Master Thesis

Productivity of different rice production systems in plot and field scales; an economic approach.

Farming Systems Ecology
FSE-80436

Supervisor: Dr. ir. Kees Van Veluw

Student: Cindy Chang

Student number: 751020156120

Period: Jan 2017 - February 2018

WAGENINGEN UNIVERSITY

WAGENINGEN UR

Abstract

Maintaining a financial sustainable status for small-scale farmers in developing countries such as Indonesia is a key to keep farmer stayed in farming and insure food security. Complex Rice System provides a new prospective on how to increase crop yield and farmer's income while protecting environment and ecosystem. This study is to analyze factors that affect economic performance in varying rice farming systems. A field trial with market and farmer surveys was conducted in the lowlands of East Java, Indonesia. By comparing crop's yields of different rice production systems in two monocultures: rice conventional (RC) and rice organic (RO) and two complex rice system: complex rice system organic (CRO) and complex rice system conventional (CRC). Monetary financial results, Land Equivalent Ratio (LER) and Total Factor Productivity (TFP) indexes of four different rice farming systems were calculated.

The LER of complex system is better than mono rice system. The LER number was 2.322 (CRO) and 1.481 (CRC). The result LER>1 in both CRO and CRC mainly contributed from the better of rice yield in complex system. The TFP indexes of this research were 0.48 (CRO), 0.62(CRC), 0.6(RO) and 0.72(RC). The local organic rice farming showed the highest TFP number 3.98. All four rice systems record net loss in financial result of one season. Due to the duck's price variation, both complex system loss more than 10 million IDR. However, complex rice system could potentially create similar finance outcome as convectional with low risk on chemical pesticides impact to farmer and environment. Training farmer on how to manage this rice-livestock integrated system is recommended to establish a successful complex rice system.

Keywords: integrate farming system financial statement, complex rice system. duck, rick, fish Azolla, LER, TFP

Table of Content

List of Figures

List of Tables

1 Introduction

Indonesia, as the fourth populous country in the world, has a current population of 255 million (OECD, 2016). 45.3% of these people are living in rural districts and depend on farming to make a living. This makes agriculture a crucial sector in the economy of Indonesia (IFAD, 2015). Even though Indonesia is the third-largest rice producing country (FAO, 2015), the country still depends on rice imports. This situation is caused by farmers' use of sub-optimal product techniques in combination with large per capita rice consumption. Smallholder farmers account for around 90 percent of Indonesia's rice production, each holding an average land area of less than 0.8 hectares. (Food and Agriculture Organization of the United Nations and Indonesian Ministry of Agriculture, 2015).

Indonesia is a country highly dependent on rice. Not only for their diet, but also for social and cultural customs. Rice can be seen on Indonesian's table almost every meal, every day. In fact, Indonesia has the sixth largest rice per capita consumption in the world of around 140 kilograms of rice per person per year (Wailes, 2016). Furthermore, during traditional festivals, such as harvesting festival, people like to make rice cakes or handcrafts for praying a better future and luck. In both daily consumption and cultural needs, rice is playing an important role in Indonesians' everyday life. As domestic rice production is inadequate, Indonesia imported 1.35 million metric ton rice during 2015 (USDA Foreign Agriculture Service, 2015). Thus, one of the goals of Indonesia's rice policy is providing adequate domestic rice production. To maintain food security in Indonesia, the government tries different agricultural policies. These policies are aimed at raising rice yield in the hope to become self-sufficient in rice production. Since early 2004, the government has officially banned rice import. Advocates of this policy say it reduces poverty by assisting poor farmers (Warr, 2005). Due to the rice import policy, local rice prices are higher than international prices. However, the rice farmer's average income still ranks as one of the lowest income levels of all different sectors in Indonesia's income distribution. (FAO, 2007). According to data from the Badan Pusat Statistik (BPS- Statistics Indonesia) there were around 41.5 million workers engaged in agriculture, forestry, hunting and fisheries in August 2010; this is about 38.3% of Indonesia's total workforce. Despite its high contribution to the national economy, the development of agriculture sector, especially paddy farming, is relatively low (Hidayat, 2011).

In 2015 the annual rice production in Indonesia was 75.4 Million tons, being the third greatest producer in the world (FAO, 2015). Rice production dominated the food-crop sector, and the production increased four and a half times between 1961 and 2015 (Shiostu, 2015) mostly due to increased yields. Adoption of modern varieties and fertilizers played an important role in securing higher rice production yield. As rice remains the staple food, national self-sufficiency carries great political significance (Alston et al., 2010). However, high utilization of chemicals and artificial fertilizers caused a series of environmental problems limiting the potential production effectiveness of arable lands. Therefore, some farmers in Indonesia started to look for new sustainable ways of farming. As a result, organic rice farming has drawn big attention and has been implemented in several regions in Indonesia (Lestari, 2013).

Regarding organic farming, traditional rice cultivation in Asia can provide inspiration for organic system. The traditional cultivation method is rice-livestock culture. It was originally from Asia. China boasts a history of 1700 years in rice-fish-farming practice (Lu & Li, 2006), while it is only being used in Indonesia for more than a hundred years (Coche, 1967). The rice fish systems became more diverse, and ruminants and non-ruminants started to be integrated into rice fields. These systems have diversified products making better use of certain resources, thus making it beneficial for small holder farmers to spread potential risks (Devendra, 1995). According to the Indonesian Agricultural Census figures, the average farm size is about 0.4 hectares per household in Java. Using this farm size, it is difficult to maintain a stable profitable income for farmers who are mono-rice producer even if the domestic rice price is higher than the international prices. The introduction of intercropping system might be considered as one of solutions to provide better income from diversified production systems.

In recent years, there was a boost in development on the concept of agro-ecosystems. Complex rice systems (integrating rice with fish and ducks) have been explored. Several studies indicate that rice-fish and rice-duck systems reduce Nitrogen leaching and increase output by fishes, ducks and rice yield, which resulted in better Nitrogen balances compared to conventional rice production (Li, 2008). Fish and ducks can provide nutrients into the system by their droppings and their eating behavior contributes to weed and pest control. In the study of Ahmed (2004), density of some pests was significantly decreased in the rice-duck system compared to conventional ones, and the yield was significantly increased. Several studies even showed that rice-duck and rice-fish production systems can increase rice yield. This research aims to further analyze if the financial situation of farmers improves when using complex rice systems. A high yield crop is not necessarily a high-profit crop for farmers (Sylvia Kantor, 1999). During this research a complete economical analysis of rice farming systems is done based on market values.

Upon further research, Uma Khumairoh, a PhD from Wageningen University, has completed a series of experiments exploring the improved complex rice system in Malang, Indonesia. The complex rice system (CRS) integrates rice, fish, ducks and azolla as Cagauan (1996) designed (Figure 1). In complex rice systems, fishes, ducks and azolla are integrated into paddy fields with compost as fertilizer produced on the same field. Within the system, the fishes and ducks provide nutrients to rice by releasing their excrement into the water. In terms of pest control, some plants are planted before rice on the border of paddy fields to attract natural enemies; ducks and fish play an important role in weed and pest control as well by their eating and moving behaviors. In addition, the trampling behavior of ducks brings more oxygen into the soil which stimulates root growth of rice which increases the rice competition ability. As for azolla, it is a floating fast-growing fern in the water that can block light and limits the germination of weed seedlings under the water. The main function of azolla is fixed Nitrogen in the complex rice system for fertilizer rice. (Khumairoh et al., 2012).

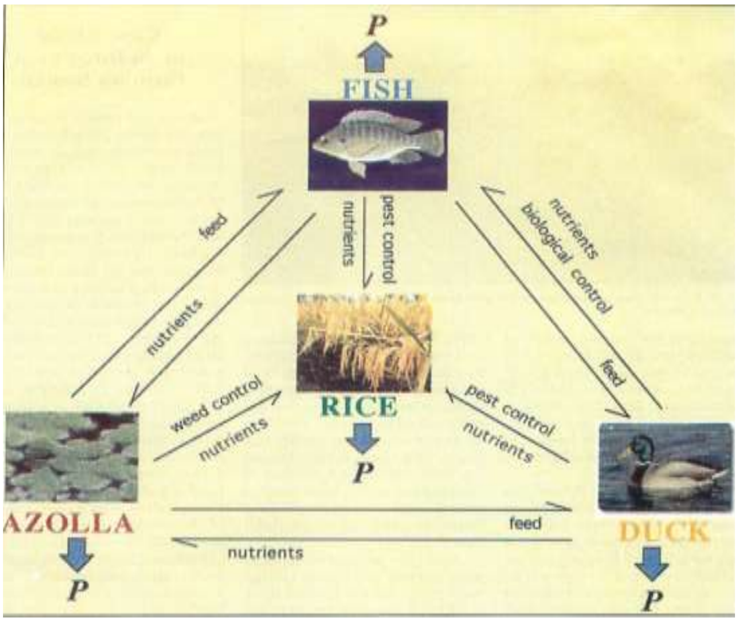


Fig. 1 Presentation of the inter-relationships among fish, rice, azolla, and duck in an integration farming system (P refers to production) (Source: Cagauan et al., 2000)

Complex rice systems try to reduce external inputs such as artificial fertilizers, herbicides and pesticides to increase production diversity and yield. The system might benefit the environment and increase profits for smallholder farmers. However, the labor demand for farm management could increase dramatically compared to conventional rice cultivation, as organic management and diverse production would require more labor. The source of labor for smallholder farms is mainly from family members. Based on the research by Zheng (2014), the complex rice system farmer's profit was higher than rice monocultures even calculated with higher labor input of existed complex system (rice and duck). Previous research showed similar results in earlier studies by Hossain et al. (2004) and Zheng et al. (1997) which indicated complex farming system can increase farmer's income. Different products such as duck and fish in complex rice system may increase farmer's income by diversifying different products and lowering the farmer's risk from environmental changes due to resilience multiple products brings.

This study collected information on different rice production systems to evaluate their productivity based on economic performance using total factors productivity (TFP) and land equivalent ratio (LER) approaches. Cost-benefit details include conventional rice systems with machinery applied into field management. The research of this experiment has been conducted in Malang, Indonesia.

1.1 Objectives

The aim of this research was to analyze the factors that affect economic performance in different rice production systems in Indonesia. In addition, the total factor productivity will be used to evaluate the viability of a new technology of Complex Rice System (CRS). Therefore, the most important question was: Do farmers benefit from complex rice systems if this new farming system can increase productivity more than conventional farming systems? Potential hidden costs would also be considered when switching from original farming system to complex rice system. This research aims to further analyze if the financial situation of farmers improves when using complex rice systems.

1.2 Research questions

1. Does complex rice system generate better crops yield and financial outcome for farmer compared to conventional and organic rice system?
2. Does complex rice system have better Land Equivalent Ratio, economically?
3. Compared to conventional and organic rice system, does complex rice system perform potential by more effective in the terms of total factor productivity index?
4. An initial research on the hidden cost: "What are the hidden costs caused by usage of agro-chemicals in the Indonesian rice system in east Java?"

1.3 Hypotheses

1. Complex rice system generates a better financial outcome with a higher crop yield and lower total input under compared to conventional and organic rice systems for farmers in East Java Indonesia.
2. Compared to conventional and organic rice system, complex rice systems do perform better based on economic indicator: Total Factor Productivity index
3. The Land equivalent ratio in Complex rice system is economically better
4. The complex rice system has lower hidden costs

2 Materials and Methods

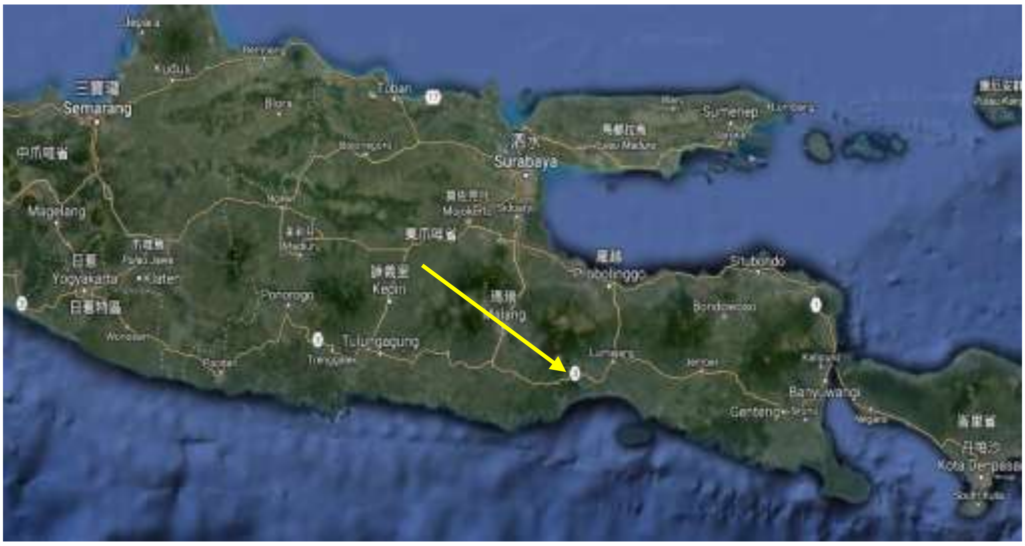


Fig. 2 Location of the experiment (Kepanjen, Malang province, East Java, Indonesia).
Source: maps. google, 10th July 2017

2.1 Experimental Site

The experiment was conducted in Jenggolo village (8°10'27.0"S 112°32'33.0"E) in Kepanjen located in south east Malang, a province of East Java Indonesia. The field experiment was conducted from 27th of February to 20th of June 2017 with a local farmer who owned the private land. According to the farmer, this land has been used for organic rice for 10 consecutive years. However, all surrounding farms applied a conventional monoculture rice cultivation system. Every year, the rice is planted two to three times without any crop rotation. This intensive farming system in Malang area is supported by fertile soil and irrigation techniques (Khumairoh 2011). Farmers have their own preference on different types of rice varieties. Agriculture shops provide rice seed for these region's farmers who might want to plant a new variety. The seed is normally first sown aside the field for 8-10 days before transplantation to field. In this experiment, rice was sown in the end of February, and seedlings were transplanted into the field from 7th to 9th of March 2017.

