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ANALYSIS

Rice Intensive Cropping and Balanced Cropping in the Mekong Delta, Vietnam — Economic and Ecological Considerations

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ABSTRACT

Rice intensification in Vietnam relies on the construction of high dykes in the Mekong Delta floodplain to prevent flood waters from entering fields during the flood season. This enables three rice crops to be grown annually instead of two. On the floodplain, two rice crops can be described as "balanced cropping" since it has a long fallow period, which conforms to good agricultural practices, and also takes advantage of the flood's benefits. For example, it integrates the natural fish, other aquatic animals, and flood sediments during the flood season as part of the rice field ecosystem. This study surveys agriculture practices among "three crop" and "two crop" farmers on the floodplain. It is argued that planting three crops ("intensive cropping") cannot provide a sustainable alternative to balanced cropping, either from an economic or an ecological viewpoint. Study findings emphasise the need to recognise the ecological value of balanced cropping systems for an efficient and environmentally sound production of food. In connection with this, it is suggested a case for limiting further dyke heightening since rice intensification, which is the aim of this large-scale water control, does not make economic sense.

1. Introduction

Agriculture on the floodplains of less developed countries has been intensified to meet population growth and economic development needs. While agricultural intensification has benefitted farmers economically, it has also raised concerns about the sustainability and cost effectiveness of an increased reliance on external inputs, especially agrochemicals. In addition, intensification often requires the building or upgrading of large-scale irrigation infrastructure which, along with moves toward intensification, requires cautious assessment for several reasons. For instance, irrigation systems that facilitate intensification can fragment floodplains and disrupt natural flows of water, sediments, nutrients, and aquatic life. This affects the ecology and the environment and this, in turn, can have feedback effects on agriculture and fishing (Campbell, 2012; Hashimoto, 2001; Hoa et al., 2008; Howie, 2011). This is particularly relevant for the floodplain of the Vietnamese Mekong River, which has high biological diversity and supports two productive sectors, agriculture, and fisheries (Baran, 2010; Campbell, 2012; MRC, 2010).

In an environmentally sensitive delta ecosystem such as the Vietnamese floodplain, an important question is whether or not intensified agricultural systems provide viable alternatives to existing less intensified systems. This paper focuses on the most recent phase of rice intensification in the Mekong wherein current targets for floodplain agriculture is the production of three rice crops per year using high dykes to completely prevent floods. Hence, two-rice crop systems, which were enabled by the use of low dykes to delay floods, are now being converted to three-rice crop systems with dyke heightening (Le et al., 2007). At present, both the two-rice crop systems and three-crop systems have become the dominant types of land use on the floodplain. There are now thousands of high dykes in the Mekong Delta (AGDSI, 2013). In only 12 years, the three-rice crop areas in the four provinces located in this floodplain have increased sevenfold, from 53,500 ha in 2000 to 403,500 ha in 2012 (Duong et al., 2014).

The two-crop system within low dykes, admits an integrated two rice crops – one natural flood capture system. Such natural flood "crop" on over flooded rice fields provides locals, especially the poor and the landless, with free goods such as wild fish, other aquatic animals, and aquatic vegetables. In terms of wild fish alone, the Vietnamese Mekong Delta (VMD) produces about 700,000 tons of inland fish per year. This accounts for one-third of the overall Mekong fish catch which is categorized exceptionally important by global standards (Baran, 2010). In addition, allowing rice fields to be overflooded during the flood season also makes use of the flood for an efficient and environmentally sound production of rice. For example, the floodwaters bring alluvial sediment, which rejuvenates the fields by adding both macronutrients (e.g., N, P, K, Ca, Mg, S) and micronutrients (e.g. B, Cu, Fe, Cl, Mn, Mo, Zn). It also provides the soil with the additional organic matter, which helps maintain soil fertility for rice cultivation. The

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amount of sediment deposited on fields ranges from a few to tens of tons per hectare (Duong et al., 2011). The flood season also provides the natural pest control mechanisms in rice fields through a combined use of species come along with it. As found by Xie et al. (2011), for example, the natural fish can act as biocontrol agents in rice ecosystems.

On the other hand, planting continuously three rice crops seems to be against good agricultural practices, for example, Integrated Pest Management, which encourages rotation, and longer fallow time. Studies in the Mekong Delta found that two-crop rice farmers have higher rice yields per crop than three-crop rice farmers (Berg, 2002; Huynh, 2011). The negative impacts of high rice cropping intensity on rice productivity are further confirmed by a long-term continuous cropping experiment in the Philippines (Dobermann et al., 2000). This study shows that yields have decreased cumulatively by 38–58% within the 24-year period of growing three rice crops a year. The average yield reduction ranged from 1.4–1.6% for each crop per year. The two-crop system is, therefore, more balanced than the alternative intensive three-crop system.

