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Infrastructural Systems:

Water Resource Development, Land Reclamation, Road Construction, etc.

Contents

Research article

Chemical Properties of Soils in Reforested and Bare Areas in Salt Affected Area of Khon Kaen Province, Thailand

JEERANUCH SAKKHAMDUANG
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan /
Recearch Center, Institute of Environment Rehabilitation and Conservation, Tokyo, Japan

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: m-mihara@nodai.ac.jp

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Abstract Salt affected soil is a severe environmental problem in northeast of Thailand. About 16.82 percent of the total land area in the region is accounted for the salt affected area. In the study area of Phra Yun district, Khon Khaen province, there were many studies since 1990 and 18 governmental projects of Thailand have been conducted for rehabilitating salt affected soil since 1999. However, attention has been paid to the current condition of salt accumulation in Phra Yun district, after many studies and projects have been implemented. So in this study, soil survey was conducted in four areas, Eucalyptus (*Eucalyptus camaldulensis*) reforested area and adjacent bare area, Acacia (*Acacia ampliceps*) reforested area and adjacent bare area. Disturbed and undisturbed soil samples were collected for analyzing physical and chemical properties of soils. The differences in chemical properties of soils were analyzed by *t*-test statistical method. The results showed that $EC_{1:5}$ values of soils in reforested and adjacent bare areas were significantly different at 99%. The sodium and calcium concentration of soils at the same depth in reforested and adjacent bare areas also showed significant different at 95% and 99%. Moreover, there was a tendency that $EC_{1:5}$ values, sodium and calcium concentration decreased with soil depth due to accumulation of salts at the surface layers. Although many studies and projects have been implemented in Phra Yun district, salt accumulation has been still severe, especially in bare areas. In addition, it was clearly observed that reforested areas of Eucalyptus and Acacia tended to be lower in electrical conductivity, sodium and calcium concentration than that of adjacent bare areas. Thus, it was concluded that reforestation is an effective approach to rehabilitate salt affected soil.

Keywords salt affected soil, reforested areas, chemical properties of soil

INTRODUCTION

Salt affected soil is a severe environmental problem in northeast of Thailand. Total area of this region is 16.928 million hectares while the salt affected land covers 2.848 million hectares or about 16.82%. From the rock salt stratum, called Mahasarakam formation, laid under soil surface at 100 m to 200 m deep, salt components are rising associated with soil water to ground surface. Salt affected soil is not only an environmental problem but also economic and social problems in rural areas.

Capillary rise of saline groundwater is one of the main causes of salinization (Kohyama and Subhasaram, 1993). One of the practices to prevent salinization is interrupting capillary rise of saline groundwater (Mihara et al., 2009) and to control the saline groundwater level (Dissataporn et al., 2002). Among several practices for controlling saline groundwater level, reforestation is also recommended to lower saline groundwater and mitigate salt accumulation (Yamklee et al., 1995 and Yuwaniyama, 2011).

Khon Kaen province is one of the provinces in northeast of Thailand that faces salt affected soil problem. The salt affected area covers around 10.85 percent of total area. Salt affected soil

problem is severe in Phra Yun district, Muang district, Ban Fang district and Ban Phai district (Khon Kaen province, 2005; Topark-ngarm, 2006).

Phra Yun district is one of the salt affected areas of Khon Kaen province. Agriculture is the main occupation of villagers in the district, paddy rice and sugarcane are the main agricultural products. Topography of this area ranges from flat land to rolling hills, elevation varies from 175 to 190 m above sea level. Paddy rice was cultivated in lowland areas while in the hill areas villagers grown sugarcane, cassava and Eucalyptus trees. Average income of population in Phra Yun district is 58,673 Baht or around 1,884 USD per year (Phra Yun Community Development Office, 2012).

In the study area, there were many studies about causes, effects and distribution of salt affected soil since 1991 (JICA, 1991). Besides that, 18 governmental projects of Thailand have been conducted for rehabilitating salt affected soil since 1999 (Land Development Department, 1999, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, Land Development Office of Region 5 (Khon Kaen), 2000, 2010, 2011a and 2011b).

Main activities of government projects for suppressing and/or ameliorating salt affected soil problem in the study area included; introducing salt tolerant rice species to farmers, increasing rice productivity by organic fertilizer and green manure application. Making groundwater drainage system, promoting salt tolerant tree included *Eucalyptus camaldulensis* and *Acacia ampliceps* and halophyte grass, *Sporobolus virginicus* in severely salt affected areas as well as planting fast growing trees in recharge areas to prevent salinization.

Moreover, in 1985, Agricultural Development Research Center (ADRC) has established in cooperated with Japan International Cooperation Agency (JICA), Thai Government and Khon Kaen University (JADES, 1997). The aims of the center are: 1) classification of agro-ecological zones and land use planning, 2) development of farm management system and 3) development of low-input technology. One of the activities of ADRC was to suppress salinization and ameliorate the salt affected areas.

However, attention has been paid to the current condition of salt accumulation in Phra Yun district, after many studies and several projects have been implemented. Therefore, the objective of this study is to investigate chemical properties of soils in reforested and bare areas in salt affected area of Khon Kaen Province, Thailand.