Soil information: The nitrogen content in the experimental field was 0.18%, with 3.8 mg/kg Phosphorus olsen, and 0.058 mg/kg of potassium. Table 1 shows the soil properties of the experimental farm (Soil Laboratorium of Brawijaya University, 2017).

Table 1 Soil analysis of experimental site (Agriculture if University Brawijaya June 2017)

Soil properties	
pH (H_2O)	6
C_{org} [%]	1.98
N_{total} [%]	0.18
C/N	11
Organic matter [%]	3.43
P. Bray1 [mg/kg]	3.8
K [me/100g]	0.58
CEC [me/100g]	32.82
Sand [%]	11
Silt [%]	48
Clay [%]	41
Texture	Silty-Clay

The Weather information: The experimental period, from end of February to June, was between raining and dry season. The average monthly temperatures ranged from 25.1^{o}C to 26.3 ^{o}C. The mean monthly rainfall and further weather details of prior years are shown in Table 2 and Figure 3. The monthly rainfall dropped substantially from May 2017. Figure 3 indicated that the raining days in April and May 2017 is much more than 2016. But, monthly rainfall is much less on May and June 2017.

Table 2 The weather information of 2016 and 2017

	Jan	Feb	Mar	Apr	May	June
Monthly rainfall 2017 (mm)	467	332	174	254	20.1	22.5
Monthly rainfall 2016 (mm)	304	369	299	376	229	114
Rainy days 2017 (days/month)	24	18	15	16	23	4
Rainy days 2016 (days/month)	16	20	20	8	10	9
Average temperature 2017 (°C)	25.7	25.8	26.1	26.3	25.5	25.1
Average temperature 2016 (°C)	26.9	26.2	27.00	27.00	27.1	26.2

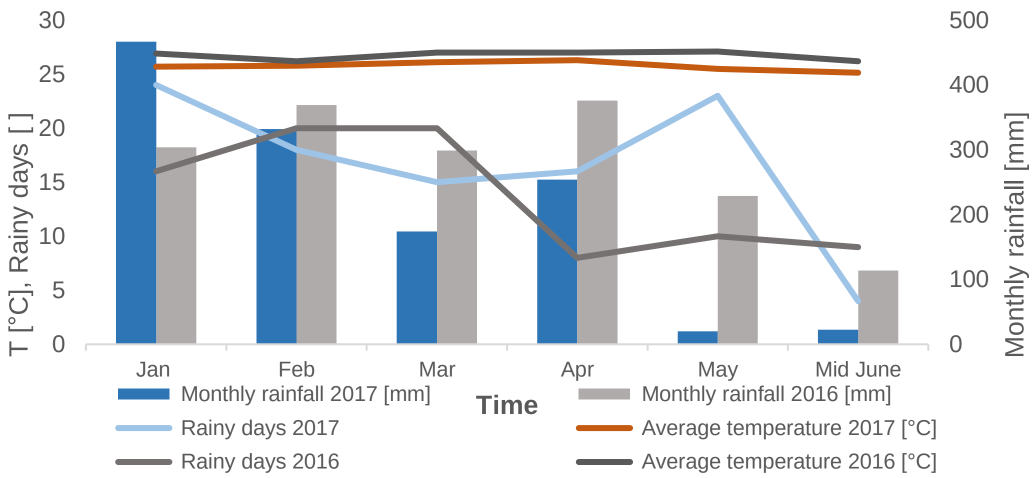


Fig. 3 The weather situation between January to June in year 2016 and 2017

2.2 Materials and Cultivation methods

2.2.1 Rice

The rice used for this experiment is *Oryza sativa* cv. Cibogo, which is a local variety from Java island. This rice resists brown plant hopper well. However, it is easy to get infected with Tungro virus. The growth period of the rice is 115 – 125 days and it has an average yield of 7 t/ha^{-1} and a potential yield of 8.1 t/ha^{-1} (INDARYANI 2009).

Rice was first sowed in the seedling bed of size 8m * 8m on 26th February 2017. At age of around 8 to 10 days, seedlings were transplanted into the field during period of 7th of March to 9th of March 2017. 3-4 seedlings were planted per hill as applied by all other local farmers. The space between rice hills was 25cm * 25cm. (Figure 4 and Figure 5)

Fig. 4 Seedling transplanted manually by farmer with 25cm x 25cm hill distance

Fig. 5 Conventional-rice plot each hill in 25cm*25cm distance (Rice Conventional block III)

2.2.2 Ducks

Anas platyrhynchos Javanicus, a local duckling, was used in this experiment. Locally the duck called Mojosari and is a widely raised variety in East Java. The adult female and male duck can reach 2 kg and 2.5 kg respectively. Female ducks can start to lay eggs at age 24-26 weeks and laying 230-300 eggs per year (Khumairoh 2011). Ducks raised in the CRS can be sold as meat products after the rice season or kept for egg production and reused in the complex rice system.

Fig. 6 Mojosari duck (Anas platyrhynchos Javanicus) released in duck house after 2 weeks in stable

103 eight-days-old ducks that received common antibiotic treatment were bought on the 14th of March 2017 and raised in stable area for two weeks. On 22nd of March 2017, ducks were introduced into the field at an age of 21 days (Figure 6). Each field had a density of 1.13 - 1.42 ducks per m². The duck's plot sizes ranged from 6 – 12 m² among three different duck plots. Duck houses bedded with rice straw were set up in the plots and consisted of bare soil

which after rainfall would be flooded. These houses were about 0.2 m^2 per duck. Ducks were raised separately in extensive and intensive treatment. Ducks in both treatments were fed twice a day; in morning and evening.

In extensive duck treatment (‘De’), ducks received in the beginning 98 g rice bran per duck per day and from an age of 46 days, ducks were fed 237 g per duck per day. In intensive duck treatment(‘Di’), ducks received in the beginning 22 g feed concentrate and 97 g rice bran per duck per day and from an age of 46 days, ducks were fed67 g concentrate and 237 g rice bran per duck per day. Ducks were kept until the age of 80 days after which they were sold.

In the East Java area, traditional monoculture duck-farmers do not keep ducks in a cage all day. Instead, ducks are raised extensively. Farmers bring the ducks to harvested rice fields where the ducks can range freely during the day and feed on weeds and leftover grains (Figure 7). Ducks are kept in temporary built fencing with a plastic roof during the night. In this way, the duck-farmers can easily move around the area from field to field once the rice is harvested. According to farmers, only limited feed was sometimes supplied during night, but the amount is unknown.

Fig. 7 Local duck farmer in the rice field right after rice harvest with local duck. Ducks feed on the rice left over in the field and farmer tried to keep them moving together

2.2.3 Fish

Nile tilapia (Figure 8A) was chosen as fish species for the experiment because it can adapt to a wide range of environments. The first batch of 70 fish was released into all fish plots on 26th of March 2017. However, due to unknown reason, all fish died within 1 to 2 days after being released into the field.

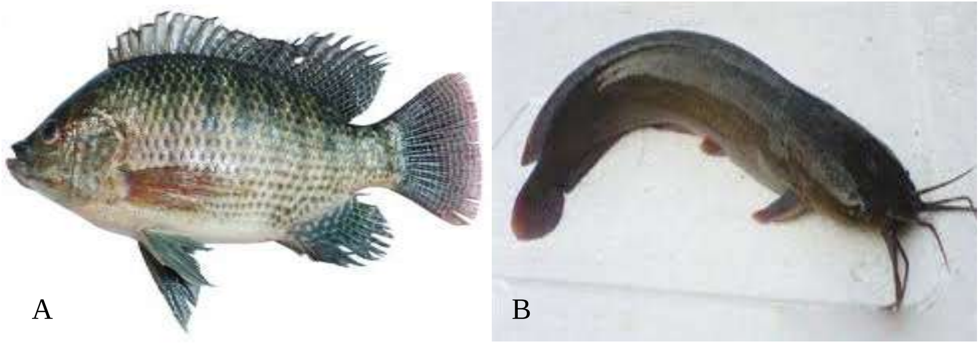


Fig. 8 *Nile tilapia* (A), and Catfish (*Clarias gariepinus*) (B)
Source: www.nwtilapia.com/ourbreeds.html

Catfish (*Clarias gariepinus*) (Figure 8B) was recommend by the farmers to use as replacement. Catfish, which locals also call Lei Lei, can survive under extreme conditions such as lower oxygen concentrations and low water levels such as during certain periods when rice field need to be drained of most water.

The plot sizes for the fish monocultures ranged from 4 to 11 m². The first time a density of 2 fish per m² was used when fish (*Nile Tilapia*) were introduced into the field. After all fish died these were replaced with catfish with a density of 1.0 to 1.6 fish per m² (Figure 9). Two treatments were used for fish; extensively ('Fe') and intensively ('Fi'). The extensive treatment fish were given rice bran at a rate of 16 - 18 g per fish per day, whereas the intensive treatment fish were fed with concentrate at a rate of 3.8 – 4.4 g per fish per day. However, the introduction of catfish failed as well and no fish bodies were found after three weeks. Fish may escape from the plots to other fields or water canals, or have been eaten by wild animals. The reason is still unknown.

Fig. 9 Fish monoculture plot (III Fe)
Nile Tilapia dead fish bodies found a few days after release. Catfish have been released into the same plots afterwards, but all disappeared as well.

2.2.4 Water Spinach

Water spinach (Ipomoea aquatic), called Kangkong by locals, is a semiaquatic perennial plant which is easy to cultivate and has a very high biomass yield. Water spinach is rich in protein, vitamins A and C and minerals, especially K, Mn, Mg, and Fe. (Hassan et al., 2007) Water spinach originates from south China. However, it is now very popular in south East Asia due to the high nutrient content. In general, water spinach has a short growth period and is resistant to common insect pests and diseases (Lin et al., 2014). In addition, this vegetable also adapts well to a wide range of temperatures: from 15 to 40 degrees Celsius. Water spinach favors higher temperature and high humidity hereby growing quickly and easier in the Malang area. Farmers can harvest at around 35-40 days after planting. In East Java water spinach can easily be found in local markets and it's a mainstay vegetable in the local's everyday diet.

Fig. 10 Water spinach is a semiaquatic perennial plant which easily grows in tropical and semi-tropical areas

Water spinach was planted in the plots on dikes with a width of 25 – 55 cm. There was a spacing of 30 cm between dikes. On the 27th of March seeds were sown in block I. On the 8th of April, Water Spanish Organic (WSO) and Water Spanish Conventional (WSC) were sown separately in plots Block III. And on the 10th of April WSO and WSC were sown in plots Block II. The space between plants in a row and between rows was about 5 cm. Along the border of the plot a dike with water spinach was maintained as well. Initially one conventional ('WSC') and one organic ('WSO') treatment were planned for the water spinach. In the end, no plot received any chemical application of either fertilizer or pesticide. Therefore, all plots are handled as one organic group treatment. When the water spinach was harvested 4 cm of stem was left for regrowth.

2.2.5 Yardlong Bean

Yardlong Bean (Vigna unguiculata subsp. Sesquipedalis) can grow up to two meters, flowers after 21 days and can be harvested 40-46 days after seeding. The optimal temperature for Yardlong bean ranges from 20 to 25 degrees Celsius, but even over 35 degrees this plant still can keep growing. Yardlong bean is from the legume family and hosts the nitrogen-fixed Rhizobia. After fruiting the plant can be used as green manure. The beans are a good source of protein, vitamin A, thiamin, riboflavin, iron, phosphorus and potassium. As well as being a very good source for vitamin C, folate, magnesium and manganese. Yardlong bean is also a widely grown vegetable in East Java and can been found in every local market.