The term “balanced cropping” in this study refers to the two rice crop–one natural flood capture system that exists with low dykes. “Intensive cropping” refers to the three-crop system with high dykes. This study is a survey of the agricultural outcomes experienced by farmers of balanced and intensive cropping systems in the Mekong Delta. It is argued that intensive cropping cannot provide a sustainable alternative to balanced cropping, either from an economic or an ecological point of view. The net income per crop from intensive cropping is lower than balanced cropping due to longer-term effects on crop productivity. It leads to an annual net income from intensive cropping that may not be as large as expected and is not significantly different from the incomes of balanced croppers. After taking into account the value of family labour at market wage rates, the annual net income from intensive cropping is significantly lower than that from balanced cropping. Moreover, spillovers effects, the side effects arising in a seemingly unrelated context, from intensive cropping constrain the productivity of neighbouring balanced cropping farms. Also, the added third crop has displaced the valuable natural flood (particularly fish) harvest. If these spillover costs and forgone fish output could be quantified, criticisms on intensive cropping as an unsustainable alternative to balanced cropping would be strengthened. The findings imply that the cumulative environmental effects of farming conversion involve changes in ecological processes that may not be well understood but which far surpass short-term issues in importance.

These findings must be seen in the context of policies favouring intensified agricultural production, which result in depletion of aquatic resources. Moreover, the case for balanced cropping is increasingly constrained by government policies that pursue large-scale irrigation infrastructures to enable intensified agricultural production. Government policies that promote balanced rather than intensified cropping systems generate more diverse systems that deliver not only food security but also safeguard biodiversity, ecosystem services, and economic security in rural areas.

2. Materials and Methods

To gain an overview of farming outcomes for floodplain rice farmers, interviews with intensive and balanced cropping farmers from two sites in An Giang province were conducted. The assumption is that, before dyke heightening, rice production between the two sites surveyed had homogenous characteristics. In addition, one more balanced cropping site in another Dong Thap province was added. The inclusion of this third site, which was originally dissimilar to the first two sites, was to ascertain balanced cropping's character in the presence of site-specific condition.

All these three sites are situated in the major rice producing areas of the VMD floodplain and all once experienced the same flooding levels before the use of high dykes (Fig. 1, Table 1). Both An Giang and Dong Thap also have the highest increase rates and the highest areas of intensive cropping (Duong et al., 2014). More than half of the rice planted areas in An Giang are now practicing intensive cropping as associated with 1939 high dykes (AGDSI, 2013; AGGSO, 2013) whereas one-third of Dong Thap province practice intensive cropping within 670 high dykes (DTGSO, 2013; DTSD, 2015). The recall survey was conducted for the rice cultivation period of November 2011 to October 2012.

2.1. Study Area Selection

The VMD is the most important rice-producing region in Vietnam. It produces almost 57% of the national rice output (GSO, 2013).The Delta lies within the humid tropics and is characterised by high mean monthly temperatures (27 °C) and high, but seasonal, rainfall (1600 mm). The rainy season is from May to November when over 90% of the annual rainfall occurs (AGDSI, 2009). The VMD floodplain or high flood zone lies in the Plain of Reeds (POR), a vast wetland covering the northern parts of Dong Thap, Tien Giang, and Long An provinces, and the Long Xuyen Quadrangle (LXQ). Formerly, the Mekong River floods covered this floodplain from July or August until November or December each year.

Thoai Son district (1) in An Giang province is an intensive cropping site. Chau Thanh district (2) in the same province is a balanced cropping site. These two sites are located in close proximity to each other, with only a canal separating them. Hence these sites formerly shared similar social and natural conditions, such as soil fertility. Intensive cropping has been pursued in Thoai Son district for more than 10 years. This period is long enough to reflect cumulative effects on rice productivity, which may have resulted from the practice of intensive cropping.

On the other hand, Tam Nong district (3) in Dong Thap province is a non-contiguous and balanced cropping site. Rice farming in this site has occurred under less favourable conditions with consistently lower rice yields (AGGSO, 2012, 2008, 2006, 2000; DTGSO, 2012, 2007, 2005, 2000).

With intensive cropping (Thoai Son), the first rice crop is grown from mid-December to mid-March, the second from mid-April to mid-July, and the third from mid-August to late November. For the contiguous balanced cropping (Chau Thanh), the first crop is grown from early December to early March and the second from early April to early July. For the non-contiguous balanced cropping (Tam Nong), the first crop is grown from mid-November to late February and the second crop from mid-April to late July. The break time between the first and second crop in Tam Nong is two weeks longer than that in An Giang.

2.2. Field Survey

At each study site, 120 rice-producing households were randomly selected and interviewed using two separate structured parts of a single questionnaire. This provided 110, 99, and 101 usable questionnaires for intensive cropping in Chau Thanh, contiguous balanced cropping Thoai Son, and non-contiguous balanced cropping in Tam Nong, respectively. As detailed information was needed to assess rice productivity and pesticide use, it took about 2 h for each respondent to complete the questionnaire. Due to the length of these interviews, which could negatively affect the quality of the respondents' answers, the questionnaire was separated into the two parts. One session was for detailed household level information pertaining to inputs, costs, and benefits of rice production. The other was for detailed pesticide use. Each took about one hour to complete. A short break in between was provided.