METHODOLOGY

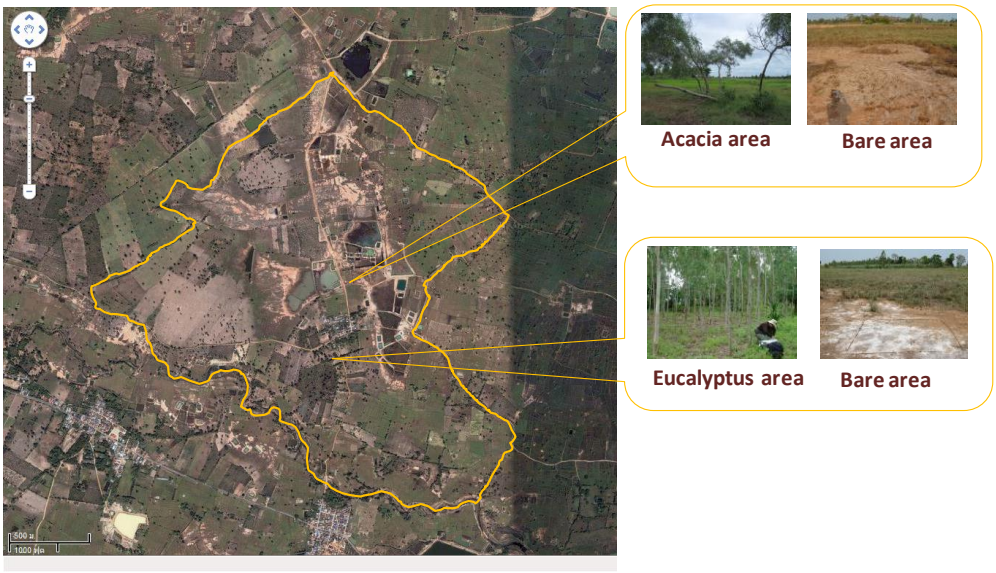


Fig. 1 Areas of conducted soil profile survey and collected soil samples

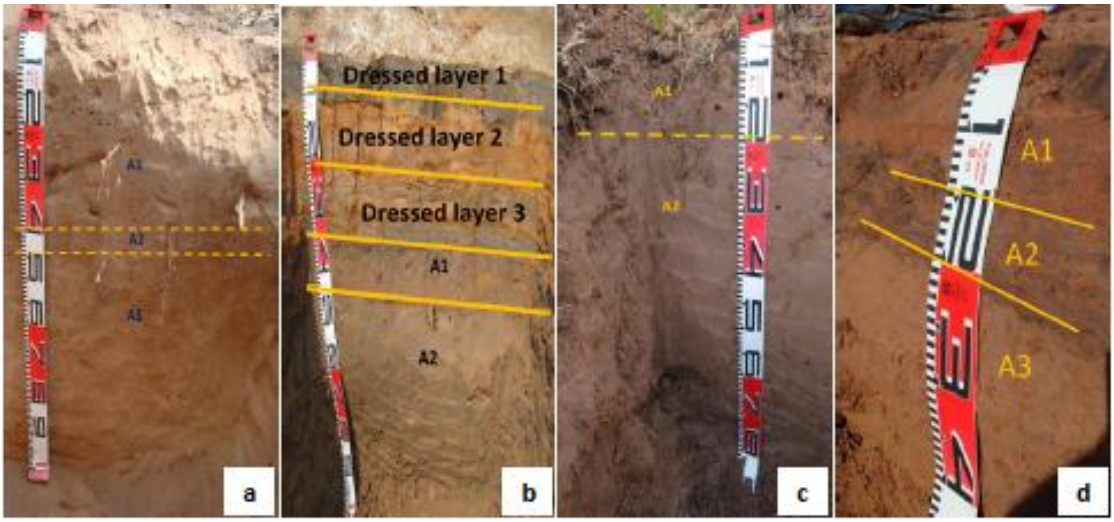
In January 2012, soil profile survey was conducted in 4 areas, Eucalyptus (*Eucalyptus camaldulensis*) reforested area and adjacent bare area, Acacia (*Acacia ampliceps*) reforested area

and adjacent bare area. According to soil profile in Eucalyptus reforested area, 3 disturbed and 9 undisturbed soil samples were collected while from the adjacent bare area of Eucalyptus, 5 disturbed and 15 undisturbed soil samples were collected. In Acacia reforested area, 2 disturbed and 6 undisturbed soil samples were collected while from the adjacent bare area of Acacia, 3 disturbed and 9 undisturbed soil samples were collected. Soil samples were analyzed for physical and chemical properties. The physical properties of soils including soil texture, dry density, specific gravity and soil permeability were analyzed. In addition, soil chemical properties including pH, electrical conductivity ($EC_{1:5}$) value, sodium, calcium, total nitrogen and total phosphorus concentration were analyzed. The differences in chemical properties of soils were analyzed by *t*-test statistical method.

RESULTS AND DISCUSSION

Physical properties of soils in reforested and bare areas

The soil textural classes of soils from 4 study sites were sand, sandy loam and loamy sand. Soils specific gravity ranges between 2.62 to 2.66. Dry density of soils in 4 study sites ranges from 1.54 to 1.80 g/cm^3. The highest percentage of loss on ignition was found in topsoil of Acacia reforested area 3.63% (Tables 1 and 2).



a Eucalyptus reforested area **b** bare area adjacent to Eucalyptus **c** Acacia reforested area **d** bare area adjacent to Acacia

Fig. 2 Soil profiles in 4 areas

Table 1 Physical properties of soils in Eucalyptus reforested area and adjacent bare area

Depth from soil surface (cm)	Horizon	Soil texture	Specific gravity	Dry density (g/cm^3)	Ignition loss (%)	Saturated permeability (x10^{-3} cm/s)
Soil in Eucalyptus area						
0 – 40	A1	S	2.62	1.80	0.89	125.90
40 – 45	A2	LS	2.65	1.79	0.67	145.10
45 – 100	A3	LS	2.64	1.78	0.47	127.60
Soil in bare area adjacent to Eucalyptus area						
0 – 10	Dress layer 1	L	2.64	1.54	3.59	0.10
10 – 25	Dress layer 2	S	2.64	1.67	0.68	133.70
25 – 34	Dress layer 3	LS	2.62	1.56	1.24	0.50
34 – 44	A1	LS	2.65	1.62	1.2	140.10
44 – 100	A2	SL	2.66	1.62	1.37	125.40

Table 2 Physical properties of soils in Acacia reforested area and adjacent bare area

Depth from soil surface (cm)	Horizon	Soil texture	Specific gravity	Dry density (g/cm^3)	Ignition loss (%)	Saturated permeability ($x10^{-3}$ cm/s)
Soil in Acacia area						
0 – 10	A1	S	2.64	1.58	1.04	134.20
21 – 80	A2	S	2.65	1.62	1.35	51.20
Soil in bare area adjacent to Acacia area						
0 – 15	A1	LS	2.64	1.63	3.63	41.90
15 – 22	A2	LS	2.66	1.64	1.33	122.40
22 – 70	A3	LS	2.63	1.63	1.02	95.90

Chemical properties of soils in reforested and bare areas

As shown in Fig 3, the $EC_{1:5}$ values of soils in 4 areas were significantly different at 99%. The $EC_{1:5}$ value in topsoil of Eucalyptus reforested area was the lowest at 0.01985 mS/cm and the highest value was topsoil of bare area adjacent to Eucalyptus at 20.00 mS/cm.

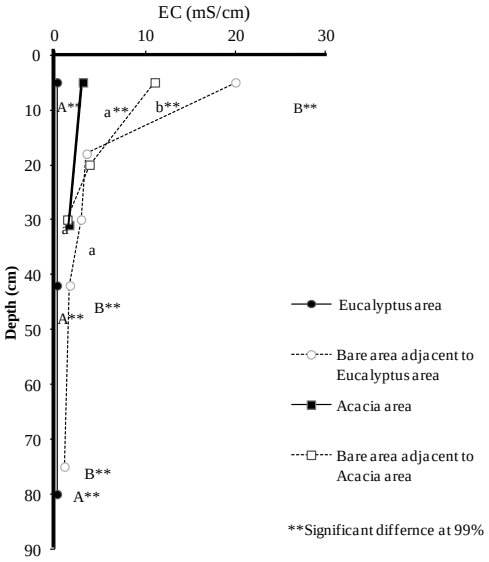


Fig. 3 Electrical conductivity values ($EC_{1:5}$) of soils in 4 areas

The sodium and calcium concentration of soils at same depth in 4 areas showed significant difference at 95% and 99%. It was observed that sodium concentration was the lowest in topsoil of Eucalyptus reforested area at 1.84 mg/kg and the highest concentration was topsoil of bare area adjacent to Eucalyptus at 21,447.86 mg/kg (Fig. 4, left side).