Fig. 11 Mono-Yardlong bean Plot Organic at day 25

Yarlong bean were sown on the 2nd of March 2017 in rows with a spacing of 60 cm in between. The distance between plant holes was 30cm. Bamboo sticks of 150 cm height were used every 60 cm from row to row. Two poly-strings were attached at a height of about 40 cm and 130 cm to connect the sticks. Two to three seeds were placed in each hole and covered with a layer of soil and chicken manure. Weeding was done manually once in the period of 9 to 18 April in each plot. The cut grass was collected as feed for buffalo.

Yarlong bean was cultivated using 2 treatments: organic and conventional. The organic beans were fertilized with 30 g of buffalo manure on the 2nd of April (31 days old). In addition, two organic pesticides were used. Self-made pesticide diluted with water in a ratio of 1: 1.4 was applied at a rate of 82 L/ ha and "OrgaNeem" was applied at a rate of 0.4 L/ha at week 7. The conventional (BC)beans were cultivated semi-conventionally. 30 g of buffalo manure was applied per bund. The pesticide 'Gallery' was used and applied at a rate of 0.3 L/ha at week 7 as pest control.

2.2.6 Sun hemp

Sun Hemp (Crotalaria juncea) is a tropical Asian plant of the legume family (Fabaceae), considered to originate from India. It can reach a height of 1.8 meter after maturing. It is now widely grown throughout the tropics and subtropics as a source of green manure, fodder and lignified fiber obtained from its stem. Sun hemp is also being looked at as a possible source for bio-fuel.

Sun hemp was planted in this experiment for purpose as green manure and feed for ducks. In addition, according to Tavares (2011), it attracts natural enemies of rice pests.

Plot sizes for sun hemp ranged from 13 to 21 m². Seeds were sown on the 2nd of March. Sun hemp was grown in rows. Plant holes were 30 cm apart within the row and rows were 40 cm apart (Figure 12). Two to three seeds were placed in each plant hole and covered with a layer of soil and chicken manure. Weeding in all plots was done manually once in the period of 9th to 18th April. Different plots received either organic or semi-conventional treatment. The organic group was grown organic, whereas the semi-conventional group received same chemical treatment as described earlier for Yardlong bean.

Sun hemp was sown on the dike, the complete border of the field and the plots. Sun hemp was transplanted from the dike into polybag for the first time on 28th of March. However, all transplants died or were eaten by ducks in the CRS plots. Sun hemp on the dike was transplanted again into pol bag on 7th of April. Once again, none of this transplanted survived. The third time, sum hemp was sown directly inside the polybag. A net was placed around the bag, both net and bag were used to prevent them from being eaten by the ducks. In the end, little sun hemp survived in the CRS farm. After these three attempts, not enough time was left for sun hemp to attract natural enemies of rice pests, even if third try would be successful. However, the mono-sun hemp plots were successful and used as manure and duck feed. None of sun hemp samples collected from the CRS plots are included in the calculations.

Fig. 12 Sun hemp planted in the mono-plots (Organic treatment) (A); Farmer manually weeding in sun hemp mono-plots (B)

2.2.7 Azolla

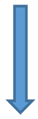
Azolla microphylla is a floating fern that lives in symbiosis with the nitrogen-fixing algae *Anabaena azollae*. In Asia, Azolla is being used widely as green manure, fertilizer and livestock diet supplement. It decomposes quickly as a compost and increases soil fertility and soil microbial biomass (Yadav et al., 2014). Azolla duplicates itself within 3 to 10 days and it has been shown that the growth rate of *Azolla* is not affected by its cultivation method.

A bag of azolla was bought and divided into all the plots equally. However, the azolla could not be found after few days after release. Second bag was divided again 2 weeks later but non of azolla found after few days again. This is due to the late time of purchase and lack of water in the field. None of azolla was measured for the data.

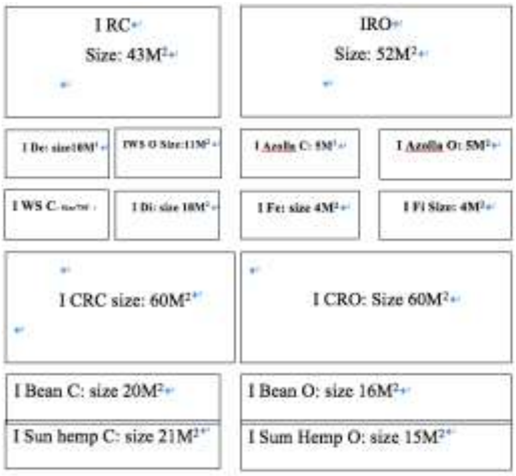
2.3 Experimental design and farm set up

The experiment was designed in a randomized complete block layout. Three repetitions (Block I, II, III) were set up with 16 plots in each block. The plot sizes and relative locations are shown in Figure 13. Two different treatments, organic and conventional, were applied to the crops and livestock. Rice, water spinach and yardlong bean were cultivated in monoculture shown as organic (O) and conventional (C) in the figure 13. Rice, fish and duck, forming the complex rice system, were applied in same plot. Shown in the figure as organic (CRO) and conventional (CRC).

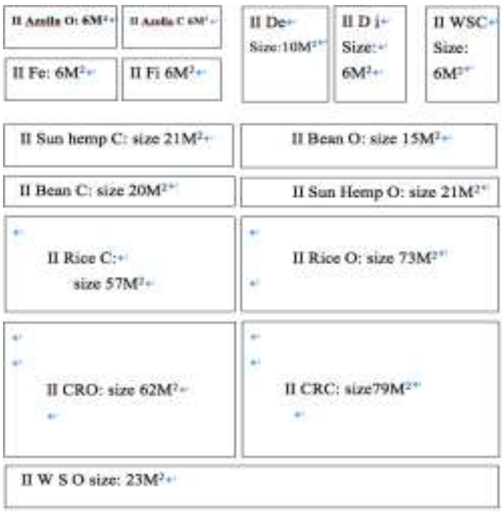
Block 1



South West



Block II



Block III

Fig. 13 Experiment layout with size details. Slope faces south-west. WS: Water Spanish. D: Duck F: fish; O: organic; C: conventional; e: extensive; i: intensive

Irrigation for the field was using the main water canal in the area, which was also used by other conventional farming fields in the area. No separated water system was used for the organic plots. Therefore, it is possible that pesticides or fertilizer used by surrounding farmers could leach and contaminate the water used for the organic farms. No tests were conducted to assess water quality.

2.4 Cultivation methods

The cultivation method used was according to the local farmer's habits for growing rice. The first step was field preparation. The soil preparation includes several round of plowing using buffaloes to mix the face soil into sub-soil making the soil more suitable for plant's root systems to develop. (Figure 14A) This plowing can also help as weed control for the initial rice growing stage by burying weeds and seeds further into the soil. Furthermore, the farmer builds a dike as border for each different plot. (Figure 14B). The farmer starts the field preparation mid-February.

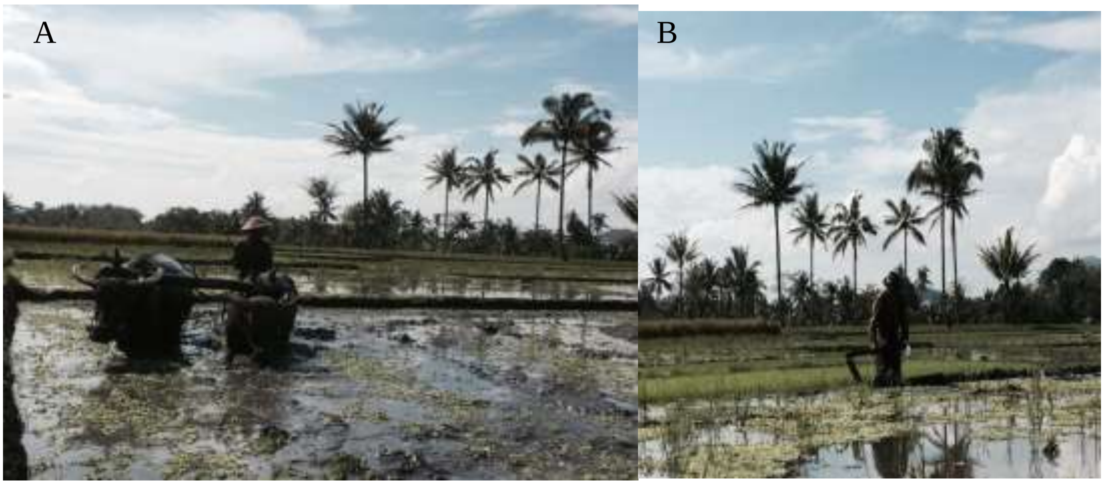


Fig. 14 Farmers were preparing opening up field for the new rice season

To keep the ducks in the field and prevent them from escaping, a 100 cm tall fence, made of bamboo sticks, was used around each complex rice plot (Figure 15). In addition, a duck house was constructed from bamboo in each plot for ducks to rest and sleep at night. Normally, the farmer will keep the water level at around 10 cm. However, during the experiment period there was construction ongoing on the irrigation channel. This resulted in a low water level most of the time, as rainfall was the only source of water. Following the local rice cultivate technique, all applied water should drain out 4 weeks after transplantation. But, during the experiment period, the experiment field never completely drained out in the first month after transplantation.

Fig. 15 Fence built around the whole block III

2.4.1 Rice in mono-culture

Rice monocultures were cultivated in two different treatment groups. In treatment group organic ('RO') rice was grown totally organic without any chemical input (Figure 5). A total amount of 13.5 tone/ha biogas sludge from buffalo manure was applied to each plot during the season. Appliance was divided over three moments: 2, 6 and 8 weeks after transplantation (WAT). Additionally, 151 liter/ha of the farmer's self-made liquid fertilizer mixture was diluted with water at 1:1.4 ratio and applied once after 2 WAT. This mixture consisted of buffalo urine, *Tinospora cordifolia* (“brotowali”), *Tithonia diversifolia* A. gray (‘paitan’) and ‘kedoya’ (*Dysoxylum gaudichaudianum)* leaves. A self-made organic pesticide mixture was diluted with water at ratio of 1:1.4 and applied twice to prevent pests. First time, at 4 WAT, the pesticide was applied at a rate of 350 l/ha. Second time, at 7 WAT, the pesticide was applied at a rate of 268 l/ha. Furthermore, organic pesticide ‘OrgaNeem’ (Organeem LLC, USA) was applied at a rate of 268 liter/ha dilution at 7 WAT.

The second treatment group was cultivated semi-conventionally (‘RC’).
The plots were fertilized using 91 kg/ha of Phonska fertilizer (N:P:K = 15:15:15, Cv. Sundag-15 Gresik Indonesia) and 91 kg/ha of SP-36 fertilizer (36 % phosphate) at 2 WAT. ZA (local name) fertilizer was applied twice at a rate of 182 kg/ha at 6 and 8 WAT. Additionally, self-made liquid fertilizer was used at 2 WAT and applied at a total rate of 15l/ha after dilution with water at 1:1.4 ratio. Self-made organic pesticide was applied at a rate of 151 l/ha at 4 WAT and the chemical insecticide ‘Gallery’, which included active ingredient ‘Dimehypo’ 403 g/L, (PT Maju Makmur Utomo, Indonesia) used against *Scirpophaga incertulas* and *Nilaparvata lugens,* was applied at a rate of 432 l/ha at 7 WAT after dilution (20 ml diluted in 12 L water). Due to the farmer’s self-made fertilizer and pesticide mixtures being prepared a long time ago, whereas leaves have constantly been added, the specific mixture ratios of the different ingredients are unknown.

Systematic weeding was done manually twice in all plots on 6 and 22 April 2017. The weeds were not removed from the plots but pulled out and mixed deeply into the soil. Weeds from the dike were cut, collected and sometimes used as buffalo feed.

2.4.2 Complex rice system (CRS)

The complex rice system consisted of rice, fish, duck, water spinach, yardlong bean, azolla and sun hemp. The main crop was rice which was cultivated the same way as the mono-rice plots. Two different treatment groups were used here as well. The group complex rice conventional (CRC) received chemical fertilizer like RC treatment, whereas the group complex rice organic (CRO) received organic fertilizer like RO treatment. No pesticides were applied in any plot. (see Section 2.2.1)
Due to the narrow dike no space was available for border crops after the fence was set up for the ducks (the original plan was to plant border crops on these dikes). Therefore, the border plants were cultivated in polybags and put alongside the fence. The polybags were placed on three border dikes, whereas on the fourth dike a duck house was built and border crops were

planted on that side of the dike. However, the border crops planted on the side of the dike did not grow well due farmers stepping on them.