Regarding pesticide use, rice farmers were asked to give the common name of the pesticide they used, the number of times they sprayed it, the quantity of undiluted chemical they used, and the price and volume per container. If respondents could not remember the common name, we asked them to show the bottle (if possible) or we showed them pictures of the bottle or described its appearance or usage in order to achieve identification. For each pesticide, we collected data

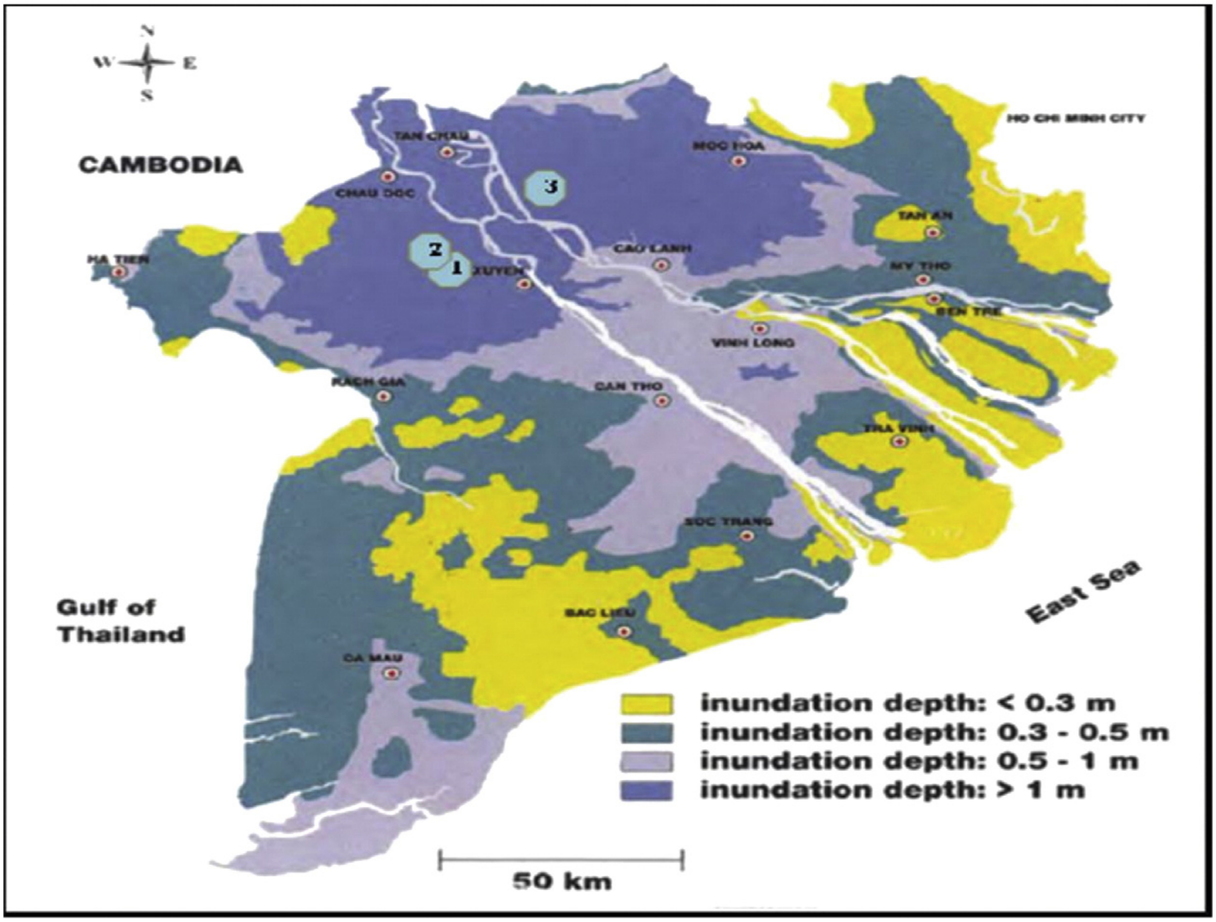

Fig. 1. Map of study location. Notes: (1) Intensive cropping site (Thoai Son district, An Giang province); (2) Contiguous balanced cropping site (Chau Thanh district, An Giang province); (3) Non-contiguous balanced cropping site (Tam Nong district, Dong Thap province).
Source of base map: Vo and Matsui (1998).

on the active ingredients from traders, shops, and producers. Based on active ingredients we then grouped the pesticides in terms of their purpose.

A draft questionnaire was pre-tested by interviewing 10 farmers who were not included in the study. After this, some changes to the draft questionnaire were made. The interviews were made by trained students and staff members from College of Economics, Can Tho University. Additional information was also collected at extension offices and plant protection stations in An Giang and Dong Thap provinces.

Differences between the three cropping sites were investigated using analysis of variance (ANOVA) comparisons of means across categories. If the ANOVA test was inconclusive, differences were further analysed by comparing medians using a Wilcoxon rank-sum test. We conducted all analysis using the software package STATA 10.

Table 1
Some characteristics of Chau Thanh, Thoai Son and Tam Nong in 2012.

Category	An Giang		Dong Thap
	Intensive cropping (Thoai Son)	Contiguous balanced cropping (Chau Thanh)	Non-contiguous balanced cropping (Tam Nong)
Total land area of district (ha)	46,886	35,506	47,433
Population size	181,194	170,817	105,474
Population in rural areas	137,592	146,325	95,187
Area of rice fields (ha)	39,299	29,222	30,300
Rice crops per year	3	2	2
Yield of rice (ton/ha/year)	6.47	6.31	5.95

Source: An Giang Statistical Yearbook, 2012 (AGGSO, 2012) and Dong Thap Statistical Yearbook, 2012 (DTGSO, 2012).

