Research article

Socio-Economic Evaluation on How Crop Rotations on Clayey Soils Affect Rice Yield and Farmers' Income in the Mekong Delta, Vietnam

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Abstract Declining land productivity is a major problem faced by small holder farmers in the Mekong Delta today. Low soil quality is one of the greatest long-term challenges for farmers in rice monocultures on alluvial soil. In order to better understand how farm characteristics and crop rotations affect crop yield and income, a socio-economic evaluation among smallholder farmers were conducted in Cai Lay District, Tien Giang province. During farm household surveys, information on household characteristics, farm cropping activities, farm production practices and performance, and household income was collected. Four types of farming practices were observed, one based on traditional rice monoculture with three rice crops per year (RRR), one based on a crop rotation with two rice and one upland crop (RUR), one based on a crop rotation with one rice and two upland crops (RUU), and a fourth based on upland crop monocultures (UUU). From the results of interviews with the farmers, it was found that rotations with RUR or RUU gave higher rice yields than RRR. The rice yield in the last five years increased when rotations with upland crops were implemented (RUR and RUU), which was strongly in contrast with the rice yield decrease over the last five years for rice monoculture systems (RRR). The benefit-to-cost ratio was the highest for RUR. Interestingly, in RUR and RUU, farmers apply less fertilizer and pesticide for rice production compared to RRR. The survey revealed that many farmers had a tendency to apply too much nitrogen as a way to compensate for the reduced rice growth due to land degradation in RRR. Regarding farm size in the study area, the average size is about 0.62 ha. The size of small farms is 0.36 ha and such small farms are found in UUU systems. The largest farms (0.91 ha) were found in RRR systems. Farms of 0.68 ha and 0.43 ha are found in RUR and RUU systems, respectively. The average profit of RUR and RUU was 2,490 USD/ha/year and 2,686 USD/ha/year, respectively. Those were higher than the profit of RRR farming (1,094 USD/ha/year), but lower than the profit from UUU systems (3,058 USD/ha/year).

Keywords alluvial soil, crop rotation, rice yield, profit, Mekong Delta

INTRODUCTION

In the Mekong Delta, Vietnam soil groups of recent alluvial sedimentation (Holocene period) occupy about 1.2 million ha (31% compared to Mekong Delta) (Le Ba Thao, 1997). The soils in this group are located on both sides of the Mekong River. They have a fine texture (silty clay to clay) and slopes are <1% slopes (Le Ba Thao, 1986). The Mekong delta has a great agriculture productive potential,

with a distinct dry and wet season. The wet season starts in May and ends in November. The average rainfall is about 2,000mm concentrated mainly between July and October (Le Sam, 1996). The fields' water level is influenced by a semi diurnal tidal regime, hence sufficient water is available for irrigation during the dry season. Agricultural production in the Mekong delta is based on private smallholding. Farming in the delta is strongly rice oriented (Xuan and Matsui, 1998). They are suitable for rice production and continuous rice cultivation is the dominant cropping pattern. However, after long-term practicing triple rice cropping, the land use system exposed its negative effects on soil quality and crop production. Long-term practicing of continuous cultivation is the main cause of degraded physical and chemical soil properties (Acosta, 2004; Achmad et al., 2003; Cotching et al., 2002). One of the most prominent types of soil degradation is soil compaction, which mainly originated from rice cultivation with high soil rotation and increased mechanization under wet conditions (Lima et al., 2009).

The objectives of this study are to better understand how farm characteristics and crop rotations of rice and upland crops affect crop yield and income, hence on the socio-economic situation of rice farmers. Our research will be helpful to provide basic information for future research in order to conserve the natural land resources and support sustainable agricultural production.

METHODOLOGY

The study was carried out in the Cai Lay district, Tien Giang province, the major alluvial region in the Mekong Delta, Vietnam. It was selected to represent major conditions of long term systems of three rice crops per year. The study area has a plain landform and an elevation of 2 m above sea level. The soil had high clay content (58-67%) and has been classified as Fluvisol (Department of Soil Science, Can Tho University, 2005). The topsoil was slightly acidic with pH of 5.0-6.0.

A farm household survey was undertaken with farmers from four villages (Long Khanh, Cam Son, Binh Phu, Long Tien). All villages included four types of crop cultivation: 3 rice crops per year (RRR), 3 upland crops per year (UUU), 1 rice and 2 upland crops per year (RUU), and 2 rice and 1 upland crop per year (RUR). A total of 109 farm households were interviewed using structured questionnaires. For the cultivation of 3 upland crops per year, 19 farmers were interviewed and for the other cultivations, 30 farmers were interviewed. The surveyed farms were randomly selected. In the interviews, sheets with following information were collected: history of people's settlement and exploitation, and crop rotation system development; cropping pattern and types of cultivation; cultivation techniques and land management like soil preparation for cultivation, application of fertilizers, irrigation and drainage, limiting factors of plant yield and soil productivity and rice yield and total cost of cultivation for calculating economic efficiency of the different land use practices. Data on the farm area were collected throughout 2010-2011.