The crops were planted in a separate polybag on 28 March 2017, and a total of ten bags of sun hemp and ten bags of beans were placed in each CRS plot. However, all plants died or were eaten by ducks. The second transplant of border plants was made on 7 April 2017 and the size of the bags was doubled, but the ducks were still able to reach the plants and again all plants died or were eaten. In the end, 25 kg bags (Figure 17), which locals commonly use for storage, were used and placed in the fields on the 22 of April. Border plants were planted divided over eight bags and placed in each complex plot distributed on the three borders (the border containing the duck house was excluded). Plant material was mixed with manure from the farmers' own buffalos and some soil inside the bags. No additional chemical fertilizer or pesticide was applied. Five to seven water spinach seedlings, one to two bean seedlings with two unfolded leaves and two to three 30 cm high sun hemp seedlings were transplanted to the bags, taken from the dike where they were sown 2 weeks earlier. The transplantation of the water spinach did not work out well; some plants died off or were growing very slowly resulting in only one harvest until the end of the rice season. Moreover, some stubbles did not regrow after the first harvest. Very little sun hemp survived in the polybags placed in the complex rice system plots. Therefore, none of sun hemp sample was collected as output.

All ducks were released into the field 2 weeks after rice transplantation, when they were 21 days old. Three to four ducks were placed in each plot. This resulted in a duck density of 0.05 per m^2 for repetition I and II, 0.06 per $m^2$for block III CRO and 0.07 per $m^2$for block III CRC due to plot size differences. The ducks received the diet as provided to the mono duck plots. Ducks in group CRO received a diet like extensive raised ducks (De) and in group CRC duck received a diet like the intensive raised ducks (Di). The ducks were moved from the field at age of 80 days when rice began to flower (at 10 WAT).

In the center of each plot, a pond was prepared with size of 0.75 m * 0.75 m for fish to stay when water level was low (Figure 16).

Fig. 16 A pond was prepared with size of 0.75 m x 0.75 m for fish to stay at low water level

Fish (*Nile Tilapia*) were introduced into the plot on 26 March 2017 with a density of 5 to 6 fingerlings per plot. The fish in the CRC plot received the same amount of rice bran as the fish in the intensive plot (Fi). Whereas, the fish in the CRO plot were fed like the fish in the monoculture fish plot (Fe). However, all fish died like those in both monoculture plots, expected due to low water level and possibly low oxygen availability. The fish were replaced with catfish which were placed in the fields with a density between 0.04 to 0.07 fish per m^2. The catfish received the same diet per fish as *Nile Tilapia, as described* before. However, at harvest, no catfish was found in the complex rice system plots. None of fish yield was calculated into the output result.

Fig. 17 The polybag with yardlong bean and water spinach and sun hemp at the 13th June 2017 in CRS

2.5 Data collection and analyses

2.5.1 Yield from rice

The sample rice was harvested on 13 June 2017 at an age of 107 days. For measuring grain yield, five times a sample of 3*3 hills was harvested per rice plot (Figure 18)., A total of 20 rice samples were collected and measured in each block.

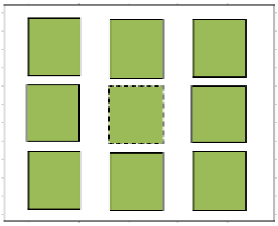


Fig. 18 Distribution of yield same in rice fields

All rice on these 9 hills, including good, sick and dead rice plants, were collected. Due to many missing hills in rice plots, a smaller sample area (0.75 m * 0.75 m) was taken to avoid missing hills influencing this study.

The sample plants were cut above soil surface. These were put, divided per hill in each square, into big bags and carried back to the farmer's place to be sun-dried for 4 to 5 hours due to the morning rain in harvest day. After sample plants were dried, sample plants of each hill were separately weighed for total fresh biomass. After determination of the total biomass, the plants were threshed to obtain the weight of fresh straw biomass and total fresh weight of grain (including filled and unfilled kernels). Straw and kernel samples were dried in the oven at 80 °C for 72 hours. After drying, the filled and unfilled kernels were separated by fan selection. The dry grain yield was corrected for 14 % moisture content when calculating the yield.

For analysis of yield components, seven undamaged panicles were taken from random hills for each plot. For each panicle separately, the amount of filled and unfilled kernels was counted. The percentage of filled kernels and total grain per panicle were calculated from this data.

2.5.2 Beans

Mono-bean plots harvesting time lasted from the 29th of April to the 22nd of May (24 days). For yield sampling, per plot three rows were randomly chosen leaving out the two plants on each border of the row. From each harvest the total pod fresh weight, pod number and the length of 10 pods (or the number of harvested pods if less than 10) were measured for each row. Dry pod weight was obtained once for each row after drying in oven for 72 hours at 80 °C.

From the complex rice system plots, three random bags of beans were chosen. The measurement method was same as the one used for monoculture plots. For each bag pod weight, pod number, pod length and shoot fresh and dry matter was obtained. Data for pod yield and yield components of plot III CRC are missing as no pod was ready for collection.

2.5.3 Water spinach

For the yield sampling of water spinach in monoculture 0.3 m^2 of dike area, where the crop was grown on, was taken as harvest area. Border plants were left out. All plants were harvested by cutting the stem leaving a stubble of 4 cm height for regrowth. Total fresh biomass was determined by weighing.

In the complex rice system plots, shoots in each bag that contained at least 4 shoots were harvested during first harvest (to reduce possible influence of density). Using the same method as for the monocultures, total fresh leaves and stems as well as the length of the shoots were measured. Since the shoots transplanted in one bag did not grow consistently, some shoots were only harvested during the second harvest. Therefore, the total fresh yield of both harvests per bag is calculated. Bags with water spinach that were eaten by ducks or died off after transplanting were Excluded.

The stubble of the harvested stem was left for regrowth and harvested a second time. It would have been theoretically possible to harvest for a third time during the rice season, but due to time constraints it was not carried out. For calculation of the water spinach harvest yield in LER, the samples were only compared with the monoculture fields for the first harvest since regrowth rate can differ.

2.5.4 Sun hemp

Experiments with the sun hemp in the complex systems were a failure. Therefore, only the height of sun hemp was measured, but no yield date was collected for calculations.

2.5.5 Ducks

It was quite difficult to maintain the duck plots well as mud and weather caused ducks to escape into other plots in the beginning (e.g. jumping to other plots or escaping under the net by digging a hole). To distinguish the ducks between the plots, the ducks' bodies were painted different colours. However, due to a lot of rain, the colour was washed away after a few days. Therefore, flexible aluminium strings were tied around the legs as the ducks were still growing. However, the ducks would bite them off. Finally, the ducks were distinguished by cable ties around the legs.

The first measurement of the duck's weight was at age 47 days, as it was difficult to separate ducks earlier. All ducks were weighed at an age of 80 days when they were removed from the complex fields. The weight increase between the first and second measurement was calculated. In addition, the mortality rate was determined by counting the loss of ducks in each plot. However, due to ducks escaping from plots II Di and II De into plot II WC and eating all the seeds of the sown water spinach, the mortality rate was not calculated for these plots. The seed coating is toxic to ducks, and it was not possible to know which ducks died because of WC seeds or because of other natural reasons. The farmer insisted that ducks in Di II and De II died resulting from eating the WC seed. Duck mortality rate was calculated as an average of both monoculture treatments and of both complex treatments. The average was taken as some ducks died before the distinction by cable ties. Therefore, it is difficult to separate which behaviour of duck can be attributed to which treatment.

2.5.6 Fish and Azolla

Fish weight as yield or output was originally planned to be obtained after removal from the complex rice system plots. However, as implementation of both fishes failed, no yield data was collected. Due to low water conditions during the experimental period, the implementation of azolla in the fields failed in both CRS and mono-azolla plots. None of the azolla data could be collected. As a result, no azolla yield is calculated.

2.5.7 Pest and predators

Yellow traps to catch pests and predators were set up in the fields three times at 5 WAT (13 April), 9 WAT (12 May) and 12 WAT (29 May).

In each field (rice monoculture and complex rice system) three yellow traps, with a size of 20 cm x 20.5 cm, were attached to bamboo sticks which were placed facing west in a diagonal line. These yellow traps were placed in the plots as showed in Figure 19. The height of the traps followed the height of the rice hills with the centre of the trap being at the same height as the hill. The traps were placed into the fields at 8 a.m. and left in the field for 24 hours. Animals attached on the traps were identified and counted carefully. Trapping was conducted on three fields of conventional neighbour farmers as well to use as a general comparison.

Fig. 19 The yellow traps were set up in the rice plots on date 13 April 2017

2.5.8 Farm production financial result

A financial income statement was made under general accounting rules applying to corporations. Output included all the farm's products having market value. The rice price was 4,500 IDR/ kilogram. This was not separated into organic or conventional, due to the organic rice price not showing any difference to conventional rice price according to interviews with organic rice farmers. The price per duck was 8,064 IDR according to the selling price of all 63 experiment ducks. However, this number is far below duck's market price which ranges between 35,000 IDR and 45,000 IDR. The price of water spinach and Yardlong bean were obtained from interviews with market sellers. 4,000 IDR/kilogram was used for beans and 2,000 IDR per 600 g was used as market price for water spinach.

The input (cost) data was collected and documented for setup of field along with all other costs. Labor cost of the farmer's work hours were calculated based on the local labor daily cost into monetary value. Even though there was no fish harvested, the cost for building up fish was included in the financial statement.

2.6 Statistical analysis

The collected data of rice yield, vegetable yields, and pest population were analyzed using software IBM SPSS 2.3. Whereas, the data of economic value were analyzed using Excel. The normality of data distribution was tested with a QQ plot. If the data showed a normal distribution, an ANOVA (Analysis of variance) was conducted to check for any significant differences between treatments. Statistical analysis was carried out for the yields and yield components of each harvested crop and livestock. The pests and predators total amount and species were tested via Skewness-Kurtosis test.

2.7 The Land Equivalent Ratio

One way to assess the benefits of growing two or more crops together, or intercropping, is to measure productivity using the Land Equivalent Ratio (LER). LER compares the yields from growing two or more crops together with yields from growing the same crops in monocultures or pure stands. The idea behind intercropping is to capitalize on the beneficial interactions between crops while avoiding negative interactions. Essentially, the LER measures the effect of both beneficial and negative interactions between crops.

The LER was calculated using the following formula (Mead & Willey 1980)

$LER_{complex}$ = Intercrop1 yield * price /pure crop1* price + Intercrop2 yield* price/ Pure crop2 yield *price +…… etc.

A LER value > 1 indicates a yield advantage of the intercropped system compared to the monoculture, whereas a LER value < 1 shows a disadvantage.

For crops harvested just one time, yield data was collected when the crop was ready for market. For crops harvested multiple times, both water spinach and bean were harvested multiple times, data was collected when a sizable portion had reached market size and at regular intervals over the harvest period. For crops harvested more than once, the same area yield data of each harvest was collected. Concerning animal products, the ducks, which were ready for sale at the end of cropping season, were counted. Data from mono-plots in the experiment was used for denominator of the equation.

2.8 Total Factor Productivity index

The Total Factors Productivity (TFP) approach is based on market value information available. Total inputs and outputs data were collected and combined into market value. To measure agriculture sustainability, the efficient use of input becomes a crucial issue. In this perspective, the research concentrates on the TFP. TFP is a suitable assessment of the sustainability of single crop, cropping systems and farming systems. Although TFP does not consider the non-market output (social and environmental aspects), it is possible to argue that a negative trend of TFP represents a resource degradation when related to the generated output (Ghelfi et al., 2012). Lyman and Herdt (1989), in an article of interest on the subject, defines sustainability as the capability of a system to approximately maintain its level of output.

To calculate TFP, revenue from all product sales are generally considered as output and intermediate consumptions as external inputs. Output is the total amount products sold including the rice yield per hectare and number of fish and ducks ready for sale. In addition, this covers all aggregated production of multiple harvest crops, such as water spinach and yardlong bean, which was produced during the 107 days' rice growing period. The input in our research included all the costs of rice seeds, compost (consisting of duckweed, straw and duck manure), duck feed (consisting of rice bran, corn and dried fish), ducklings, juvenile fish, phosphorus fertilizer if applicable and the total labor required for preparing the field, farm management, and harvest.

Formula of TFP index:

TFP = $\sum_{k=1}^{n} Qo^k Po^K$ (output) / $\sum_{t=1}^{n} Qi^t Pi^t$ (input)

Qo: the total Quantity of marketable output product

Qi: the total Quantity of marketable input element

Po: the market price of output product

Pi: the market price of input element

k: item of output products

t: item of input elements

TFP data of conventional and organic farms were collected through interviewing farmers and reviewing literature. Rice yield from conventional and mono-organic farmers was collected separately to conduct a different production system comparison.