3. Results

The different farms in the three study sites shared many basic characteristics. Each household had an average of 3.6 members of working age and produce rice on a farm with the average area of 1.95 ha. The respondent rice farmers had an average of 6.14 years of education. Only 27% of rice farmers said that they have attended a training course provided by local authorities.

The interviewed farmers in the non-contiguous balanced cropping site in Dong Thap province had a significantly higher mean age compared to the other two sites in An Giang province. Although they employed the same balanced cropping technology, farmers in Dong Thap received a significantly lower off-farm income than those in An Giang (Table 2). Hence, the non-contiguous site in Dong Thap province is, as suggested earlier, likely to be less homogenous than the other two sites located within An Giang province.

To ascertain the characteristics of intensive versus balanced cropping, the remainder of the paper is structured to compare rice inputs and outputs along with their associated costs and benefits. In comparing the two cropping systems (i.e., balanced and intensive), only the average values for the first two rice crops of all farmers were used. The third crop, which is only possible in intensive cropping, was then included to compare the overall annual costs and benefits of intensive and balanced cropping. Imputed family labour costs were also taken into account in making this comparison.

Table 2
Household composition and physical characteristics of farmers in Chau Thanh, Thoai Son and Tam Nong in 2012.

Category		An Giang		Dong Thap
		Intensive cropping	Contiguous balanced cropping	Non-contiguous balanced cropping
Age of farm owner (years)	Mean	44.10	44.17	50.16[a]
	SD	10.51	11.73	13.89
Household size (working age)	Mean	3.85	3.38	3.63
	SD	1.78	1.53	1.58
Educational level (years)	Mean	6.08	6.21	6.13
	SD	3.17	3.05	3.25
Training (%)	Mean	27	32	23
	SD	45	47	42
Total farm area (ha)	Mean	2.02	1.93	1.88
	SD	1.54	1.75	1.27
Off-farm income rate (%)	Mean	0.08	0.18[a]	0.08
	SD	0.15	0.20	0.15

Superscripted letters denote significant difference among cropping systems. Means that do not share the same letter are significantly different ($P < 0.05$).
SD denotes standard deviation.

It was found that intensive cropping farmers chose to plant rice varieties with average to high levels of resistance to diseases and insects. These varieties are also able to tolerate the unfavourable environment conditions of low PH. However, these varieties have lower commercial value and face a restricted export market so their selling prices are significantly lower than other rice varieties. Balanced cropping farmers, by comparison, selected high quality and more valuable rice varieties. These varieties enabled them to sell rice output at a higher price even though their levels of resistance to diseases and insects are low and they are more likely to be infected by major pests such as the brown planthopper and rice blast (Table 3).

For each crop, intensive cropping farmers use around 186 kg of rice seed, which yields approximately 7 tons of rice per hectare. They apply 16% more rice seed input but obtain similar yields as nearby balanced cropping farmers (see Table 4).

Howie (2011) reported a 40% decline in rice yield per ton of fertiliser when high dykes replaced low dykes in areas where high dykes had been built for more than ten years. The present study does not confirm such clear effects. Instead, the intensive cropping farmers apply, on average, less nitrogen, more phosphorus, and similar amounts of potassium compared with their balanced cropping neighbours (Table 4).

In comparing the total pesticide use between the two systems, it was surprisingly found that intensive cropping farmers applied a lower amount of insecticides and molluscicides per crop compared with farmers in contiguous balanced cropping sites. As a result, intensive cropping farmers also use lower amounts of pesticides overall as compared with their balanced cropping neighbours. It was found that there is a substantially high use of molluscicides by farmers in contiguous balanced cropping site. This is probably caused by the water management process associated with high dykes. In this process, a significant amount of golden apple snails and their eggs are pumped with the water from intensive cropping sites inside high-dyke areas to nearby overflooded low-dyke areas during the heavy rains of the flood season (Fig. 2). If we exclude molluscicides in the comparison, intensive cropping farmers then use higher amounts of pesticides, with approximately 63% being fungicides and bactericides (Table 4).

Table 4
Rice yield, seed input, and agrochemical input per hectare and per crop for the first two crops of both intensive and balanced cropping in An Giang and Dong Thap.

Category		An Giang		Dong Thap
		Intensive cropping	Contiguous balanced cropping	Non-contiguous balanced cropping
Seed (kg)	Mean	186.04[a]	155.81[b]	171.55[c]
	SD	39.91	20.72	18.55
Total N (kg)	Mean	110.12[a]	116.57[b]	112.33[ab]
	SD	27.47	34.59	17.91
Total P (kg)	Mean	73.14	60.74[a]	66.70
	SD	28.58	26.24	16.98
Total K (kg)	Mean	59.72[a]	57.24[b]	55.15[c]
	SD	26.23	29.03	23.30
Herbicides (kg a.i.*)	Mean	0.71	0.41	0.59
	SD	1.55	0.31	0.74
Insecticides (kg a.i.)	Mean	0.35	0.45[a]	0.38
	SD	0.42	0.68	0.54
Fungicides&	Mean	2.07[a]	1.38[b]	1.00[c]
Bactericides (kg a.i.)	SD	1.40	0.71	0.77
Molluscicides (kg a.i.)	Mean	1.54[a]	5.05[b]	0.71[c]
	SD	1.97	5.32	0.79
Other pesticides (kg a.i)	Mean	0.11	0.18	0.08a
	SD	0.17	0.22	0.14
Total pesticides (kg a.i.)	Mean	4.84[a]	7.59[b]	2.80[c]
	SD	3.21	5.40	1.52
Total pesticides with no	Mean	3.30[a]	2.54[b]	2.10[c]
molluscicides (kg a.i.)	SD	2.30	1.18	1.29
Rice yield (ton)	Mean	7.00	6.95	5.7[a]
	SD	0.81	0.84	0.88