Analyzing the differences between the means was tested using SPSS v17. Significant differences were determined using the Duncan multiple range test at 5% significance level.

RESULTS AND DISCUSSION

Present land use systems and cultivation practices

Interview results showed that upland crops (cucumber, tomato, water melon, maize, hot pepper, okra, mungbean, vegetables) are normally cultivated on raised beds, with the soil dug to 20-30 cm depth for making raised beds and furrows. Meanwhile, rice is planted on flat fields after ploughing and puddling with a small tractor for every rice crop season. Current canal systems which are carrying the fresh water irrigation and dike systems preventing flood water, farmers are able to cultivate 3 crops a year, i.e. a winter-spring crop (from November to February), a summer-autumn crop (from March to June) and an autumn-winter crop (from July to October). Inorganic fertilizers such as Diammonium phosphate (DAP), Urea, Superphosphate, Potassiumclorua, NPK (Nitrogen, Phosphorous, Potassium) 20-20-15, NPK16-16-8 are broadcasted by hand. Organic manures are

not applied. Rotations of rice with upland crops have been practiced for 5 years (since 2006) on fields that have serious soil compaction problems, which resulted in decreased rice yield even though farmers apply higher doses of fertilizer.

After harvest, some farmers dried their rice product first and stored them for a while. After some time, when the household needs cash or when the market prices were high, they sell their product. More than 80% of the farms sell their products directly to buyers after harvest.

The sowing density of rice in RRR is higher in comparison with RUR and RUU. In the winter-spring season, about 57% of the surveyed farmers in RRR used 100 to 150kg seeds/ha, and 43% used 150 to 200 kg/ha, whereas this was 73% and 27% for RUR, and 83% and 17% for RUU, respectively. In the autumn-winter seasons about 23% of the surveyed farmers in RRR used 100 to 150kg seeds/ha, and 77% used 150 to 200 kg/ha. For RUR, this was 53% and 47%, respectively.

Regarding fertilizer application for rice growing, the optimum fertilizer level for this area is 100 kg N/ha (Vo Thi Guong and Tran Ba Linh, 2008). The results of the survey revealed that farmers in RRR had a tendency to apply high doses of N as a way to compensate for the reduced rice growth and rice yield resulting from land degradation. N fertilizer application of 77% of the surveyed farmers in winter-spring season and 63% in autumn-winter in RRR system was over the recommended dosage, ranging from 101 to 130 kg N/ha/crop season. This is remarkably higher as compared to RUR and RUU. Although, farmers apply less fertilizer and pesticides in rice-upland crops, rotation systems for rice production compared to RRR, the rice yield was higher for RUR and RUU than for RRR (Figure 2). The heavy inorganic fertilizer and pesticide use in RRR might further causes water pollution and unbalanced rice field ecology.

Farm size

The average area under cultivation per farmer for the different rotations is shown in Figure 1. Agricultural production in Cai Lay is based on private smallholding with an average farm size of less than 1 ha. The average farm size in the study area is about 0.62 ha. The farm size of the RRR system ranged from 0.45 to 2.50 ha with an average of 0.91 ha. The average size of small farms is 0.36 ha and such small farms are found in UUU systems. Farms of average size of 0.68 ha and 0.43 ha are found in RUR and RUU systems, respectively. The RUU and UUU systems was practiced on significantly smaller farm as compared to RRR ($p<0.05$).

Farmers who choose rice monoculture cropping system have a large part of their land under cultivation in contrast with the small scale farmers who seem to adopt a strategy of diversification. The diversification of the farming system corresponds to a strategy by small scale farmer to stabilize their economic situation and improve their soil. Nevertheless, it is expected that their economic situation is threatened because of the tendentious depreciation of rice yield. Farmers who cultivate mono rice does not like to replace with another crop because of the high investment, the market price of upland crops is not being stable and the limited storage possibilities of their product if they cannot sell it immediately after harvesting.