2.9 Measurements for calculating hidden costs (TEEB, 2015)

2.9.1 Biodiversity

Shannon-Wiener diversity index is used to calculate the bio-diversity in each plot using the following formula:

H = -SUM[(pi) * ln(pi)] E=H/H_{max}

Where, SUM = Summation pi= Number of individuals of species i/total number of samples S = Number of species or species richness H_{max} = Maximum diversity possible

2.9.2 Healthy cost as hidden cost of rice production

The study uses “The economics of Ecosystems & Biodiversity Agri-Food ‘valuation framework’” as approach. The TEEBAg Food valuation framework is a frame of analysis that can enable us to answer the question “what should we value, and why?”.

2.10 Market and Farmer Survey

To obtain the local market prices of rice, duck and vegetables, several surveys were conducted in the local market and with farmers. Five random vegetable sellers in the local Jenggolo morning farmers market were interviewed for the water spinach and yardlong bean price. Another market price interview was conducted in the Kepanjen city market as well. Five vegetable sellers were interviewed to get vegetable market price from city’s market. The market price of duck was obtained from both market sellers and local duck farmers’ interview.

Conventional farmers were surveyed twice at different times. The first time, 11 conventional farmers were interviewed around the experimental farm area. The second time, 15 conventional farmers, whose rice was harvested around the same period as the experimental field, were surveyed. Furthermore, 9 organic farmers from the organic farming co-operation were interviewed on 12 April 2017. (Figure 20)

Fig. 20 Organic farmers interviewed. Pak Kemin, the Chairman of the organic farming organization, explained how this organization operated

3 Results

3.1 Result for research question1- crops yield

3.1.1 Rice Grain Yield

The average grain yield of each treatment is shown in Figure 21. Average grain yield showed no significant difference between each treatment (F>0.05) even though the average grain yield from RO is much lower. The grain yield of CRO is 200% more than RO and the grain yield of CRC is 60% more than RC.

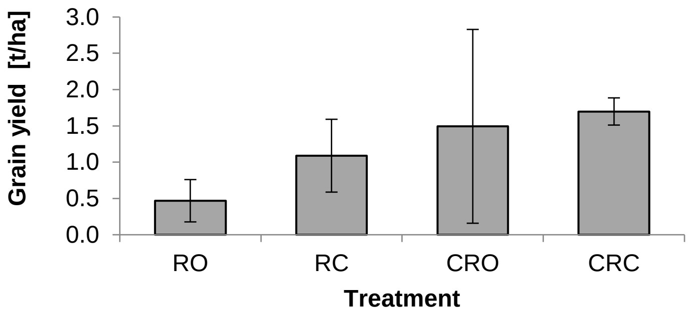


Fig. 21 Grain yield, corrected by 14 % moisture content, for each treatment of rice and interpolated to an area of 1 ha. RO, rice organic; RC, rice conventional; CRO. complex organic; CRC, complex conventional. standard deviation showed in bars (CRO: n = 3; CRC: n=2)

3.1.2 Grain number per panicle

The average number of grains per panicle showed no significant differences between different treatments. The average number of grains per panicle ranged from lowest 96.52 in RC to highest 152 in CRC (Figure 22). There was no significant difference in the percentage of filled kernels in different treatments either. The percentage ranged from 65% to 71%.

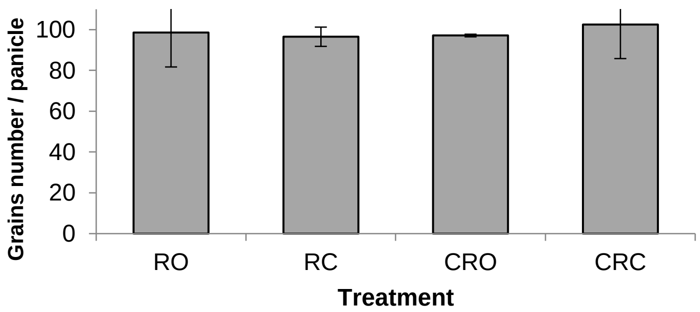


Fig. 22 Number of grains in each panicle for each different rice treatment. Bars indicate standard deviation (RO, RC: n = 3; CRO, CRC: n = 2)

3.1.3 Duck

Duck results of this experiment shown in Table 3. Initially, ducks were only weighted at day 47. The weight at day 47 did not show significant differences across the different treatments. But, the ducks in CRC plot did weigh heaviest. Lowest weight was found in De at 485.71g. Weights at day 80 did not show significant differences (P>0.05), either. However, the CRC ducks still showed higher weights as they did at day 47. The end weight of Di, CRO and CRC at 80 days were similar. The weight growth did not show significant differences between treatments. The weight of most lagging behind duck was De treatment at 891.27g.

There were no dead ducks found in CRO or CRC plots after day 47. However, the mortality rates were 39% in De plot and 54.7% in Di plots. Mortality Rate in both Di and De are much higher than the rate local duck farmers provided. The reason might be the bird flu which out broke in Malang area while experiment was conducted. However, ducks in CRS would have been at risk as well. This experiment can not provide a reason for the zero duck mortalities in the complex rice system plots.

Table 3 Summary of duck results in the different treatments (Di: duck intensive, De: Duck extensive)

Treatment	Midterm Weight (g)	End Weight (g)	Weight gain [%]	Mortality rate [%]
De	485.71	891.27	183.85	39.68
Di	589.05	1047.22	178.03	54.76
CRO	594.44	1061.11	181.61	0.00
CRC	671.53	1084.03	161.42	0.00

All ducks were sold at the same price at the same time. Duck prices should be in difference due to different sizes in the treatments. However, duck wholesalers would only buy all ducks together at same price. Average duck selling price was 8,064 IDR per duck. After taking mortality rate into account for calculating LER, the results used are a yield of 5,508 ducks per hectare in monoculture and 400 ducks per hectare in complex rice system. Relative yield for ducks in complex systems is therefore 0.07.

3.1.4 Water Spinach (WS)

Water spinach yield of complex rice system and mono-plot are shown in Table 4. Days until harvest were 29 and 33 for WSO plot and 32 for CRO and CRC plots.

The WS yields from both CRS plots were much lower compared to the monoculture plot. This might be due to the soil and manure component in the polybags was not suitable for WS growth. Also, WSO shoots were planted on bunds within the field with a spacing of about 30 cm between bunds. Spacing might have led to better growth of shoots due to a higher radiation.

Table 4 Fresh yield and shoot yield of water spinach in different farming treatments

Treatment	**Yield [t ha^{-1}] based on gross land area**	**Shoot $yield^{-1}$ [g]**
WSO	3.73 (0.37)	4.1 (0.2)[z]
CRO	0.02 (0.00)	3.9 (0.9)
CRC	0.03 (0.00)	3.9 (0.6)

[z]Standard deviation

3.1.5 Yardlong Bean

Bean yield details for different treatments are shown in Table 5. In monocultures field, the harvest period of yardlong bean was lasted for 19-24 days but only 6 days in complex rice system due to ducks foraging behavior. No beans were ready for harvesting in CRC block III, therefore, there is no data from CRC block III. The bean yield of CRO is higher than CRC even though they are cultivated in the same way. Bean yields showed no statistical significant difference between CRO and CRC plots. Furthermore, the pod data collected from different treatments also showed in same table. The pod weight of BO and BC was significantly higher than of CRC (Tukey HSD, $p < 0.05$). Pod length was significantly higher for BO than for CRC (Tukey HSD, $p < 0.05$).

Table 5 Yardlong beans data from different farming treatments

	Fresh yield [kg/ha]		Harvest Index		Pod weight [g]		Pod length [cm]	
Treatment	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BO	4026.6	794.5	0.5	0.2	15.3	1.0	49.6	1.7
BC	4457.5	1804.5	0.5	0.3	15.1	4.1	48.3	4.0
CRO	14.9	3.1	0.6	0.1	9.7	0.4	43.8	2.0
CRC	6.4	2.4	0.5	1.0	5.6	1.6	39.3	4.8

*SD= standard deviation (n = 3, CRC: n = 2) BO= bean organic BC= bean conventional CRO=complex rice organic CRC=complex rice conventional

3.2 Results for Research question 1: Financial results

All numbers showed in Table 6 of conventional and organic were obtained through farmer's interviews. The profit and cost of conventional was calculated from 26 conventional farmers' average rice production per hectare. Organic number of profit and cost calculated from 9 organic farmer's average production per hectare.

Table 6 The completed financial statement of all different rice farming system

1 USD=13000 IDR	Conventional	Organic	CRO	CRC	RO	RC
Output						
Rice	22,995,000	22,500,000	6,831,000	7,650,000	3,402,000	4,860,000
Duck	-	-	3,225,600	3,225,600	-	-
Fish	-	-	-	-	-	-
Vegetables -Konkong	-	-	84,000	58,966	-	-
Vegatables -Bean	-	-	19,200	14,000	-	-
Gross Profit (IDR)	22,995,000	22,500,000	10,159,800	10,948,566	3,402,000	4,860,000
Input						
Rice						
soil preparation	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
seeding	770,000	770,000	770,000	770,000	770,000	770,000
Rice seed	150,000	150,000	150,000	150,000	150,000	150,000
Pest management	200,000	200,000	-	-	200,000	200,000
Weed manangement	800,000	800,000	-	-	800,000	800,000
Bio-pesticides	-	-	-	-	-	-
Pesticide	2,000,000	-	-	-	-	1,000,000
Furtilizer	1,000,000	-	-	600,000	-	600,000
Manure	-	500,000	500,000	-	500,000	-
Tools for Plow	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Tools for Harvesting	240,000	240,000	240,000	240,000	240,000	240,000
Total cost for rice (IDR)	8,160,000	5,660,000	4,660,000	4,760,000	5,660,000	6,760,000
Duck						
Net and bamboo			1,500,000	1,500,000		
Ducking	-	-	1,600,000	1,600,000	-	-
Labour for first month	-	-	1,200,000	1,200,000	-	-
Other labour input	-	-	1,000,000	1,000,000	-	-
Feed (KG)	-	-	7,950,000	7,950,000	-	-
Total cost for duck (IDR)	-	-	13,250,000	13,250,000	-	-
Fish						
Fish	-	-	700,000	700,000	-	-
labour for fish	-	-	600,000	600,000	-	-
Feed	-	-	1,000,000	1,000,000	-	-
Total cost for fish(IDR)	-	-	2,300,000	2,300,000	-	-
Vegetable						
Seed	-	-	188,500	188,500	-	-
Labour for harvest	-	-	600,000	600,000	-	-
Total cost for vegetable (IDR	-	-	788,500	788,500	-	-
Total cost (IDR)	8,160,000	5,660,000	20,998,500	21,098,500	5,660,000	6,760,000
Net Profit/(loss) (IDR)	14,835,000	16,840,000	-10,838,700	-10,149,934	-2,258,000	-1,900,000

3.2.1 Cost and benefit result of different farming systems

According to Table 6, the organic farmers made the most profit among all rice systems. The net profit of an organic farmer is 16 million IDR. Cost and benefit analysis calculations show all negative profit result in this experiment's four farming system. The CRO plot showed the most negative number -10.8 million IDR/ha, with CRC loss close to -10.1 million IDR/ha. This result was caused by low rice yield and low duck's sales income. Both RO and RC show negative financial results as well. Compared to RO, the RC cost was higher due to the cots of chemical pesticides and fertilizers. The vegetables, beans and water spinach, contributed very little to the total income due to low productivities and low market price. Vegetable income accounted for only 1% and 0.6% of gross profit of CRO and CRC. In CRC, planting vegetables did not help increase farmer's income after including setup costs. Farmer loss money in planting border vegetables.

Both CRO and CRC system have more than 50% cost from duck raising. Also, in order to keep duck inside field, net and bamboo also needed and considered as part of cost of ducks. That's about 7% of total cost. The duck selling price in this experiment was 8064 IDR. Profit from duck is about 30 percentage of total profit in complex rice system.

Fish cost is about 10% of complex rice system total cost. Cost from ducks and fish showed more than 70% of total cost. The total cost in complex system increases 15 million IDR in order to make the system work. In this calculation, the total cost of CRO and CRC did not include of the labor requested for selling vegetables in market. In local practice, the farmers sell their own small production in local morning farmer market than sell to whole seller. The total labor cost of selling vegetable is unable to estimate. Cost of RO and RC plots looks very similarly due to the RC is cultivate semi-conventionally.