Superscripted letters denote significant difference among cropping systems. Means that do not share the same letter are significantly different ($P < 0.05$).
*a.i. denotes active ingredient.
SD denotes standard deviation.

To compare the annual net income of intensive versus balanced cropping, the third crop associated with the intensive system was accounted for. Since family labour is employed for almost three months in cultivating the third crop, this cost forms an important part of the total production cost. Here family labour costs are imputed at market prices in calculating the annual net income for each of the farming systems. Apart from its dependence on each type of farming task, the market wage rate also fluctuates with the cropping calendar. For example, wage rates are high during harvest time when there is a labour shortage. Given the different cropping calendars associated with these farming systems, the average hired labour wage rate in each cropping season

Table 3
Characteristics of rice varieties of the first two crops in intensive and balanced cropping systems of An Giang and Dong Thap.

Category		An Giang		Dong Thap
		Intensive cropping	Contiguous balanced cropping	Non-contiguous balanced cropping
Main varieties used		IR 50404 OM 6976	Jasmine 85 OM 4218	VD20
Farmers using these main varieties (%)		74–77	80–94	82–91
Features of these main varieties		Average to high resistance on the main insects and diseases	Infected to heavy infected by the main insects and diseases	Infected to heavy infected by the main insects and diseases
Seed price	Mean	9.53[a]	13.01	12.81
(thousand VND/kg)	SD	4.29	1.67	3.13
Output price	Mean	4,406[a]	5,319[b]	5,834[c]
(thousand VND/ton)	SD	526.88	557,99	443,64

Superscripted letters denote significant difference among cropping systems. Means that do not share the same letter are significantly different ($P < 0.05$).
SD denotes standard deviation.

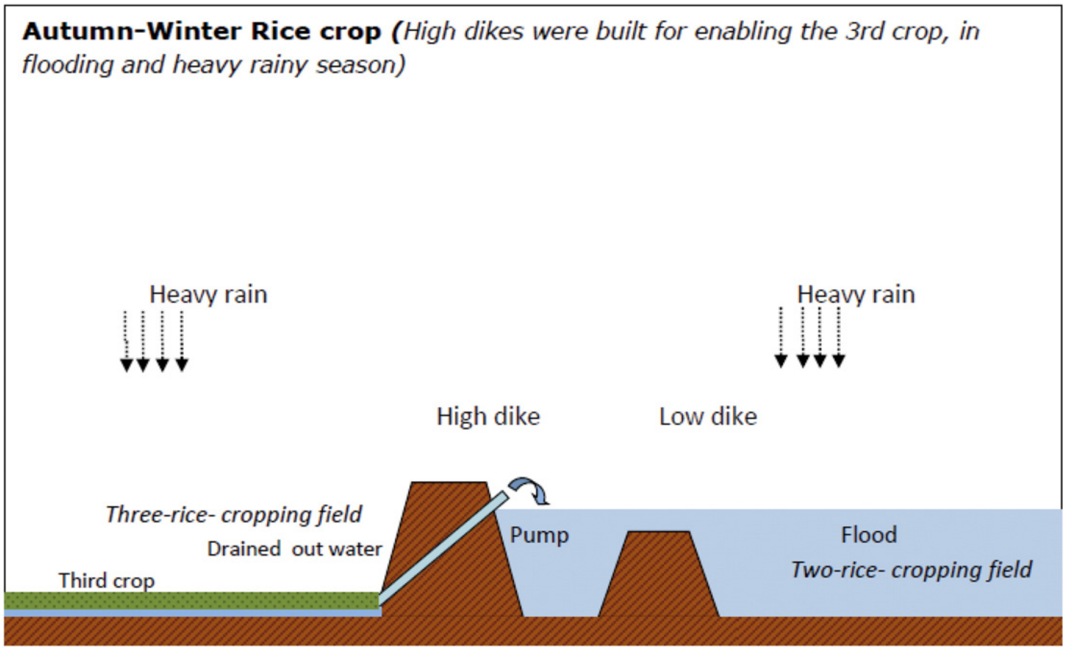

Fig. 2. Golden apple snails are pumped along with water from high dyke areas to low dyke areas.

was used to calculate the imputed family labour costs in that season. This was summed over all seasons to get the annual imputed family labour costs (Table 6). Understandably, intensive cropping households spend more working days both on a per crop and on an all-year-round basis than those in contiguous balanced cropping sites. Overall, switching from two to three crops meant that intensive cropping farmers spend more than three times the imputed family labour costs of balanced cropping farmers each year.