Calcium concentration was the lowest in topsoil of Eucalyptus reforested area at 10.10 mg/kg and the highest concentration was topsoil of bare area adjacent to Acacia at 1,926.84 mg/kg (Fig 4, right side). Moreover, there was a tendency that the $EC_{1:5}$ values, sodium and calcium concentration decreased with depth due to accumulation of salts at the surface layers.

As shown in Fig. 5 (left side), the total nitrogen concentration of soils in 4 areas was significantly different at either 95% or 99%. A significant difference at 95% in the total nitrogen concentration were found in soil of 2nd layer and 3rd layer of Eucalyptus area and adjacent bare area, while a significant difference at 99% were found in topsoil of Acacia area and bare area adjacent to Acacia. The highest total nitrogen concentration at 522.89 mg/kg was found in Acacia reforested area due to high amount of nitrogen in Acacia leaf litter. Low total nitrogen concentration in topsoil of Eucalyptus plantation might be due to allelopathic affect of Eucalyptus trees to soil macronutrients (Tilashwork, 2009).

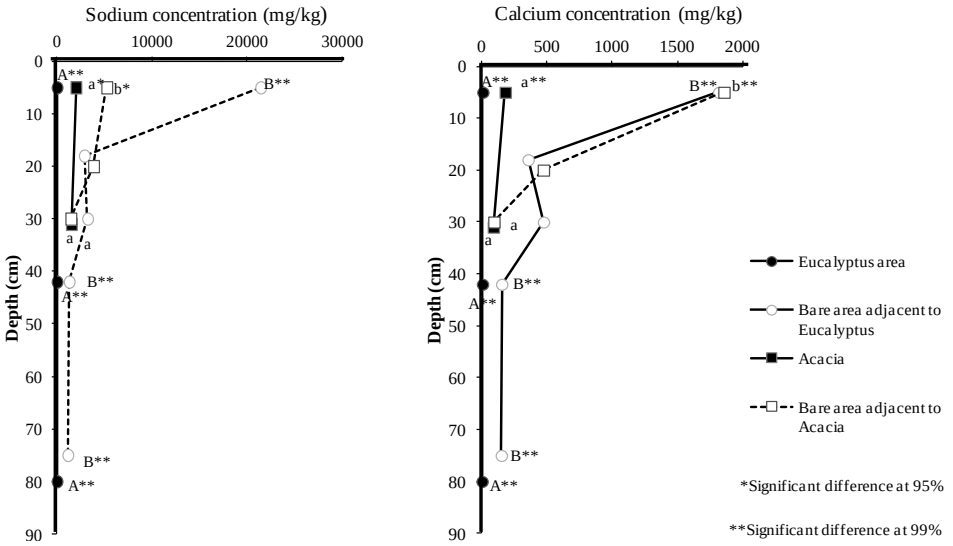


Fig. 4 Sodium concentration (left) and calcium concentration of soils (right) in 4 areas

The total phosphorus concentration of topsoil of Acacia area was significantly different at 95% from that of adjacent bare area. The total phosphorus concentration found in 4 areas was relatively low ranging from 0.67 to 6.64 (Fig.5, right side). From the result, the highest value of total phosphorus was found in the bare area adjacent to Eucalyptus area, the possibility is frequently burning residues in bare area might be increase total phosphorus in soil (Li et al., 2012).

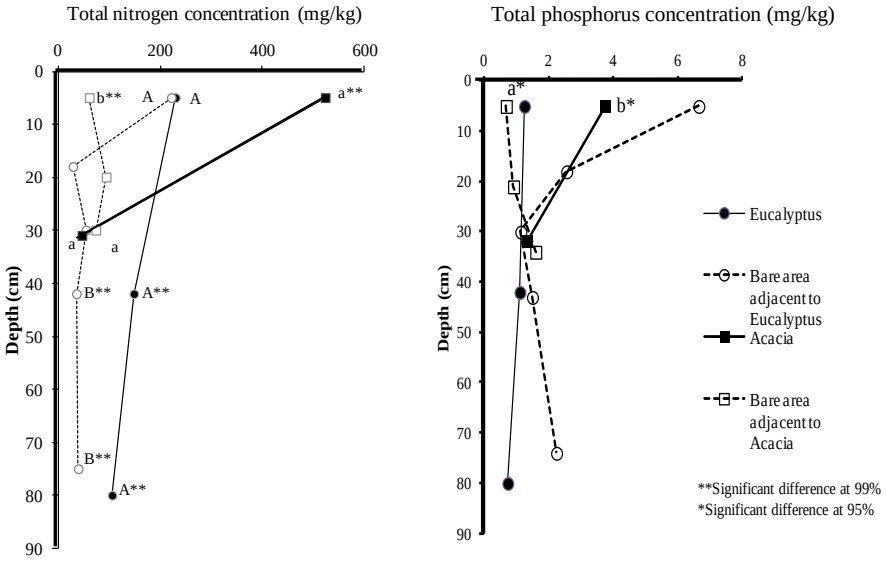


Fig. 5 Total nitrogen concentration (left) and total phosphorus concentration (right) of soils in 4 areas

Table 3 Changes in salt affected areas in Phra Yun district, Khon Kaen province

Year	Severely affected area (salt crust cover more than 50%) (ha)	Strongly affected area (salt crust cover 10- 50%) (ha)	Moderately affected area (salt crust cover 1- 10%) (ha)	Total salt affected area (ha)	% of total area (17,200 ha)
1991	310	1,480	3,550	5,340	31
2003	441.6	1,404	4,250	6,095	35

Source; JICA (1991); REO 10 (2003)

Although 18 development projects of Thai government has been conducting in the study area since 1991, the results of this chapter revealed that the soil salinity still severe, especially in bare area. Moreover, the salt affected areas are increasing from 31 percent of total district area in 1991 to 35 percent in 2003 (Table 3-3).

Strategy for promoting reforestation in salt affected area

Based on the results of this study, it was supported that reforestation is an efficient way to rehabilitate salt affected soil. However, low economic benefit with reforestation became the constraint for the locals to grow more trees in salt affected area of Khon Kaen province, Thailand (Sakkhamduang et al., 2012).

In 2001, Sakkhamduang et al. report that agro-forestry system in Salt affected area in Khon Kaen Province had a lower practice than that of in non-salt affected area according to the salt affected soil condition. Agro-forestry practices on salt affected area can be categorized into five types; patch forests, trees on paddy bunds, tree plantations associated with animal husbandry, home gardens and trees in vegetable gardens. Moreover, Im-Erb et al. (2004) reported that an agro-forestry system being promoted on 2003 in recharge area of Nakhon Ratchasima province was well accepted by farmers according to their additional income.

Thus, agro-forestry system that combined salt tolerant tree with salt tolerant or halophyte vegetables or field crops should be introduced to farmers in the study area for increasing their income as well as rehabilitating salt affected soil.