Table 6 indicated that organic farmers spend less money in growing rice per hectare. The total cost of local organic farmers spent per hectare per season was 5.6 million which is same as RO plot but with higher outcome. According to organic farmers, they used home produce buffalo and cow manure for making composite to fertilize crops, therefore there was no extra fertilizer cost needed. Also, due to the organic rice system already practice for more than 10 years, the farmers did not need any bio-pesticides applied.

3.2.2 Financial effect

The financial comparison of different farming systems is listed in Table 6. After analyzing the financial results, comparing to other farming system, complex rice system did not contribute to farmer a better net profit in this experiment.

Financial Effect of rice

The conventional rice farmer has the highest gross profit at about 23 million IDR/ ha follow with organic rice farmers which is 22.5 million IDR/ ha. However, after including costs (input), organic farmers make more money than conventional farmers. The reason is that the costs of organic farming is around 2 million IDR/ha lower. Organic farmers did not spend money on chemical pesticides and fertilizers since they have made fertilizers from cow manure by themselves. However, according to organic farmers, they do have to study on how to control pest damage to lower rice yield loss. Due to the study on new knowledge build up most from the chairman to lead all members in the organization, the cost of the study time as labor cost was not able to count into cost-benefit analysis.

In this experiment, four treatments' financial results were all at net loss. In the integrated system of rice, ducks, fish and border crops, rice is still the main income. Net rice profits of CRO and CRC are at around 2.2 million IDR and 1.7 million IDR respectively. RC and RC are both in net loss at around -2 million IDR. The loss of rice yield caused by unknown pest and disease outbreaks which directly lead to a financial trouble for farmers.

Financial effect of raising animals

Earlier studies by Hossain et al. (2004) and Zheng et al. (1997) showed that different products in the complex rice system, such as duck and fish, may increase farmer's income by diversifying different products and lowering the farmer's risk from environmental changes. The results of this experiment showed that raising ducks did not increase the total profit due to the high set up cost of duck. In CAGAUAN et al. (2000) study indicated that duck, fish and *Azolla* integration into the rice field returns a lower net profit in the first cropping season due to the high initial costs of purchasing ducks, but shows an increase of profit from the second cropping season on. Figure X showed that the different net profit in different rice yield with two different duck sales prices. The complex rice system could make similar profit as conventional farmer when the rice yield reached 5,000 (kg/ha) if duck sold a good price.

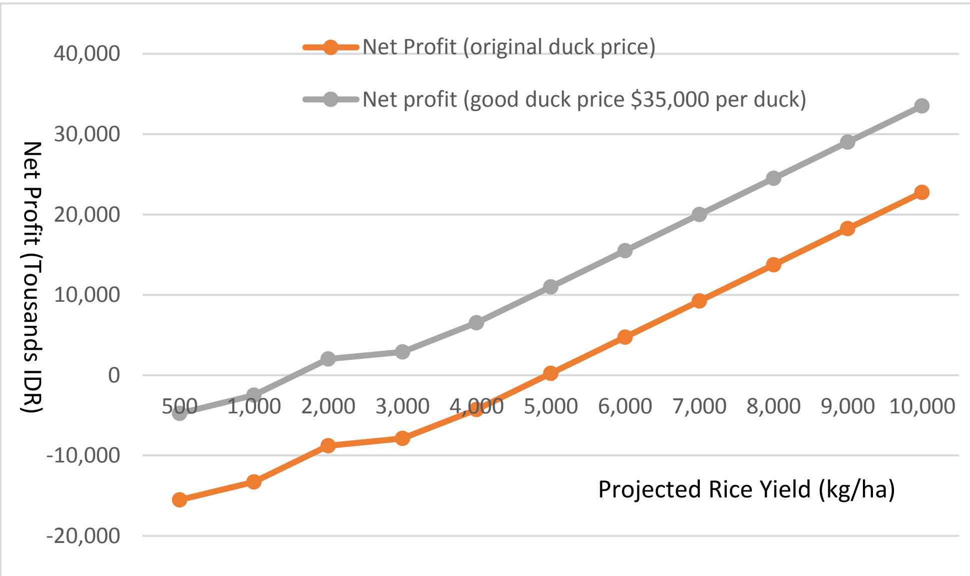


Fig. 23: The net profit in different rice yield and duck sales price

3.3 Result for research question 2- Land Equivalent Ratio (LER)

CRO block II showed the highest Land Equivalent Ratio which is 2.99. All LER numbers of complex rice system are above 1. The LER>1 indicates that complex system was more productive than a mono cultivate rice crop. (Table 8) In block I, CRO have 65% more productivities than RO, and in Block II, the ratio is almost 200% more than RO in same block. In CRC, LER also showed more productivities in complex system. The dominate number which contributed the high LER number of complex system is rice. Rice yield contributed the most improvement of land productivities. Duck only contribute 0.072 cross all complex systems. None of vegetables cross four different blocks contributed more than 0.01. the highest number is from CRO black I bean’s number 0.027 which is only represent 1.6% of LER number 1.654. Vegetable increase very little of land’s productivities. This low number may due to the yield of vegetables from polybag. If the vegetables been planted on the dike as plan, the number might improve.

Table 7 The LER number of different Plots

	Harvested Yields			
	CRO		CRC	
Product	**Block1**	**Block II**	**Block I**	**Block II**
Rice	1.552	2.897	1.743	1.048
Duck	0.072	0.072	0.072	0.072
Bean	0.027	0.016	0.006	0.008
Water spinach	0.005	0.008	0.008	0.008
LER	1.654	2.991	1.827	1.134

The LER number after adjusted with market price here did not show any different from only calculated yield. There is no price different used in both numerator and denominator since in the experiment all products price sold in the same. No price different between organic and conventional rice, or ducks in the Kepanjen area. Therefore, the LER number is the same as only yield was calculated.

3.4 Result for Research question3 -Total Factor Productivity index

Table 8 TFP numbers of different rice cultivate farmer

	Conventional	Organic	CRO	CRC	RO	RC
TFP[z]	2.81	3.98	0.48	0.52	0.60	0.72

[Z]Total Factor Productivity = Gross profit/ total cost

In this experiment, TFP number of RC is the highest. Even the number in RC is the best amount all treatment, but it is still below one. Both TFP index of CRO and CRC are around 0.5 (Table 9) which means that only half of all input turn into output. The efficiency of using resource is still low cross all CRO, CRC, RO and RC. Form the economics point of view, all treatments need improve the efficiency of food production.

Unexpectedly, the TFP index number showed organic farmers perform better in transfer the input into output. Organic farmer's efficiency of using input is 41% better than conventional farmer under the output of rice yield similar condition (5,100 kg/ha of conventional and 5,000 kg /ha of organic). Figure X showed that TFP of CRO could reach 1 at rice yield 2000 kg/ha with good duck price.

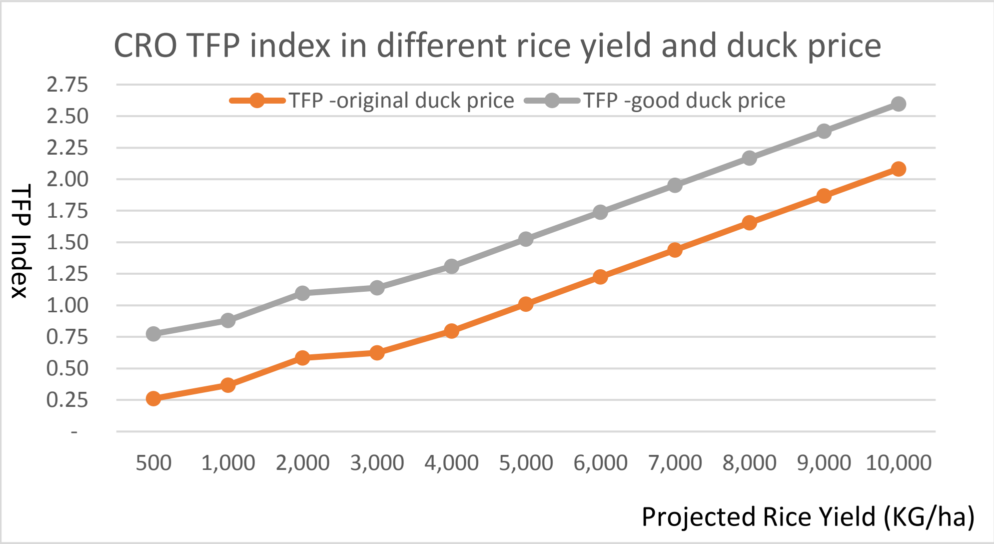


Fig. 24: CRO TFP index in different rice yield and duck price

3.5 Result for research question 4: The Economics of Ecosystems &Biodiversity survey

3.5.1 Biodiversity and Shannon Weiner biodiversity index

The numbers and species of pests and predators caught in different plots showed no significant different between each treatments of rice plots (F>0.05).

The Shannon Weiner biodiversity index result showed similar numbers, between 1.718 – 1.778 range, in each treatment (Table 11). The result only reflected insect and predators caught in yellow trap. There were many different type of bird species, frogs, even different dragonflies were saw and found in the field but not been counted into the index. Also, there are many different water plants in RO plots and aside of borders without been counted into the index. The diversity index calculated here is not including all of others animal and plants found in the field which indicated that the number showed in Table 11 may under estimate the real biodiversity in some treatments.

Table 9 Shannon Weiner index result

	RO	RC	CRO	CRC
Shannon -Weiner index	1.762	1.790	1.718	1.773

3.5.2 Hidden cost in health

Although there were not many interviews with farmer regarding to the health cost in the Jeggolo area, this research still managed few interviews conducted with Jeggolo city hospital and local farmers and try to find the hidden cost in health of rice production in Indonesia.

According to the hospital administrator, the hospital has few emergency patients might be linked to pesticides poison. However, there was no researches conducted or further information been followed from hospital, therefore, the hospital cannot confirm the correlation between sick people to chemical pesticides. Data from farmer interviews also showed that the real medical cost found through farmer interviews was under estimate the real health cost of rice farmer because very few of farmers aware of chemical pesticides can cause human’s healthy issue.

In the Jeggolo area, there are around 150 farmers and households. During the experiment, there was a farmer who spent 6.5 million for medical treatment and stay 5 nights in hospital due to pesticide poison. If 1 of 150 farmer sick caused by chemical pesticide, it means 0.6 percentage of total farmer got sick in this rice season this area. Using Jeggolo farmer’s number as baseline, the expected value of one farmer’s medical cost is 39,000 IDR. Rice farmer is approximately 77 percent of all farmers (25.9 million) in Indonesia (USDA 2012).

This country could carry 777 billion IDR (59.8 Million USD) hidden cost in health when produce rice conventionally.

4 Discussion

4.1 Crops yield and financial results

In this experiment, the results showed no statistically significant difference to support the hypothesis: Complex rice system generate a better crop yield. Also, analyzed the financial results, complex rice system did not contribute a better financial result for farmer. The research showed that rice profit per season of CRO was around 2.2 million IDR and the whole integrated system is net loss of -11 million IDR. The net rice profit of CRC was 3 million IDR, and net loss of CRC is -10.8 million IDR (see table 7). The integrated system did not increase rice yield enough to cover the increasing cost of setting up livestock into complex system. The research result is contrary to Zhang (1997) showed in his research. The reasons maybe caused by following reasons.

4.1.1 Low rice yield

During the experiment period, Jenggolo suffered severely damage from unknown pests and plants diseases. The outbreak of insect and disease in this area directly caused of rice plant died, rice yield loss and thus lower revenue from rice. In the block III both complex system plots lost all of the rice yield and nothing to be heaveted. According to local farmers, that was one of incidents which they had never faced before. Local farmers blamed the outbreak of insect and disease caused from unstable weather conditions with a longer raining season in 2017 than previously years. This experiment did not address the experimental data of the correlation between weather and rice yield. Candradijaya (2014) research conducted in west Java indicated that rice yield reduction is highly sensitive to the time of planting and irrigation scheduling in different temperature. In his research showed that rice yield decreases by 32.00% and 31.81% in comparison to baseline. Rice yield can be highly impacted by the climate change especially the shifting schedule of raining season in Java. Look into the weather record, the main different weather data in 2017 compared to 2016 is the number of raining days after April and average temperature drop 1-2 degree. There is no information to prove that the climate changed lead to this insect outbreak in the rice farm. In this research, the average yields of four treatments were all far below 7 tone ha^{-1} the recommended yield of rice cibogo.