Including the net income of the third crop, which is VND 15,669 thousand per hectare, farmers with intensive cropping obtain similar annual net income as their balanced cropping neighbours although they cultivate one extra crop and input almost three additional family labour months. Taking into account family labour at market prices, intensive cropping farmers obtain lower annual net income than their neighbours who practice balanced cropping (Table 7).

4. Discussion

The study found that switching from balanced to intensive cropping is not simply adding a third crop. It changes the character of the whole farming system in terms of cultivation conditions, water management, cropping calendar, and so on. These changes, in turn, imply different required input combinations to be able to achieve similar yields across the two systems (Tables 3 and 4). For example, with three continuous crops, “bridges” between each crop exist through which insects and diseases are transmitted throughout the cropping year and cause organic acid poisoning of rice crops at the cropping time as a result of the shortened rice straw decomposition process (Nguyen, 2012; Nguyen et al., 2015). Switching to rice varieties with higher levels of resistance to diseases and insects is then a likely solution of intensive cropping farmers in dealing with such unfavourable conditions (Table 3). A change in rice variety could also be one of the factors that alter fertiliser application needs (Table 4).

There is also evidence that intensive cropping has spillover effects on adjacent areas. This is seen in the lower quantities of insecticides used per crop in intensive cropping compared to that applied in contiguous balanced cropping sites (Table 4). As mentioned, intensive cropping farmers have switched to rice varieties with high resistance to insects (see Table 3). As a result, contiguous balanced cropping with more vulnerable rice varieties serves as an extra feed source for insects originating from intensive cropping sites, thereby requiring farmers in balanced cropping sites to apply more insecticides. The spillover effect of intensive cropping is also seen in the significantly high levels of molluscicides applied by contiguous balanced cropping farmers per crop (Table 4). As previously indicated, this could be the solution of balanced cropping farmers in dealing with the abundant of golden apple snails diverted from high-dyke areas to low-dyke areas (Fig. 2).

In comparing total pesticide use across the two systems, molluscicides are ignored because it is impossible to ascertain how much molluscicides was used to address spillovers from adjacent intensive cropping sites. Then our results indicate that intensive cropping farmers use higher amounts of pesticides (Table 4). This suggests that the conclusion of increased use would be strengthened if adjustments between intensive cropping and contiguous balanced cropping sites were made reflecting spillovers from molluscicides and insecticides. This finding is consistent with the result of many other studies that have pointed out that agricultural intensification is characterised by a more intensive use of agrochemicals (Berg et al., 2012; NCST, 2005; Nguyen, 2012).

The non-contiguous balanced cropping site in Dong Thap, used in this study as an additional counterfactual site, confirms the characteristics of balanced cropping found in the An Giang contiguous balanced cropping site. In comparison with intensive cropping, both balanced cropping sites apply rice varieties with higher commercial value but a lower level of resistance to insects and diseases, and they apply lower inputs per crop in terms of seed and pesticide (Tables 3, 4). On the other hand, the Dong Thap balanced cropping site is not adjacent to intensive cropping as is the An Giang balanced cropping site. Predictably, because of the absence of spillover effects, the balanced cropping farmers in Dong Thap use less insecticides and molluscicides per crop than intensive cropping farmers in An Giang (Table 4). This confirms the spillover effects that intensive cropping farms can impose on neighbouring farms.

Including, in the comparison, the balanced cropping site in Dong Thap further confirms the disadvantages of the intensive cropping. As shown in Table 5, the conversion from balanced cropping to intensive cropping lowers net income that farmers may gain per crop. This finding is consistent with that of Berg (2002) who found that three-crop farmers have a lower net income per crop than two-crop farmers in

Table 5
Average costs and benefits (thousand VND/crop) of the first two crops in An Giang and Dong Thap province.

Category		An Giang		Dong Thap
Rice costs		Intensive cropping	Contiguous balanced cropping	Non-contiguous balanced cropping
Seed	Mean	1,705[a]	2,016[b]	2,192[c]
	SD	639	334	587
Fertiliser	Mean	5,743[a]	5190	5262
	SD	1619	1442	872
Pesticides	Mean	4209	3991	2,911[a]
	SD	1878	1421	1280
Capital (rented machines) and hired labour	Mean	5,245[a]	5,750[b]	6,657[c]
	SD	1578	1624	1664
Total rice costs	Mean	16,903	16,948	17,022
	SD	3210	2773	2867
Rice income	Mean	30,914[a]	37,077[b]	33,092[c]
	SD	4927	5609	5274
Rice net income	Mean	14,011[a]	20,129[b]	16,070[c]
	SD	6149	5990	6429

Superscripted letters denote significant difference among farmers. Means that do not share the same subscript letter are significantly different ($P < 0.05$).
SD denotes standard deviation.

other parts of the Mekong Delta. Planting three crops hence diminishes rice productivity per crop compared to planting two crops. Berg (2002) concluded that the marginal cost for producing rice increases with the number of crops, indicating decreased "per crop" production efficiency with increased production intensity. In the present study, this decreased production efficiency is reflected in the fact that the marginal income from selling rice output decreases with the increase in the number of crops. Switching to rice varieties with higher resistance to diseases and insects implies a lower valued rice output (compare Table 3), and thus also lower net income compared to that received by balanced cropping farmers (Table 5).