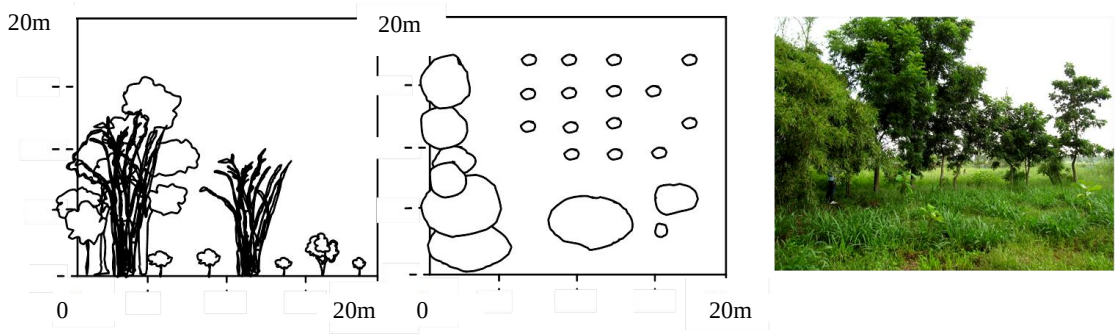


Fig. 6 Cross section and top views of home garden, one of agro-forestry systems existing in salt affected area

CONCLUSION

Many government projects have been implemented in Phra Yun district since 1991. The activity of those projects included; introducing salt tolerant rice species to farmers, increasing rice productivity by organic fertilizer and green manure application. Making groundwater drainage system, promoting salt tolerant tree included *Eucalyptus camaldulensis* and *Acacia amplicep* and halophyte grass, *Sporobolus virginicus* in severely salt affected areas as well as to planting fast growing trees in recharge areas for preventing salinization.

Although several projects were implemented, salt accumulation is still severe; especially in bare areas that has EC value of 20 mS/cm. In addition, it was clearly observed that reforested areas of Eucalyptus and Acacia tended to be lower in electrical conductivity, sodium and calcium concentration than that of adjacent bare areas. Moreover, Thaweethavornsawat (1999) reported that the decreasing of forest area in Phra Yun district increases the distribution of salt patches in the area. Thus, it was concluded that reforestation is an effective approach to rehabilitate salt affected soil.

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Research article

Comparison of Fertilizer Management to Increase Yield and Quality of Rice

PUMISAK INTANON*
Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok, Thailand
Email: pumisak_intanon@hotmail.com

Received 12 December 2012 Accepted 30 January 2013 (*Corresponding Author)

Abstract The purpose of this research was to improve the productivity and quality of rice. This research was to compare various types of fertilizers that are suitable for growing rice. Six experimental models were arranged in RCBD with 3 replications consisting of 18 field plots comprising a total of 5 Rai. Each model was designated as: T0 (no fertilizer: Control group), T1 (pellet compost), T2 (Compost mixed bio-liquid fertilizer), T3 (compost mixed mineral formula called formula-1), T4 (compost mixed higher mineral formula called formula-2), and T5 (compost mixed the highest mineral formula called formula-3). Each type of fertilizer was used at a rate of 50 kilograms per Rai. The rice seed used in the testing was Phitsanulok #2. The experiment was located at Moo 13, Ban Huaidang, Prompiram city, Phitsanulok Province, Thailand during April 2012 to September 2012. The soil data and fertilizers used in an experiment were collected for reference and analysis. Plant Environmental data, growth data, Yields, yield components and production costs were also collected. The data were statistically analyzed using ANOVA and DMRT at a 95% level of confidence. The analysis on the macro- nutrients from the fertilizer was designated: T5, T4, T3, T2 and T1, respectively. The plant growth data the maximum outputs are ranked from T3, T5, T4, T2, T1 and T0 models, respectively. According to the study results on yield and yield components the maximum outputs are ranked from T3, T5, T4, T2, T1 and T0 models (1,119.4, 990.3, 949.3, 872.2, 813.2 and 781.0 kilograms per Rai, respectively). In case of the T3 model compared with T0 (no fertilizer), it was found that the productivity increased 43.3% and the percentage of withered rice decreased 60%. In the study of total production costs, it was found that the maximum production costs per Rai was T5, T4, T3, T2, T1 and T0 models with 6,850, 6,800, 6,730, 6,540, 6,380 and 5,880 Baht per Rai, respectively. When compared with the yields, the least-costs rice production per 1 kilogram were ranked from T3,T5, T4, T2, T0 and T1 models with 6.01, 6.19, 7.16, 7.49, 7.52 and 7.84 Baht per kilogram, respectively. When selling rice at 11,500 Baht per ton, it was found that the highest profits of the models were as follows: T3, T5, T4, T2, T0 and T1 with 6,143.1, 4,538.4, 4,116.9, 4,390.3, 3,101.5 and 2,971.8 Baht per Rai, respectively.

Keywords fertilizer, fertilizer management, rice, quality of rice

INTRODUCTION

The farmers at Moo 13, Ban Huaidang, Prompiram Sub-district, Prompiram District, Phitsanulok Province, Thailand utilize water from Naresuan dam located in Phitsanulok Province to irrigate their rice farms twice a year. The majority of farmers use chemical fertilizer and pesticide to increase the productivity without any basic knowledge on types of fertilizers, proper use or rice production costs. This lack of knowledge leads to higher production cost, soil deterioration, and chemicals left on the product that is unsafe to the consumers (Intanon et al., 2011). As a result of the poor farming methods these farmers have a low income with higher debts.

OBJECTIVE

Therefore, this research aimed to improve productivity and the quality of rice by promoting the cultivation of high-yield rice using effective economical fertilizers.

METHODOLOGY

1. The Experimental Plan: The six experimental models were arranged in RCBD with 3 replications. There were 18 field plots covering a total of 5 Rai. Each model consists of T0 (no fertilizer: Control group), T1 (pellet compost), T2 (Compost mixed bio-liquid fertilizer), T3 (compost mixed mineral formula called formula-1), T4 (compost mixed higher mineral formula called formula-2), and T5 (compost mixed the highest mineral formula called formula-3). Each type of fertilizers was used at a rate of 50 kg per Rai 1) Rai = 1,600 M^2(, the rice seed used for the testing was Phitsanulok #2. The growing test area was located at Moo 13, Ban Huaidang, Prompiram Sub-district, Prompiram District, Phitsanulok Province, Thailand, the test period was between April 2012 to September 2012.

2. Data Collection: data collected consists of following information: 1) weather condition and plant environment at the field plots; 2) analysis of soil before and after the experiment by exploring the macro-nutrients (N, P, K) ,the secondary nutrients (Ca, Mg, S), the micro-nutrients (B, Fe, Cu, Zn, Mn), and the analysis of pH and OM; 3) analysis of the fertilizers by investigating the macro-nutrients (N, P, K), the secondary nutrients (Ca, Mg, S), the micro-nutrients (B, Fe, Cu, Zn, Mn), these tests were conducted at the Soil Science Lab, Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok; 4) data on the vegetative growth collected every ten days (e.g. the stem and leaf height, the number of leaves per plant, the number of stem per clump, root-system length and total weight per plant); 5) data on yields and yield components after harvesting and an investigation on the length of panicle of rice, number of rice seeds per panicle of rice, number of healthy seeds and withered seeds per panicle of rice, the number of panicle of rice per square meter, the number of panicle of rice per field plot, the weight of 1,000 seeds, the weight of seeds per field plot, and production per Rai; 6) data on the total production costs. The data were statistically analyzed using ANOVA and DMRT model at a 95% level of confidence used for comparison of treatments.