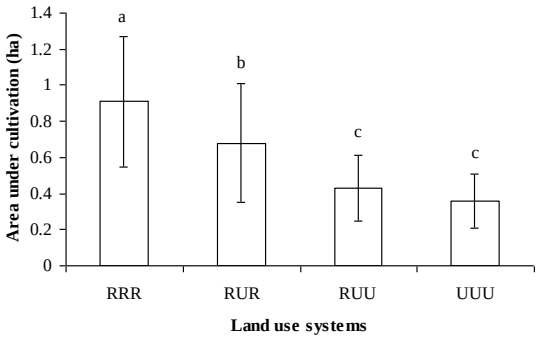
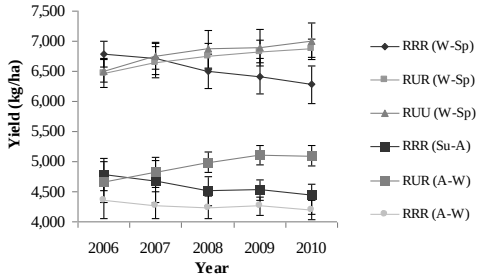


Fig. 1 Average area under cultivation per farmer (ha) for the different land use systems

Rice yield evolution

Based on the interviews with local farmers in the study area, the following information on rice crop yield was collected (Fig. 2). It was shown that rice yield is different among farmer groups. Farmers of rotation groups RUR or RUU obtained a much higher rice yields than RRR system. The mean difference was statistically significant in all seasons. Rice yields were significantly different ($p<0.05$) among the systems of RRR (6.3 ton/ha) and RUR (6.9 ton/ha) or RUU (7.0 ton/ha) in winter-spring and among the systems of RRR (4.2 ton/ha) and RUR (5.1 ton/ha) in autumn-winter. Besides that, rice yield in the last five years (since 2006) increased when rotations with upland crops were implemented (RUR and RUU), with for RUR an increase of 9% for autumn-winter and with 6% for winter-spring, and for RUU an increase of 8% for winter-spring. This was strongly in contrast with the rice yield decrease over the last five years for rice monoculture systems (RRR), which showed a decrease of 8%. The yield increase in the rice-upland crop rotations can be associated with improved soil quality resulting from cycles of drying (upland crops) and wetting (rice cultivation). The rice monocultures recorded the lowest yield because, according to the farmers, soil fertility was reduced.



W – Sp: Winter-Spring; Su – A: Summer-Autumn; A – W: Autumn-Winter.

Fig. 2 Rice yield within recent-past 5 years (kg/ha) for the different land use systems

There was also a large variation in rice yield over seasons was observed. The rice yield was much higher for winter-spring rice than for the summer-autumn or autumn-winter cropping period (Fig. 2). In the winter-spring season, rice showed much higher yield on average of five years (6.5; 6.7 and 6.8 ton/ha for RRR, RUR and RUU, respectively) as compared to summer-autumn (4.6 ton/ha for RRR) and autumn-winter seasons (4.3 and 4.9 ton/ha for RRR and RUR, respectively). This may be due to the better climatic conditions with planting just after the flood season, higher solar radiation and adequacy of irrigation water and that is the reason why rice is preferably cultivated in the winter-spring period. According to the farmers, the weather and insect pests are the major cause of yield loss in rice production in the summer-autumn and autumn-winter seasons.

Economic evaluation

The total economical balance for each land use system was analyzed based on a 1 ha farm size. The production costs like those for seeds and materials, fertilizer, labor and pesticide constitute an important part of the total variable cost of the system. Figure 3 shows the costs for seeds and materials, fertilizers, pesticides and labor on the one hand (input) and income on the other (output) with total profit, the difference between both for the different land use practices. The total cost of upland crop monoculture (UUU) and rice-upland crop rotation systems (RUR and RUU) were significantly higher than those of RRR farms. This is supported by findings of Huynh Dao Nguyen et al. (2010) in a rice-upland crop survey conducted in Cho Moi district, An Giang province.

For the whole sample, labor cost is the main input contributing about 56% of the total production cost, followed by fertilizer (26%), pesticide (13%) and seed (6%). Although most farmers have enough family laborers for rice production, most farmers hired labor for seasonal activities. On average, the hired labor cost contributed about 40-45% of the total labor cost. On the whole, the production cost in the wet seasons is higher than that in the dry season. Usually, wet

fields are more difficult to work, especially for harvesting. Harvesting of the wet season crop occurs at a time of heavy rains so that farmers face serious problems for postharvest activities such as drying, cleaning and hauling. In rice farming, hand weeding, harvesting and post harvest use a predominant portion of the labor input. Tractors reduce the labor requirement for land preparation. The planting of modern varieties and a high rate of fertilizer application increase the need of labor for weeding, although farmers apply herbicides to control the weeds. The labor requirement for harvesting and post harvesting also increases in function of the increased output.

The contribution of seeds and materials to the total cost is low (7%) for RUR and RUU. Fertilizer application accounts for 21 to 23% of the total cost for RUU and RUR, respectively. Labor manifests the highest contribution to the total cost (61-62% of total cost). The use of upland crops in the rotations creates more labor because of the need for raised beds that have to be dug. This makes the total cost to increase with increasing use of upland crops in the rotation. In rice-upland crops rotation systems, farmers apply less fertilizer and pesticide for rice production so that the rotation with one or two upland crop shows the lowest costs for pesticides. The interruption of the rice cultivation by an upland crop can break off the food-supply for rice specific pests and decreases the need for pesticides.

