farmers for planting ER would be less, equivalent to only US$1,679. However, annual income from rice was much higher than the poverty threshold in Zhejiang.

Government rice support program

With the accession of China to World Trade Organization in 2001, the government introduced three subsidy schemes to producers of grain, including rice. These are 1) small direct payment, 2) partial rebate for farm machinery purchases, and 3) price support for paddy (Gale, 2013). During the survey, farmers reported receiving direct payments amounting to US$125 ha^{-1} for ER cropping and US$250 ha^{-1} for double rice crops, which were deposited in their respective individual bank accounts. The direct payment aimed to induce farmers to adopt improved seed varieties and appropriate inputs and to compensate for the increasing cost of production inputs. Additionally, partial rebates (30% of the total price of purchased machine for land preparation and 50% of that for harvesting and postharvest) were given to farmers. The amount is placed in the farmer's individual account after submission of the sale invoice and verification by the Ministry of Finance. Similarly, paddy support price was higher by US$80 t^{-1} than the market price, which was only given for paddy produced in ER. On top of these, the national government has also eliminated the tax in agriculture and fees on irrigation water coming from state canals.

In Zhejiang, the local government also provided award payments to farmers who consolidate parcels of land into large-farm operation. Overall, these government support measures aimed to ensure stable net returns to farmers. It can also be observed that government subsidies were not able to offset the rising production costs.

SUMMARY & IMPLICATIONS

Zheijiang, China's success in increasing its paddy production, despite the decline in rice area, was attributed to the growth in yield. In the last 15 years, yield grew across cropping seasons compared with yield in the RTDP sites. The adoption of high-quality seed such as certified seed in ER and newly developed hybrid rice varieties in LR with high yield potential has improved yield in the province. Although yield increased in both seasons, the 2013 survey results showed that the use of hybrid rice in LR has a significant yield advantage over inbred rice, by 1.46 t ha^{-1}. Additionally, mechanization in labor-intensive farm operations and adoption of labor-saving technology (such as direct seeding) had reduced the utilization of labor inputs, which resulted in high labor productivity of rice production.

In spite of these developments, the cost of producing rice in the area appears to be high. This can be explained by rising farm wages and opportunity cost of land, which is attributed to fast economic development and rural-urban migration happening in the area, thereby leading to high cost of labor and land rent. In addition, crop management practices of farmers, particularly the extensive use of fertilizer, were associated with rising material input cost and possibly lower productivity of fertilizer. These resulted in high total costs and low net returns in rice production.

Accordingly, the high cost of producing rice in the area may lower the competitiveness of rice production. Similarly, this may affect rice food security because farmers may shift from less profitable rice to more profitable high-value cash crops. Hence, there is a need to further improve input productivity to help increase production and thereby reduce per unit cost in order to improve competitiveness of rice production, Zhejiang in particular and China in general have to sustain rice food security. To improve input productivity, farmers should be trained on proper nutrient and pest management to lessen extensive use of fertilizers and pesticides. The adoption of mechanical transplanters and other machinery for crop care and management should be promoted intensively to reduce labor input and cost and consequently further increase productivity of labor.

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