RESULTS AND DISCUSSION

The weather condition and plant environment at the field plots during the test period of April to September 2012 showed that temperature ranged between 23-36^{o}C, the average rainfall was 73.3 millimeters per month. However, the model area was also irrigated with water from the Naresuan dam. The analysis of soil before the experiment illustrated poor soil conditions, low to moderate level organic compounds of soil, acid soil with a low pH, a very low level of phosphorus and potassium and low acidic water (Japkaew and Intanon, 2010). After the experiment, it was found out that the acidity of the soils that were fertilized with the three types of compost mixed mineral formula was reduce. This could result from the minerals, calcium or dolomites contained in the formula adjusting the levels of the acid soil pH.

Fertilizer analysis data in Table 1 showed that the analysis of fertilizer nutrients used in the experiment and the models that contained maximum nutrients (the macro-nutrients, the secondary nutrients, the micro-nutrients) were T5, T4, T3, T2, and T1with 66.07%, 62.09%, 61.53%, 12.29%, and 9.66%, respectively.

Vegetative growth data showed that the models having the highest results on vegetative growth were as follows: T3, T5, T4, T2, T1, and T0, respectively. The height of the stem and leaves was in accordance with nutrient balance of the fertilizers which provided high level of nitrogen, secondary nutrients, and micro-nutrients. As a result, the compost mixed mineral formula (T3, T5, T4) provided a better growth than other fertilizers (Intanon, 2009). Besides having nitrogen which is necessary component in cell division in the fertilizers, the secondary nutrients,

and the micro-nutrients were also correlated to cell division, the construction of chlorophyll, photosynthesis in plants, growth of stems and leaves (Table 2).

Table 1 Analysis of fertilizers used in the experiment

Treatments	pH	OM %	Total N,P,K (%)	Total Ca, Mg, S (%)	Total B, Fe, Cu, Zn, Mg (%)	Total (%)
T0 No fertilizer (Control)	-	-	-	-	-	-
T1 Pellet compost	6.8	14.50	4.12	4.54	0.004221	8.66
T2 Compost mixed bio-liquid fertilizer	6.8	12.20	7.31	4.98	0.005323	12.29
T3 Compost mixed mineral formula, called formula-1	7.0	5.09	50.90	10.63	0.006268	61.53
T4 Compost mixed higher mineral formula, called formula-2	7.2	3.23	50.50	11.59	0.005687	62.09
T5 Compost mixed the highest mineral formula ,called formula-3	7.5	3.13	53.00	13.07	0.006165	66.07

Table 2 the analysis of vegetative growth

Treatments	stem height*	number of leaves per plant	number stem per tussock	root-system length	total weight per plant
T0 No fertilizer (Control)	80.2c	27.8c	7.6d	25.0c	4.8d
T1 Pellet compost	86.5b	29.8c	7.7d	26.4b	5.5c
T2 Compost mixed bio-liquid Fertilizer	86.5b	31.6b	8.2c	26.6b	5.5c
T3 Compost mixed mineral formula, called formula-1	94.7a	37.3a	9.8a	28.9a	7.0a
T4 Compost mixed higher mineral formula, called formula-2	88.5b	33.8b	8.8b	27.6a	6.2b
T5 Compost mixed the highest mineral formula, called formula-3	91.8a	36.2a	9.5a	28.6a	6.8a
F-Test	*	*	*	*	**
% cv	9.5	9.6	6.6	8.7	8.8

* *Significant at 95% confident interval in each column of the same period, the different in small letter indicated significant at 95% by DMRT*

** *Significant at 99 % confident interval in each column of the same period, the different in small letter indicated significant at 99 % by DMRT*

Yields and yield component data showed that the yields and yield components related to the length of panicle, number of rice seeds per panicle of rice, number of healthy seeds and withered seeds per panicle of rice, the number of panicle of rice per square meter, the number of panicle of rice per a field plot, the weight of 1,000 seeds, the weight of seeds per a field plot. The highest results were from methods as follows: T3, T5, T4, T2, T1 and T0 methods. In addition, it was found that the maximum outputs production per Rai were ranked from T3, T5, T4, T2, T1 and T0 methods (1,119.4, 990.3, 949.3, 872.2, 813.2 and 781.0 kilograms per Rai, respectively). In case of the T3 model compared with T0 (no fertilizer), it was found that the productivity increased 43.3% and the percentage of withered rice decreased 60% (Table 3).

As illustrated in Table 3, fertilizers had a continuous and relative influence on the plants and vegetative growth. Plants grew fast and well resulting from the balance of nutrients which consists of the macro-nutrients, the secondary nutrients, and the micro-nutrients. In the vegetative phase, there were more green area which could be seen from the higher shoots, more leaves, and more clump. Therefore, this created more areas for photosynthesis in plants. Nutrients (Nitrogen, Iron, Copper, Zinc, Sulphur, and Magnesium) were the main factors in synthesis which created organic compounds (carbohydrate and sugar) in plants. The greater number of nutrients, the more organic compound was produced (Chuinon and Intanon, 2011). As a result, there was the weight gain in terms of the weight of each ear of rice and the weight of 1,000 seeds due to the accumulation of

more carbohydrate. It was shown that the yield components improvement resulted in high productivity. It is clear that compost mixed higher mineral formula provided the maximum outputs production (T3, T5, and T4, respectively). In contrast, inadequate and unbalanced nutrient use could significantly result in an increase of withered rice grains per ear (T0 and T1 respectively).

Table 3 Yield and yield components

Treatments	ear length (cm)	number of seeds per ear (seed)	number of healthy seeds per ear (seed)	number of withered rice per ear (seed)	number of ear per square meter (ear)	number of ear per plot field (ear)	weight of ear (g)	weight of 1,000 seeds (g)	weight of ear per plot field (kg)	yield (kg/Rai)
T0 No fertilizer (Control)	19.5c	114.1c	81.7d	50.6c	197.0d	5,920d	2.24c	22.4c	13.26e	781.0d
T1 Pellet compost	22.1c	126.1b	88.4d	36.2b	219.7c	6,226d	2.43b	28.4b	15.12c	813.2c
T2 Compost mixed bio-liquid fertilizer	22.2c	126.7b	103.0c	35.4b	222.3c	6,590c	2.45b	28.6b	17.14b	872.2b
T3 Compost mixed mineral formula, called formula-1	26.8a	135.3a	120.5a	12.6a	236.3a	7,550a	2.93a	35.2 a	22.12a	1,119.4a
T4 Compost mixed higher mineral formula, called formula-2	23.6b	130.5a	113.1b	18.5a	229.3b	7,264b	2.66a	32.1a	19.32b	949.3b
T5 Compost mixed the highest mineral formula ,called formula-3	24.8b	132.6a	116.0a	15.5a	232.0a	7,332b	2.78a	32.5a	20.38a	990.3a
F-Test	*	**	*	**	**	*	*	**	*	**
%cv	6.5	8.8	6.6	9.6	12.2	9.5	12.7	8.8	9.6	12.2

* *Significant at 95 % confident interval in each column of the same period, the different in small letter indicated significant at 95 % by DMRT*

** *Significant at 99 % confident interval in each column of the same period, the different in small letter indicated significant at 99 % by DMRT*

In the study of total production costs, it was found out that T5 has the highest production cost of 6,850 Bahts follows by T4) 6,800 Bahts, T3) 6,730 Bahts, T2) 6,540 Bahts, T1) 6,380 Bahts, Baht per tons, it was found that the highest profits of the successive models were as follows: T3, T5, T4, T2, T0 and T1 (6,143.1, 4,538.4, 4,116.9, 4,390.3, 3,101.5 and 2,971.8 Baht per Rai, respectively).