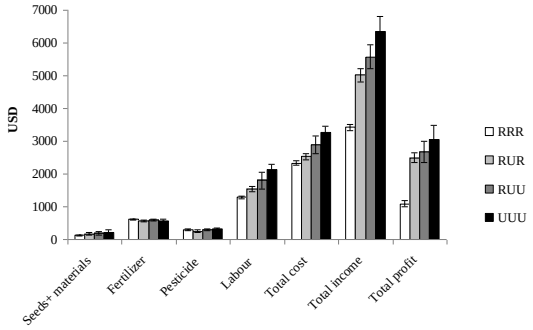


Fig. 3 Cost and income for the different land use systems (in USD)

Farmers practicing rice monoculture generally receive a lower farm income per hectare than those applying rotated farming systems, per year or and per season. In other words, farmers growing other crop rotations with rice or monocultures of upland crops can receive a higher income. The total income is highest for UUU, followed by RUU and RUR, and finally RRR per season and per year. The total income of RUR and RUU was 5,025 USD/ha/year and 5,575 USD/ha/year, respectively. Those were higher than the net income of RRR (3,424 USD/ha/year), but significantly lower than the net income from the UUU system (6,338 USD/ha/year). It is believed that rotated farming systems not only help farmers to increase their farm income, but also contributes to rural development and sustainable agriculture. On the other hand, there were large total profit differences among the farmer classes. The rotation of farmer's profit was more than two times higher than that of mono rice farmer's and the profit of upland crop farmers was almost three times higher than that of mono rice farmer's. Indeed, the total profit of RRR was only 1,094 USD/ha/year, whereas the UUU farmers gained a very high of 3,058 USD/ha/year, and RUR and RUU farmers a modest 2,490 USD/ha/year and 2,686 USD/ha/year, respectively.

Table 1 shows that the costs-benefit ratio (B/C) in rice-upland crop rotation farming systems was higher than in traditional mono rice crop patterns. The B/C shows that rice monoculture has the lowest profit over costs (46 to 51% lower than the other land use systems) and that RUU is the most successful with B/C 100%. Although there was not significance in B/C between RUR and RUU, they were significantly higher than that of the RRR system.

Compared to rice monocultures, rotations of rice and upland crops give higher values of farm diversity and economic efficiency. The rice-upland crop systems are therefore more ecologically sustainable than rice monoculture systems. The rice-upland crop rotation farming systems could be expanded further in future. However, low market prices sometime for rice and upland crop, lack of capital investment, low level of technological skills, inadequate knowledge on natural resource

management, and unfavorable marketing system, among others, are major constraints for rotated rice-upland crops systems in the target area. Moreover, farmers who cultivate upland crops have to face low prices at the farm gate, since upland crops, especially vegetables are quickly damaged after harvest. In order to help the farmers, better models of farmer organizations should be developed. An appropriate and efficient credit scheme and integrated and interdisciplinary research are urgently suggested to improve and widely develop rotated rice-upland crop systems in this area.

Table 1 Costs-benefit ratio for different land use systems.

Land use system	RRR	RUR	RUU	UUU
Winter-Spring	0.86d	1.24b	1.35a	1.15c
Summer-Autumn	0.09b	0.82a	0.88a	0.90a
Autumn-Winter	0.45c	0.98a	0.78b	0.76b
Whole year	0.47b	0.98a	1.00a	0.93a

Within rows, values followed by the same letter are not significantly different at P=0.05

CONCLUSIONS AND RECOMMENDATIONS

Rice yield in the Cai Lay district, Tien Giang province in the Mekong Delta, Vietnam alluvial soils with a clay texture was found to be lower in rice monocultures (RRR), than in rotation systems with upland crops (RUR or RUU) which both showed similar high rice yield. On the other hand, rice yields were higher in the winter-spring season than the summer-autumn and autumn-winter cropping period. Applying upland crops to paddy fields can positively enhance the biodiversity and increase farmer's income. The cost benefit ratio was highest for rotations upland crop with rice cultivations. It is also assures a lower application rate of agro-chemical in rotation systems. Total income was highest in upland crop monocultures (UUU), followed by RUR and RUU, with significantly lowest values for RRR. Our study showed that replacing the practice of rice monocultures with rotations with upland crops is very promising. Farmers who adopt new land use systems not only generate more goods for the society, but also more income for their family and more protection of land resources. The expansion of rice rotated with upland crops should be encouraged to increase income, effective utilization of labor and improve the soil quality. However, for national food security, and to sustain rice production, farmers should be encouraged to cultivate two times of the rice crops and one upland crop per year. More research should be realized in order to evaluate the effect of the rotation systems on soil quality and thus to better understand the yield differences.

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