Furthermore, bird damage reduced rice yield heavily. (Figure 31) While waiting for rice ready to harvest, during this period the percentage of grain loss from bird-eating was high. Birds damage included not only grain been eaten but also grains loss on the ground which those grain would not able to be harvested. Farmers had to stand near the side on the dike to chased away birds in order to avoid further grain loss but there was no possible to guard the field for 24 hours. The experiment did not arrange any facilities to scare away birds before harvest. Almost all rice plots suffered from grain loss caused by birds but more grains on the ground can be found in complex rice system. The sum hemp plots might be the reason of experiment field attracted many birds that sum hemp could provide the hiding habitat for birds and easier to approach rice next to. Fields close to breeding or roosting sites are most susceptible to damage from birds (de Mey 2013). The presence of trees, bushes or reeds in the vicinity of the field increases vulnerability because these provide birds with perches and nesting sites. Measurement was not taken on how much of the grain loss from birds in this experiment. The yield loss information by bird in this research remains unknown. According to IRR (2016), rice-eating birds chew rice grains, and can cause whitehead or unfilled panicles. De Mey et al (2012) in the research indicated that the Global Rice Science Partnership (GRiSP) identifies birds as the second most important biotic constraint in African rice production after weeds, based on farmer surveys in 20 African countries (IRRI et al., 2010) but no research found in estimating what's the financial loss caused by bird in Java Indonesia.

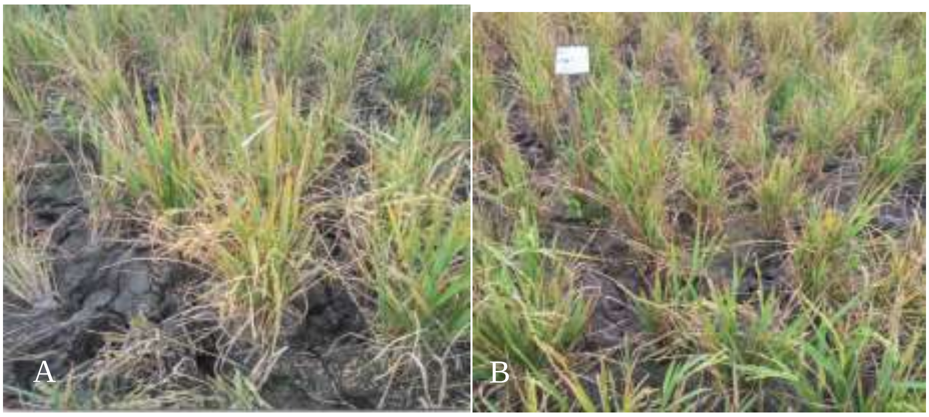


Fig. 25 (A) from CRO block II (B) from RO Block II. Lots of grain on the ground which might be shaken down from birds while eating. All rice plots suffered from bird damage. But the damage percentage was unknown

4.1.2 Failure on managing livestock price

Besides low rice yield, another reason caused the net loss (Table 7) of complex system could be the failure of live-stock in this experiment. Due to the total cost of raising duck was as high as 13.25 million IDR, having duck actually caused farmer lost more money in the complex system. The duck was sold at $8,064 IDR which was lower than cost of the duckling.

The normal duck market price is between 30,000 to 45,000 IDR. The local duck can reach 2-2.5 kg when matured. In this experiment, the harvested ducks were relatively smaller than normal size. When ducks moved from the field for sell at age 80 days, the highest duck weight was 1.192 kg. Although farmer had checked three different wholesalers to obtain the bid price, all of them provide similar bid prices. One reason is that the farmer did not have enough experience to sell ducks to the wholesaler and thereby forced to sell at below market price and caused a negative financial result. The other reason caused the loss in raising duck was the high cost of duckling. In the experiment, duckling was purchased through a middle man. The purchasing price was over normal cost which was 3.500-4.500 IDR per duckling. Only if 400 ducks in one hectare all survived and duck can sell at good price, raising duck can create positive profit. However, Malang is under bird flu (Avian influenza, H5N1) epidemic area. Keeping ducks in the open farm could increase more risk and volatility. If there was a bird flu outbreak, the highest levels of mortality rates often over 50% (Rushton et al., 2005). In this experiment, duck intensive and extensive plots suffered mortality rate from 33.33% to 71.43%. If those mortality rates were taken into account for calculating duck's financial result in complex system, the financial result of CRO and CRC could have further loss. Therefore, keeping ducks might not always be a guarantee for a positive finance result.

However, besides increasing the yield of rice, the infestation of weeds and insect pests was controlled by ducks in complex system. As a consequence, labor and pesticide costs for controlling weeds and insects decreased or were eliminated. If the long-term adverse health and environmental effects of insecticides could calculate into the statement, herbicides and chemical fertilizer use were also substantially reduced, thus making the system beneficial to the environment (Hossain et al., 2005). Training farmer to manage the integrated system especially on livestock and keep the system into a positive financial number is a way to attract more farmer to change the farming system.

4.2 Land Equivalent Ratio

In this study, the initial plan on set up the experiment field was not processed completely. Due to beans and water spinach were only grown in few polybags around the border, the vegetable relative yield of LER were very low. In the fields, each complex rice system could place more poly bags on the border, but it took too many laborious to carry out. However, according to farmer even if vegetables are grown on the bunds as plan, farmers would mainly produce for own consumption than sell them in the market (PAK YOPI 2017, BU YAMI 2017, pers. comm.). Therefore, an economic analysis of the complex rice system may show an income increase if there was an increase in rice yield per unit area or by the additional sale of ducks (and possibly fish). In reality, farmers would not sell ducks after removal from field but keep them longer for egg production and sell for meat when production lowers down (CIVAS 2004). More following research suggested to carry out with long-term experiment over more seasons to calculate relative yields for ducks by egg production and to analyze yield stability of rice during different seasons.

4.2.1 The LER of local farmer's Complex Rick System

During the experiment period, there was an interview with Mr. Yopi who applies the complex rick system (Figure 32) in his farm located in Surabaya. According to Mr. Yopi, the rice yield from his farm can reach 800KG from his 800 m^2 size farm. (10 tones $hectare^{-1}$) in dry season and 500-600 kg (6.25-7.5 tones $hectares^{-1}$) in raining season. The farmer raised 24 ducks in his farm (300 ducks per hectare). He used the local species duck Mojosavi (*Anas platyrhynchos* Javanicus). Also, hybrid fish Neil Tilapia with a local species was released in the farm. Mr. Yopi also prepared a pond for fish. Mr. Yopi prepared bigger size of pond aside in rice field showed in Figure 32 (A).

Fig. 26 Complex farmer Yopi's system. (A) fish pond (B) Border crops

According to Khumairoh (2012) research, the rice production of complex rice system can reach 10 $tones/ha^{-1}$ in dry season., duck could reach $320/ha^{-1}$, fish could be harvested 625 kg/ha^{-1} in the complex rice system. literature indicate Neil Tilapia can reach 19,000 Kg/ha^{-1} as mono cultivated (Zhu, 2010). Using the reference number as basic, LER of Mr. Yopi's farm could be calculated as follow.

LER for CRS farmer 1.291 = 1.25 (rice) + 0.033 (fish) + 0.008 (duck)

Mr. Yopi's farming system showed that the complex rice system might be able to apply in Malang area successfully. Apply the complex farming system, farmer was able to benefit from finically and 29% better use of land according to LER number. However, Mr. Yopi is the only one complex system farmer in whole area. Due to lack of other farmer's data, it's difficult to prove if the rice yield is higher or financial result of practical complex system is better.

4.3 The Economics Ecosystems & Biodiversity

Rice farmer is approximately 77 percent of all farmers (25.9 million) in Indonesia (USDA 2012). Using Jenggolo number as baseline, this country might carry 777 billion IDR (59.8 Million USD) hidden cost when product rice in conventional cultivation very rice season. The truth cost account of farming and food system is promoted recently year to reflect health cost and environmental cost of a society. Look into this 777 billion IDR might still under estimate the real medical cost of Indonesia rice production because very few farmers aware of chemical pesticides can cause human's healthy problem. In Malang, rice farmers normally don't do any protection when they apply pesticides as Figure 33 showed. In the interviews with farmers regarding to the potential healthy risk, farmers expressed that they were not aware the potential health risk cause by pesticides.

Fig. 27 Farmer applied pesticides next to the experiment field without wear any protection. Farmer's hands and arms directly exposed to pesticides. Also no mask was with farmer neither. Farmer could inhale pesticides directly

Farmers might have to face huge threaten and potential cost of medical treatment when apply chemical pesticides. If pesticides poison happened, farmer could loss whole season's income and fall into financial difficulty situation. Government or local institution should help farmers to improve their knowledge of how to apply pesticides safely and make farmer aware of the potential health damage caused from chemical pesticides.

5 Challenges and Recommendations

5.1 Challenges of a complex rice system

The recommended complex rice system incorporates with several components and thus requests different management and cultivation skills for each of those. In this rice, fish, duck, border crop integrated system, rice was still main income. In this experiment, the area for rice growth was slightly reduced by bags for border crops, a duck house and a fish pond. Therefore, if rice grain yield is improved, the reduced area can be compensated for. Despite the income of rice, farmers can sell ducks and fish in addition and input costs for fertilizer and pesticides can be reduced. Border crops like water spinach and bean are cultivated for own consumption solely.

CAGAUAN et al. (2000) study showed that duck, fish and *azolla* integration into the rice field returns a lower net income in the first cropping season due to the high initial costs of purchasing ducks, but shows an increase from the second cropping season on. Even if farmers are aware of environmental effects and health benefits, the system will only be implemented and spread widely if it is feasible and shows a positive input-output balance. The feasibility of an integrated system will depend on the management of the individual components. According to KHUMAIROH et al. (2012), in a functional system of rice, duck, fish and *Azolla* net profit can be increased by 114% from 5282 USD ha^{-1} . To ensure a positive input-output balance, farmers should be trained in managing the complex rice system as in raising livestock, the optimal rates of crop and livestock density and additional fertilizer input if *Azolla* inoculation fails.

Furthermore, farmers net revenue can be improved by a higher grain yield and also by a higher market price since rice of the complex rice system could be sold as organic. But, the problem of organic production in Indonesia is that the demand of organic product is very small and organic farmers could not easily sell crops at higher price. Also, in this study found that chemical applications of surrounding conventional fields can leach into organic fields and prevent organic farmers to obtain the organic certification for their products. One solution is to build up a private buyer group to whom farmer can sell their product as ‘healthy’ product if consumers still believe in a higher value of it. (PAK KEMIN, 2017, BU YAMI 2017, *pers. comm*). However, for local farmers, this is another challenge on top of managing complex rice system.

5.2 Recommendations for the establishment of a complex rice system

5.2.1 Ducks

In this experiment, the duck house built aside the rice field and thus a high amount of duck manure and spilled feed was found there. In order to include this ‘waste’ in the nutrient cycling of the system, it is suggested to build an upraised duck house above the fish pond following the setup of CAGAUAN et al. (2000). This way, duck manure and spilled feed in the house drop into the fish pond increasing the nutrient content of the irrigation water for rice and fish. Furthermore, in this way not only rice fertilization is improved and labor input for cleaning the duck waste is reduced, but also increases the area for rice cultivation.

Furthermore, farmers should be trained in how to raise ducks. If the specific feed rate per day for different duck ages is known to the farmer and the mortality rate could be managed lower, the input-output financial balance can be improved. Also, training on how to access into right market price is a knowledge farmer needed.

5.2.1 Border Crops

Bean and water spinach yields were very low in this experiment because polybags were put with a great distance to each other. More polybags with vegetables could have been arranged at the borders, but as the establishment of bags was quiet laborious, this way of vegetable implementation into the rice field is not recommended. As local farmer’s practice, complex rice system farmers can grow crops on the bunds surrounding the rice field (Fig. 32), which in this experimental site was not possible due to the bunds were not built wide enough in the field preparation time and had to be shared with neighbors to walk on. If border crops grown on bunds and not inside the field, the problems of vegetable did not grow well in polybag and ducks eating the vegetables faced in this experiment resolves itself. Seeds could be sown before rice transplantation and is recommended if flowering plants are cultivated. This way plants will be in blossom before the end of the rice season and natural enemies of rice pests attracted by flowers can possibly benefit rice growth.

6 Conclusions

This thesis aims to evaluate the financial results of complex rice system. According to the finding of this study, due to the high volatility of duck's output, there is not proof to support the hypothesis: the complex rice system provides a better financial result. The complex system could provide a better financial outcome when all components' yields perform well.

Regarding to the hypothesis: The land equivalent ratio is economically better in complex rice system, the research results showed that Land Equivalent Ratio (LER) of complex rice system is better than 1 (LER>1). Complex rice system has more productivity than rice monoculture in terms of land use. In CRO block II even showed 3 times more productivity than RO monoculture. About the Total Factor Productivity index of complex rice system, both index from CRO and CRC plot are lower than one (TFP<1). The complex rice system in this research showed low efficiency in converting input into output due to the duck output in this experiment was very low. Improve ducks output by higher the sale price would be able to improve TFP index substantially. The organic rice system managed by local organic farmer association shows the best TFP index among all different rice system.