Total production cost was indicated that the production cost of the three types of compost mixed higher mineral formula were higher, especially T3, however, it yielded the highest productivity per Rai which reduced the production cost per kilogram .Even though T3 had the higher production cost, it provided the highest profit (Intanon et al., 2010). While T0, T1, and T2 had the lower production cost, they received less productivity. It is clear that the production cost per kilogram of T0, T1, and T2 were higher when selling rice at 11.50 Baht per kilogram or at 11,500 Baht per ton and obtained less profit (Table 4).

Table 4 The total production costs

Description	T0 No fertilizer (Control)	T1 Pellet compost	T2 Compost mixed bio-liquid fertilizer	T3 compost mixed mineral formula, called formula-1	T4 Compost mixed higher mineral formula, called formula-2	T5 Compost mixed the highest mineral formula ,called formula-3
1. ploughing and levelling (2 times x 300 Baht/Rai)	600	600	600	600	600	600
2. seeds (35 kg/Rai x 20 Baht)	700	700	700	700	700	700
3. fertilizer/bag	-	400	560	750	820	870
4. plant growth hormones (250 Baht x 1 time) and plant hormones for ear of rice(300 Baht x 2 times) = 850 Baht per Rai	850	850	850	850	850	850
5. pesticide (220 Baht x 1 time)	220	220	220	220	220	220
6. insecticide (200 Baht x 2 times)	400	400	400	400	400	400
7. fuel for water pump and fuel for looking after rice plants	800	800	800	800	800	800
8. harvesting machine rent, included fuel	600	600	600	600	600	600
9. total expense	4,170	4,570	4,730	4,920	4,990	5,040
10. labour cost during the production period *	1,710	1,810	1,810	1,810	1,810	1,810
11. total cost	5,880	6,380	6,540	6,730	6,800	6,850
12. rice yield(kg/Rai)	781.00	813.20	872.20	1,119.40	949.30	990.30
13. cost of productivity (Baht/kg)	7.52	7.84	7.49	6.01	7.16	6.19
14. income when selling 11,500 Baht/ton or 11.50 Baht/kg	8,981.5	9,351.8	10,030.3	12,873.1	10,916.9	11,388.4
15. profit (Baht/kg)	3.98	3.66	4.01	5.49	4.34	5.31
Profit(Baht/Rai)	3,101.5	2,971.8	3,490.3	6,143.1	4,116.9	4,538.4

** a labour cost of production six-month-period excluded T0 which had no fertilizer and direct seeding labour cost.*

CONCLUSION

According to the research findings, it can be concluded that:

1. The fertilizers that contained the most N, P,K, Ca, Mg, S and micro nutrients were T5, T3, T4, T2, and T1, respectively.
2. Fertilizers that enhance rice growth to achieve maximum vegetative growths must have a balance of nutrients consisting of a high number of macro-nutrients and secondary nutrients. It can be little of micro-nutrients and complete with all types of nutrients.
3. Fertilizers or yield models used to maximize outputs were ranked from T3, T5, T4, T2, T1 and T0 (1,119.4, 990.3, 949.3, 872.2, 813.2 and 781.0 kilograms per Rai, respectively). In case of the T3 model compared with no fertilizer, it was found that the productivity increased 43.3% and the percentage of withered rice decreased 60%.
4. In the study of total production costs, it was found that the maximum production costs per Rai was T5, T4, T3, T2, T1 and T0 models (6,850, 6,800, 6,730, 6,540, 6,380 and 5,880 Baht per Rai, respectively). When compared with the yields, the least-costs rice production per 1 kilogram were ranked from T3,T5, T4, T2, T0 and T1 models (6.01, 6.19, 7.16, 7.49, 7.52 and 7.84 Baht per kilogram, respectively).

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Research article

The Influence of Different Types of Fertilizers on Productivity and Quality of Maize in the Area of Kwaew Noi Bamrungdan Dam, Phitsanulok Province, Thailand

PUMISAK INTANON*
Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok, Thailand
Email: pumisak_intanon@hotmail.com, pumisakintanon@gmail.com

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Abstract The purpose of this research was to improve the productivity and quality of corn. The test plant was located at Moo 2 Ban Nongping, Tha-Ngarm sub-district, Watbot District, Phitsanulok province, Thailand; and the test was undertaken throughout June 2011 to September 2011. Six experimental models were arranged in RCBD with three replications consisting of eighteen field plots. Each model was designated as T0 (no fertilizer: Control group), T1 (pellet organic fertilizer from farm manure), T2 (granular organic bio-fertilizer), T3 (chemical and granular organic fertilizer), T4 (chemical fertilizer from the soil analysis programs) and T5 (chemical and granular organic fertilizer with hormones mixed formula). Each type of fertilizer was used at a rate of fifty (50) kilograms per Rai. The corn seed used in the testing was type NK#48. Plant environmental data, vegetative growth data were collected every ten days. Yields, yield components and production costs were also collected. The data were statistically analyzed using ANOVA and DMRT at a 95% level of confidence. The analysis on the chemical property of the fertilizers indicated the maximum macro-nutrients ranking from Nitrogen, Potassium, and Phosphorus, respectively. The model having the highest macro-nutrients was T4 (chemical fertilizer from soil analysis programs). The model containing the highest secondary nutrients was T5 (chemical and granular organic fertilizer with hormones mixed formula). The vegetative growth data which was the measure of the stem heights and size, leaf length and leaf width were designated T4, T5, T3, T2, T1 and T0, respectively. It was clear that this result was a function of the Nitrogen level contained in the fertilizers. According to the study results on yield components in terms of the length and a diameter of corn ear, total weight per corn ear, weight of kernels per ear and weight of 100 kernels, the maximum outputs were ranked from T4, T5, T3, T2, T1 and T0 models. The highest number of withered kernels and the heaviest corn husk were T0, T1, and T2, respectively. The models having greatest weight productivity per Rai were T4, T5, T3, T2, T1 and T0 models (1,319 kg, 1,305 kg, 970 kg, 857 kg, 775 kg, and 428 kg respectively). The results indicated that there was no statistically significant difference between T5 and T4 models in relation to the weight productivity per Rai. In the study of total production costs, it was found that the minimum production costs per Rai were T0, T5, T2, T1, T3 and T4 models (8,288, 8,538, 9,080, 9,238, 9,438, 10,108 Baht per Rai, respectively). When compared with the yields, the least cost of corn production per one kilogram were T5 and T4 models with no statistically significant difference between the two. Therefore, the model that should be encouraged and promoted to the farmers for sustainable production was T5 model; this type of fertilizer contained a balance of nutrients, soil amendments and effective microorganisms. In addition, it provided high productivity with the highest financial return.