Aside from the intensiveness of the farming system, site-specific conditions are also an important factor in determining the net income a system may deliver. As shown in Tables 5 and 7, farmers in disadvantageous locations, such as Dong Thap, gain low net income per crop regardless they follow balanced cropping. Consequently, these farmers earned the lowest annual income.

The case for intensive rather than balanced farming requires that the value of the additional third rice crop exceeds the lost value in its first two crops plus the increased labour costs incurred plus the value of the foregone fish output. The results from this study indicate that this is unlikely. The net benefit per crop for the first two crops is significantly lower in intensive cropping than in balanced cropping (Table 5). Hence, in practicing intensive cropping, the value of adding one additional crop does not compensate enough for the lost net income of the first two crops. As a result, the annual net income from intensive cropping with one additional crop is not significantly different from that received from balanced cropping even if ignoring the extra imputed labour costs and the value of foregone fish harvesting outputs (Table 7). Also, if adjustments were possibly made to address and enforce intensive croppers to pay for the spill-overs that their intensive cropping imposes on contiguous balanced cropping sites, spillover costs will then all point towards an even greater level of production cost resulting in lower annual net income from intensive cropping.

In addition, when imputed family labours costs are considered, intensive cropping under-performs further since this farming system requires more family labour days not only on the extra crop but also on the first two crops (Tables 6, 7). Again, this result is strengthened if adjustments are made reflecting the substantial natural fish value, of that has been replaced by the third crop. Phan and Pham (1999) found that the fish harvest from rice fields during the flooding season contributes up to 40% of the total fish catch in An Giang. The majority of the Mekong fish species depends on the floodplains for food and reproduction (Baran, 2010) but Vietnam decision makers seem to consider only the value of the Mekong waters for irrigating rice fields and as a way to stop saline intrusion (Baran et al., 2007). Indeed, no official report recognises the foregone revenues from floodplain fisheries imposed on fishers as a result of the conversion from balanced to intensive cropping or as a cost of dyke heightening. Although accurate information on fisheries and agriculture interactions seems unavailable, the increased intensive use of chemicals in cultivation and the elimination of the seasonal flood that is crucial in sustaining fish productivity, both of which are consequences of the switch to intensive cropping, are clearly

Table 6
Family labour days per crop and labour wage per crop in intensive and balanced cropping in An Giang and Dong Thap.

Category	Cropping season		An Giang		Dong Thap
			Intensive cropping	Contiguous balanced cropping	Non-contiguous balanced cropping
Family labour days (day)	Winter-spring (first crop)	Mean	53.63	36.49[a]	46.63
		SD	34.92	29.07	32.07
	Summer-autumn (second crop)	Mean	53.27	36.00[a]	45.26
		SD	34.91	28.02	30.09
	Autumn-Winter (third crop)	Mean	53.23	N/A	N/A
		SD	34.29		
Market wage rate (thousand VND)	Winter-spring (first crop)	Mean	100.25	80.87	128.05
		SD	106.93	63.31	144.14
	Summer-autumn (second crop)	Mean	96.50	81.81	128.14
		SD	93.35	64.48	145.30
	Autumn-Winter (third crop)	Mean	97.04	N/A	N/A
		SD	94.27		
Imputed family labour costs (thousand VND)	Winter-spring (first crop)	Mean	5855.57	2888.88[a]	7120.14
		SD	8889.91	3466.10	11,794.75
	Summer-autumn (second crop)	Mean	5564.47	2862.85[a]	6762.99
		SD	8328.24	3372.83	11,103.74
	Autumn-Winter (third crop)	Mean	5688.97	N/A	N/A
		SD	8418.89		
Annual family labour days (day)		Mean	161.14[a]	72.49[b]	91.89[c]
		SD	104.00	56.97	61.55
Annual imputed family labour costs (thousand VND)		Mean	17,244	5,752[a]	13,883
		SD	25,281	6,696	22,858

Superscripted letters denote significant difference among farmers. Means that do not share the same subscript letter are significantly different ($P < 0.05$).
SD denotes standard deviation.

Table 7
Annual net income, benefit-cost ratio with and without taking into account imputed family labour costs at market prices in An Giang and Dong Thap.

Category		An Giang		Dong Thap
		Intensive cropping	Contiguous balanced cropping	Non-contiguous balanced cropping
Duration of cropping time (month)		09	06	07
Annual net income	Mean	43,687	40,258	32,140[a]
(thousand VND/ha/yr)	SD	16,989	11,979	12,859
Annual B/C ratio	Mean	1.92	2.24[a]	2.01
	SD	0.44	0.48	0.55
Annual net income taking into account for family labour costs at market price (thousand VND/ha/yr)	Mean	26,443	34,507	18,257[a]
	SD	31,241	14,486	29,484
Annual B/C ratio taking into accounting for family labour costs at market price	Mean	0.74	1.10[a]	0.84
	SD	0.42	0.48	0.56

Superscripted letters denote significant difference among farmers. Means that do not share the same subscript letter are significantly different ($P < 0.05$).
SD denotes standard deviation.

reasons why inland fisheries capture in the Mekong Delta is declining (Baran et al., 2007; Brakel et al., 2011).