On hidden cost of research in biodiversity and potential healthy cost, the research indicated that the expected value of potential medical cost per conventional farmer per season is about 39,000 (IDR) by using chemical pesticides. In Indonesia more than 45% population still involved with agriculture activates which the country might face high hidden cost when produces food. This research provides a glance of Indonesia rice production hidden cost. In order to lower the cost, the government or local institution should help farmers to improve knowledge and awareness of pesticides and the potential health damage from pesticides.

Even though many challenges faced in this experiment, this study still recommends that establishment of an integrated system of rice, livestock and vegetables can possibly help farmers on the way to improve productivity and farmer's financial status by better training on how to manage a rice –livestock integrated system. Meanwhile, the system provides a solution with low risk on chemical pesticides impact to farmer and environment. Further economic analysis on how to calculate the hidden cost of complex rice system would be interest to further investigate on its potential of improving long-term food security.

7 References

Alston, J. M., Babcock, B. A., & Pardey, P. G. (2010). The shifting patterns of agricultural production and productivity worldwide. Midwest Agribusiness Trade Research and Information Center.

Altieri, M. A. (1999). The ecological role of biodiversity in agroecosystems. Agric. Ecosyst. Environ. 74:19–31.

Balvanera, P., Pfisterer, A. B., Buchmann, N., He, J. S., Nakashizuka, T., Raffaelli, D., & Schmid, B. (2006). Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecology letters, 9(10):1146-1156.

Berg, H. (2001). Pesticide use in rice and rice–fish farms in the Mekong Delta, Vietnam. Crop Protection, 20(10):897-905.

Candradijaya, A., Kusmana, C., Syaukat, Y., Syaufina, L., & Faqih, A. (2014). Climate Change Impact on Rice Yield and Adaptation Response of Local Farmers in Sumedang District, West Java, Indonesia. International Journal of Ecosystem, 4(5):212-223.

Cao, Z., Liang, Z., Zhao, Y., & Dong, Y. (2001). Symbiotic effect of cultivating fish in rice field in north China. *Ying yong sheng tai xue bao*= The journal of applied ecology, 1*2*(3):405-408.

Cagauan, A. G., Branckaert, R. D., & Van Hove, C. (2000). Integrating fish and azolla into rice-duck farming in Asia. *Naga, the ICLARM Quarterly*, *23*(1), 4-10.

CIVAS (Centre for Indonesian Veterinary Analytical Studies) (2004). A review of free range duck farming systems in Indonesia and assessment of their implication in the spreading of the highly pathogenic (H5N1) strain of avian influenza (HPAI). Food and Agriculture Organization of the United Nations, Rome.

Christensen, L. R. (1975). Concepts and measurement of agricultural productivity. American Journal of Agricultural Economics, 57(5):910-915.

Coche, A. G. (1967). Fish culture in rice fields a world-wide synthesis. Hydrobiologia, 30(1), 1-44.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). An introduction to efficiency and productivity analysis. Springer Science & Business Media.

Das, H. K., Mitra, A. K., Sengupta, P. K., Hossain, A., Islam, F., & Rabbani, G. H. (2004). Arsenic concentrations in rice, vegetables, and fish in Bangladesh: a preliminary study. Environment international, 30(3):383-387.

De Mey, Y., Demont, M., & Diagne, M. (2012). Estimating bird damage to rice in Africa:

evidence from the Senegal River Valley. Journal of Agricultural Economics, 63(1):175-200.

De Mey, Y., & Demont, M. (2013). 19 Bird Damage to Rice in Africa: Evidence and Control. *Realizing Africa's Rice Promise*, 241.

Devendra, P. S. (1995). Salicylic acid functionalized polystyrene sorbent amberlite XAD-2. Synthesis and applications as a preconcentrator in the determination of zinc (II) and lead (II) by using atomic absorption spectrometry. Analyst, 120(2), 403-405.

Devendra, C. (1996). Overview of integrated animals-crops-fish production systems: achievements and future potential.

Dobbs, T. L., & Smolik, J. D. (1997). Productivity and profitability of conventional and alternative farming systems: A long-term on-farm paired comparison. Journal of Sustainable Agriculture, 9(1):63-79.

Duelli, P. (1997). Biodiversity evaluation in agricultural landscapes: an approach at two different scales. Agriculture, ecosystems & environment, 62(2-3):81-91.

Economics Program：http://www.uark.edu/ua/ricersch/pdfs/2016%20Baseline_World%20Rice%20Outlook%202015-2025.pdf

FAO, 2007 Valid at 31st Aug 2017: http://www.fao.org/docrep/010/ai409e/AI409E06.htm

Food and Agriculture Organization of the United Nations and Indonesian Ministry of Agriculture, 2015 Valid at: http://www.fao.org/countryprofiles/index/en/?iso3=IDN

Ghelfi, R., Bertazzoli, A., Marchi, A., Rivaroli, S., & Samoggia, A. (2012). Inputs use in the agriculture of Emilia-Romagna: Farm comparison through the total factor productivity approach. *Food Economics*, *9*(1-2), 78-86.

Glen, D. M., M. P. Greaves, and H. M. Anderson (eds.). (1995). Ecology and integrated farming systems. Wiley, Chichester, U.K.

Gregory, P. J., S. N. Johnson, A. C. Newton, and J. S. I. Ingram. (2009). Integrating pests and pathogens into the climate change/food security debate. J. Exp. Bot. 60:2827–2838.

Gurr, G. M., S. D. Wratten, *and* M. A. Altieri (eds.). (2004). Ecological engineering for pest management, advances in habitat manipulation for arthropods. CAB International, Wallingford, U.K.

Haroon, A. K. Y., & Pittman, K. A. (1997). Rice-fish culture: feeding, growth and yield of two size classes of Puntius gonionotus Bleeker and Oreochromis spp. in Bangladesh. Aquaculture, 154(3-4):261-281.

Hassan, L. G., Dango Umar, K. J., ggo, S. M., & Ladan, M. J. (2007). Nutritional composition of water spinach (Ipomoea aquatica Forsk.) leaves. Journal of Applied

Sciences, 7, 803-809.

Hidayat, A.S., Lesmana, T (2011). The development of organic rice farming in Indonesia. RIEBS 2(1):71-87.

Hossain, S. T., Sugimoto, H., Ahmed, G. J. U., & Islam, M. (2005). Effect of integrated rice-duck farming on rice yield, farm productivity, and rice-provisioning ability of farmers. Asian Journal of Agriculture and Development, 2(1):79-86.

Huang, Yibin, Wen Boqi, Tang Jianyang, and Liu, Zhongzhu. (2001) Effect of rice–azolla–fish system on soil environment of rice field Chinese Journal of EcoAgriculture, 9(1):74-76.

IFAD. (2015). Investing in rural people in Indonesia. Valid at 31 Aug. 2017 www.ruralpovertyportal.org

IFC (2013) Valid at: 31 Aug. 2017 http://www.ifc.org/wps/wcm/connect/Careers_Ext_Content/IFC_External_Corporate_Site/IFC+Careers

INDARYANI R. (2009). Kajian penggunaan berbagai jenis alat/mesin perontok terhadap susut perontokan pada beberapa varietas padi. Departemen teknik pertanian fakultas teknologi pertanian institut pertanian bogor.

IRRI 2016 Valid at 26th Aug 2017: http://www.knowledgebank.irri.org/step-by-step-production/growth/pests-and-diseases/birds

Kantor, S. (1999). Comparing yields with land equivalent ratio (LER). *Renton, WA: Washington State University Agriculture and Natural Resource Fact Sheet*, *532*(4).

Kassar, I., & Lasserre, P. (2004). Species preservation and biodiversity value: a real option approach. Journal of Environmental Economics and Management, 48(2):857-879.

Khumairoh, U., Groot, J. C., & Lantinga, E. A. (2012). Complex agro-ecosystems for food security in a changing climate. Ecology and evolution, 2(7):1696-1704.

Khumairoh Uma (2011) Effects of duck fish and azolla fully integration into an organic rice system in Lalang, Indonesia

Lin, Z., Jiang, H., Wu, Y., Chen, X., Hu, Y., Li, Y., ... & Dong, Q. (2014). Daily intake of polybrominated diphenyl ethers via dust and diet from an e-waste recycling area in China. Journal of hazardous materials, 276, 35-42.

Little, D. C., Surintaraseree, P., & Innes-Taylor, N. (1996). Fish culture in rainfed rice fields of northeast. Thailand. Aquaculture, 140(4):295-321.

Lu, Jianbo. (1986). Rice–fish farming experiments in double rice cropping system. Chunan Journal of Sciences and Technology, 4:40-42

Lu, J., & Li, X. (2006). Review of rice–fish-farming systems in China—one of the globally important ingenious agricultural heritage systems (GIAHS). Aquaculture, 260(1):106-113.

Lestari, Y. K., & Suryana, A. T. (2013). Sustainability of Organic Rice Farming in Indonesia.

Lin., Zhonghua, (1996). Technology and benefits of controlled paddy field. Journal of Soil and Fertilizer, 4:37-41.

Lynam, J. K., & Herdt, R. W. (1989). Sense and sustainability: sustainability as an objective in international agricultural research. *Agricultural economics*, *3*(4), 381-398.

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. Proc. Natl. Acad. Sci. USA 104:19680–19685.

OECD (2016). Economic surveys Indonesia. Valid at: http://www.oecd.org/eco/surveys/indonesia-2016-OECD-economic-survey-overview-english.pdf

Odeck, J. (2007). Measuring technical efficiency and productivity growth: a comparison of SFA and DEA on Norwegian grain production data. Applied Economics, 39(20):2617-2630.

Rushton, J., Viscarra, R., Bleich, E. G., & McLeod, A. (2005). Impact of avian influenza outbreaks in the poultry sectors of five South East Asian countries (Cambodia, Indonesia, Lao PDR, Thailand, Viet Nam) outbreak costs, responses and potential long term control. World's Poultry Science Journal, 61(3), 491-514.

Shiotsu, F., Sakagami, N., Asagi, N., Suprapta, D. N., Agustiani, N., Nitta, Y., & Komatsuzaki, M. (2015). Initiation and Dissemination of Organic Rice Cultivation in Bali, Indonesia. Sustainability, 7(5):5171-5181.

Shennan, C. (2008). Biotic interactions, ecological knowledge and agriculture. Philos. Trans. R. Soc. Lond. B. 363:717–739.

Smolik, J. D., Dobbs, T. L., Rickeri, D. H., & Wrage, L. J. (1993). Agronomic, Economic and Ecological Relationships in Alternative (Organic), Conventional, and Reduced-till Farming Systems.

Tavares, W. S., Cruz, I., Silva, R. B., Figueiredo, M. L. C., Ramalho, F. S., Serrão, J. E., & Zanuncio, J. C. (2011). Soil organisms associated to the weed suppressant *Crotalaria juncea* (Fabaceae) and its importance as a refuge for natural enemies. Planta daninha, 29(3):473-479.

TEEB (2015). TEEB for Agriculture & Food: an interim report, United Nations Environment Programme, Geneva, Switzerland.

Uphoff, N. (1999). Agroecological implications of the System of Rice Intensification (SRI) in

Madagascar. *Environ. Dev. Sustain.* **1**:297–313.

USDA Foreign Agriculture Service, 2012. Valid at: 31st Aug 2017 https://www.pecad.fas.usda.gov/highlights/2012/03/Indonesia_rice_Mar2012/

USDA Foreign Agriculture Service, 2015. Valid at 10th Feb. 2017: https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Indonesia%20Grain%20 and%20 Feed%20Update%20December%202015_Jakarta_Indonesia_12-14-2015.pdf

Van Noordwijk, M., & Swift, M. J. (1999). Belowground biodiversity and sustainability of complex agroecosystems. Management of agrobiodiversity in Indonesia for sustainable land use and global environmental benefits, 8-28.

Wailes, E.J., and Cjavez, E.C. (2016). International Rice Outlook. Arkansas Global Rice Economics Program.

Warr, P. (2005). Food policy and poverty in Indonesia: a general equilibrium analysis. Australian Journal of Agricultural and Resource Economics, 49(4):429-451.

Zhang, Chengyuan, S., Zhifen, L., Zhaoansheng (2001). Outline of rice–fish culture and cropland ecology. Chinese Journal of Ecology, 20 (3):24-26

Zheng, Y. H., Deng, G. B., & Lu, G. M. (1997). A Study on Economic Benefits of Rice-Fish-Duck Complex Ecosystem. Chinese Journal of Applied Ecology, 8(4):431-434.

Zheng, H., Huang, H., Li, D., Li, X., Fu, Z., & Chen, C. (2014). Assessment of nomadic rice-duck complex ecosystem on energy and economy. Ecological Processes, 3(1):1-8.

Zhu Hung G. (2010). The development of global aquaculture. 全球漁業發展現況及未來趨勢分析.