Keywords fertilizer, influence of fertilizers, maize, quality of corn

INTRODUCTION

The farmers at Moo 2 Ban Nongpling, Tha-Ngarm sub-district, Watbot District, Phitsanulok

province, Thailand utilize water from Kwaew Noi Bamrungdan dam located in Phitsanulok Province to irrigate their corn farms. The use of the current chemical fertilizers leads to soil deterioration, hard and compact soil making it difficult for water and air to penetrate, soil erosion due to rain, strong acid soil, and higher production cost (Intanon et al., 2011).

OBJECTIVE

Therefore, this demonstrative research project investigated the influence of fertilizers on yield and yield components and corn quality in the area of Kwaew Noi Bamrungdan dam as a learning resource and solution for the farmers.

METHODOLOGY

1. The experimental plan: Six experimental models were arranged in RCBD with three replications consisting of eighteen field plots. Each model was designated as T0 (no fertilizer: Control group), T1 (pellet organic fertilizer from farm manure), T2 (granular organic bio-fertilizer), T3 (chemical and granular organic fertilizer), T4 (chemical fertilizer from soil analysis programs) and T5 (chemical and granular organic fertilizer with hormones mixed formula: An Innovation of the Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok Province, Thailand. The mixture of fertilizers used in the experiment was in Table.1.Each type of fertilizer was used at a rate of fifty (50) kilograms per Rai. In addition, the corn seeds used in the testing, three kilogram per Rai was type NK#48. The size of each plant plot was 10X20 meters or 200 square meters. The test was located at Moo 2 Ban Nongpling, Tha-Ngarm sub-district, Watbot District, Phitsanulok province, Thailand and the test period was from June 2011 to September 2011.

Table 1 The mixture of fertilizers used in the experiment

Types of fertilizers	Ratio per weight of 50 kilograms						Total
T1 (pellet organic fertilizer from farm manure)	Pig manure powder (60%)		Soil mixed EM (20%)	Rice bran meal (10%)	Diluted molasses (10%)	-	100%
T2 (granular organic bio-fertilizer)	Pig manure powder (40%)	Bagasse silage (30%)	Rice bran meal (10%)	Mung Bean compost (10%)	Diluted molasses (10%)	-	100%
T3 (chemical and granular organic fertilizer)	Granular organic fertilizer from farm manure (50%)			Chemical fertilizer 46-0-0 (50%)			100%
T4 (chemical fertilizer from the soil analysis program)	Urea 46-0-0 = 21 kg (39 %)		Phosphorus 0-46-0 = 18kg (33%)		Potassium 0-0-60 = 15kg (28%)		100%
T5 (chemical and granular organic fertilizer with hormones mixed formula)	Chemical Fertilizer 15-15-15 =10 kg (20%)	Pig manure powder (30%)	Rock phosphate and dolomite 1:1 (20%)	Bio liquid fertilizer (10%)	Extract herbal liquid (10%)	Organic hormones (10%)	100%

Sources: Intanon (2009)

2. Data collection: the data collection consisted of information as follows: 1) weather condition at the field plots; 2) analysis of soil before and after the experiment by exploring N- P- K, pH, OM and the analysis of pH water; 3) analysis of the Major-nutrients (N, P, K) and the secondary nutrients (Ca, Mg, S) of fertilizers used in the experiment. These tests were conducted at the Soil Science Lab, Naresuan University, Phitsanulok, Thailand; 4) data on the vegetative growth collected every ten days (e.g. the stem height, stem size, number of stems per square meter, the number of leaf per stem, leaf length, and leaf width; 5) data on yields and yield components(e.g. the length of corn ear , a diameter of corn ear, corn ears per square meter, number of healthy and withered kernels per corn ear, the total weight per corn ear, the weight of corn husk per corn ear,

the weight of corn cob, the weight of kernels per corn ear, weight of 100 kernels and the weight yield per Rai; 6) data on the total production costs. The data were statistically analyzed using ANOVA and DMRT model at a 95% level of confidence used for comparison of treatments.

RESULTS AND DISCUSSION

The weather condition and plant environment at the field plots during the test period of June 2011 to September 2011 showed that temperature ranged between 23-36^{o}C, the norm for this area, the rainfall ranged from 190-460 millimeters which was a high density of rainfall (Japkaew and Intanon, 2010). The analysis of soil chemical property before and after the experiment indicates in Table 2. The soil consists of sandy loam with laterite, it was in poor conditions, with a low pH (acid soil), a low level of organic matter, and a very low level of phosphorus and potassium (Table 2).

Table 2 Soil chemical property before and after the experiment

Treatments	pH	OM %	N %	P %	K %	pH water
Before the experiment	5.7	0.66	0.45	0.35	0.0052	6.7
After the experiment						
T0 (no fertilizer)	5.7	0.76	0.45	0.0034	0.0055	6.7
T1(pellet organic fertilizer from farm manure)	5.9	0.86	0.92	0.0049	0.0051	6.7
T2 (granular organic bio-fertilizer)	5.9	0.98	0.94	0.0065	0.0072	6.8
T3 (chemical and granular organic fertilizer)	5.8	0.95	1.34	0.0052	0.0055	6.7
T4 (chemical fertilizer from the soil analysis programs)	5.7	0.75	1.67	0.0089	0.0097	6.5
T5 (chemical and granular organic fertilizer with hormones mixed formula).	5.8	0.95	1.72	0.0078	0.0088	7.0

The analysis of fertilizers nutrients used in the experiment illustrated in Table 3. It was found the highest nutrients ranked as follows: Nitrogen, Phosphorus, and Potassium respectively. The models that contained maximum macro-nutrients were T4, T5, T3, T2, and T1 (54.00%, 34.00%, 27.83%, 3.41%, and 3.23%, respectively). The models that contained maximum secondary nutrients were T5, T2, T1, T3 and T4 (7.15%, 4.55%, 2.99%, 2.73%, and 0%, respectively).
T5 model had the maximum secondary nutrients due to the mixture of rock phosphate and dolomite which contained high secondary nutrients. Some secondary nutrients were in liquid, organic and organic hormones. Contrary to T5, T4 model was a mixture of chemical fertilizers containing macro-nutrients, as a result, there was no secondary nutrient in it (Table 3).