To estimate the foregone value from floodplain fish catch because of the switch to intensive cropping, assume the whole price per kilogram of fish is between USD 1 and USD 1.8 and between USD 2 and USD 3.6 on retail markets (Hortle, 2009). Use the exchange rate in 2012 to convert this rate to Vietnamese currency (i.e., USD 1.00: VND 20,828) (WorldBank, 2013). Baran (2010) estimated that Mekong fish productivity is conservatively 50–100 kg/ha/year and may reach up to 200 kg/ha/year. The forgone fish output per year then corresponds to a large range of VND 1000 – VND 7500 thousand per hectare at wholesale and VND 2100 – VND 15,000 thousand per hectare at retail. This possible forgone value of natural capture fisheries further confirms that intensive cropping is an economically costly alternative to balanced cropping.

Noticeably that the exceptional importance of the Mekong fisheries is matched only by its economic role in rural livelihoods and food security (Baran, 2010; Baran et al., 2007). The adverse effects on fishers, therefore, can escalate socio-economic tension by increasing poverty and reducing community self-sufficiency. According to Pham (2009), the level of dependence upon aquatic resources remains very high among the 32% of the population qualifying as poor and very poor. Even though there are few full-time fishers (8%), capture fisheries remain to be an important part of livelihoods with part-time fishers who account for 44% of the VMD's population. By devoting fish habitat to the third crop, conversion to intensive cropping affects aquatic resources, which provides the last resort of security for the poorest as well as important to wealthier groups of society.

Apart from fishers, there is evidence that other people not directly involved in rice intensification also incurred spillover costs. One example is that dyke heightening was found to have a negative economic impact on the contiguous balanced croppers. This was due to the pests that transferred into the fields in the low-dyke areas and the resulting required expenditure to buy molluscicides to tackle the problem. In addition, intensive cropping compels farmers to apply more pesticides per crop and has an additional third crop. Thus, pesticide externalities imposed by this system are higher than in balanced cropping, both per crop and all year round. Being toxic by design, pesticides can also harm organisms other than pests, such as beneficial insects and soil organisms, aquatic life and humans (Pretty et al., 2000). Rice intensification, therefore, brings additional costs to society and the environment in the form of pest resurgence and pesticide resistance, chronic and acute health problems for people taking in pesticide residues, pollution of water resources including drinking water, and also costs in terms of having to monitor food systems. These are called external costs, as they are not included in the price that farmers pay for pesticides or that consumers pay for the food they consume.

From the perspective of farmers who are directly involved in rice intensification, we observed that they have a high adaptation capacity in dealing with negative intensive cropping impacts such as by increasing input use and changing rice variety. However, these changes are capable of offsetting possible rice yield losses at the expense of value in rice output (Table 3). Hence, farmers do not improve their net income by switching to intensive cropping (Table 5). They are, instead, constrained to work harder but less effectively (Tables 6, 7). They also cannot revert to the balanced cropping because of the irreversible investment in high dykes. This explains why rice farmers in An Giang province have complained that, even though they work harder, they still have low incomes and face higher pressures in getting a loan to pay for production costs and other dyke fees thereby increasing risks of indebtedness and landlessness (Duc, 2013).

Intensive rice cropping is optimised to only provide a single ecosystem service, that is marketable rice. In contrast, balanced cropping is designed to deliver a variety of interlinked ecosystem services such as rice, fish, pest control, and nutrient recycling. Hence, this diverse system is more sustainable since the farmers take better advantage of the natural productivity of the rice field ecosystem. The aim of a sustainable food production in the Mekong Delta should be "to reduce resource use, avoid overuse of agrochemicals, and improve production efficiency through increased recycling of nutrients and matter" (Berg, 2002, p.95). Future farming systems should, therefore, maintain and enhance the value of balanced cropping. Similar suggestions have also been confirmed in other countries. In China, for example, the conservation of the rice field ecosystem and biodiversity is suggested. Specifically, degraded intensive rice field ecosystem can be restored through protecting the ecological environment surrounding the rice fields, planting mixed multi-species or row planting, growing rice with low agrochemicals, integrating rice systems with animals and plants and promoting ecological education and public awareness (Luo et al., 2014). Most likely, this would not only improve the farmer's income and health but will also make ecological and economic sense for the whole region in the long run.

Finally and accordingly, the long-term sustainability of recent policies favoring farming conversion on the floodplain can be questioned. Instead of focusing on increasing rice output to achieve rapid economic development based on exports, the government should incorporate a greater appreciation of the Mekong Delta as an environmental system which provides multiple highly-valued ecosystem services. In this regard, the use of low dykes is preferable to reliance on full-flood protection high dykes. Also, compared to high dykes, it is more flexible for low dykes in allowing adaptation strategies reliant on land-use change to take place. Such an ensemble of hard and soft options is likely to provide the most effective results for people's livelihoods in the Mekong Delta (Smajgl et al., 2015). In addition, the main aim of high dykes is to enable intensive cropping. If converting from balanced cropping to intensive cropping does not make economic sense, this makes a strong case to question the economic viability of the dyke heightening from a social perspective. This is because the main addition to assess such project as a whole are the construction costs of the dykes and some unwanted externalities from society's viewpoint such as the increase in external costs of pesticide use.

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