Table 3 Analyzing of macro-nutrients and secondary nutrients of fertilizers applied in the experiments

Treatments	pH	OM (%)	N (%)	P (%)	K (%)	Total (%)	Ca (%)	Mg (%)	S (%)	Total (%)
T0 control (no fertilizer)	-	-	-	-	-	-	-	-	-	-
T1(pellet organic fertilizer)	6.8	14.51	3.22	0.015	0.015	3.23	0.25	0.38	236.	2.99
T2 (granular organic bio-fertilizer)	6.8	12.22	3.41	0.015	0.015	3.41	0.68	0.65	3.22	4.55
T3 (chemical and granular organic fertilizer)	7.0	5.14	27.83	0.015	0.022	27.83	0.62	0.46	1.65	2.73
T4 (chemical fertilizer by soil analysis programs)	7.2	0.0	21.04	18.005	15.00	54.00	0.0	0.0	0.0	0.0
T5 (chemical and granular organic fertilizer with hormones mixed formula)	7.5	3.14	15.12	12.402	6.500	34.00	1.5	0.85	4.80	7.15

Table 4 Vegetative growths analysis

Treatments	stem height	stem size	number of leaves per plant	leaf length	leaf width	number stem per m^2
T0 (no fertilizer)	158.2d	1.156e	42d	42d	2.1d	7.6d
T1(pellet organic fertilizer)	230.4c	1.784b	64c	64c	3.2c	7.7d
T2 (granular organic bio-fertilizer)	241.9b	1.856c	68b	68b	3.3c	8.2c
T3 (chemical and granular organic fertilizer)	247.6b	1.954b	71b	71b	3.5b	9.8a
T4 (chemical fertilizer from the soil analysis programs)	257.5a	1.985b	82a	82a	3.8a	8.8b
T5 (chemical and granular organic fertilizer with hormones mixed formula).	255.6a	2.112a	80a	80a	3.8a	9.5a
F-Test	*	*	*	*	*	*
% CV	8.7	8.4	9.5	9.5	8.4	6.6

**Significant at 95% confident interval in each column of the same period, the different in small letter indicated significant at 95% by DMRT*

Table 5 Yields and yield components

Treatments	length of corn ear (cm)	diameter of corn ear (cm)	total weight per corn ear (g)	number of kernel per ear	number of corn per square meter	number of withered kernels per ear	weight of kernels per ear (g)	weight of 100 kernels (g)	weight of corn ear with kernels removed	yields (kg/Rai)
T0 (no fertilizer)	14.7d	4.7d	167e	280d	7a	61e	105e	30c	35.3c	428e
T1(pellet organic fertilizer)	17.2c	5.4c	300d	481c	7a	32d	198d	34c	66.9b	775d
T2 (granular organic bio-fertilizer)	19.3b	6.2b	324c	495c	7a	18c	210c	42b	65.4b	857c
T3 (chemical and granular organic fertilizer)	19.3b	6.5b	329b	542a	7a	8b	229b	47a	64.8b	970b
T4 (chemical fertilizer by soil analysis programs)	21.1a	7.2a	338a	530b	7a	5a	235a	49a	67.3b	1,319a
T5 (chemical and granular organic fertilizer with hormones mixed formula)	20.4a	7.1a	343a	530b	7a	4a	234a	49a	72.6a	1,305a

The vegetative growth analysis showed the T3, T4, and T5 models having the most effective vegetative growth development as they contained high macro-nutrients from the chemical fertilizers that dissolve quickly, delivering nutrients to the plants in a form that are quickly absorbed. However, T1 and T2 models, slow-release organic fertilizers contain less nutrients resulting in the slowing down the vegetative growth. In the case of T5 model, it promoted vegetative growth more effectively than the other chemical fertilizers due to the nutrient balance of the fertilizer which provided macro-nutrients, secondary nutrients and micro-nutrient (Intanon, 2000). The effectiveness get from the result of by mixed formula components of dolomite and rock phosphate containing high levels of secondary nutrients (Ca, Mg, S) and from the bio liquid fertilizer and organic hormones components which contained micro-nutrients (Table 4).

The yields and yield components analysis was found that the maximum output production per Rai was ranked T4, T5, T3, T2, T1, and T0 models. Interestingly, the data showed no statistical difference between T4 and T5 with respect to production yields. This resulted from the three types of nutrients found in abundance in the T4 model responsible for rapid corn growth. In addition, the analysis of soil chemical elements and the host plants before adding needed nutrients helped to promote corn growth. In case of T5 which also had high yields, there were high amount of macro-nutrients, secondary nutrients and micro nutrients in the fertilizer. It was clear that these balance nutrients were required for corn production (Intanon, 2009). When considering soil improvement and preservation for sustainable yield of crops between models T4 and T5, the T5 model seemed to be a worthy choice for farmers who grow corn in poor physical soil condition (Table 5).

The total production costs analysis was found that the minimum production costs per Rai was T0, T5, T2, T1, T3, and T4 models (8,288, 8,538, 9,080, 9,238, 9,438, and 10,108 Baht per Rai, respectively). Compared with the yields, the least-cost rice production per kilogram were ranked from T5, T4, T3, T2, T1, to T0 models (6.54, 7.66, 9.73, 10.6, 11.92, and 19.36 Baht per kilogram, respectively), as shown in Table 6 (Intanon et al., 2010).

Table 6 The total production costs

Description	T0	T1	T2	T3	T4	T5
1. ploughing and levelling (2 times x 300 Baht/Rai)	600	600	600	600	600	600
2. Seeds (1,400 Baht/ bag/5 Rai) Seeds used 2 bags in total so the cost was 280 Baht/Rai. Seeds used per 1.6 Rai	448	448	448	448	448	448
3. fertilizer/bag, Baht/bag	-	400	550	650	850	700
4. plant growth hormones for supplementary food per Rai for speeding up kernel production when corn silk develops (1 time)	200	200	200	200	200	-
5. pesticide per Rai (2 times)	400	400	400	400	400	400
6. insecticide as needed per Rai (1 time)	200	200	200	200	200	-
7. fuel for water pump and looking after crops	800	800	800	800	800	800
8. labour costs for harvesting	440	440	440	440	440	440
9. transportation (Baht/ton)	300	300	300	300	300	300
total expense (Baht/Rai)	3,600	4,000	3,700	3,950	4,420	3,700
10. labour costs during corn production*	1,300	1,450	1,450	1,450	1,450	1,450
total cost (Baht/Rai)	8,288	9,238	9,080	9,438	10,108	8,538
corn yield (kg/Rai)	428	775	857	970	1,319	1,305
cost of corn yield/kg	19.36	11.92	10.60	9.73	7.66	6.54

** labour costs during corn production listed as follows:*

1. *labour costs for ploughing and levelling (2 times X 1 person X 100 Baht/Rai) = 200 B.*
2. *labour costs for direct seeding (1 time X 1 person X 100 Baht/Rai) = 100 B.*
3. *labour costs for fertilizer application (2 times X 1 person X 75 Baht/Rai) = 150 B.*
4. *labour costs for spraying hormones after development of corn silk (1 time X 1 person X 50 Baht/Rai) = 50 B.*
5. *labour costs for spraying pesticide (2 times X 1 person X 50 Baht/Rai) = 100 B.*
6. *labour costs for spraying insecticide (1time X 1 person X 50 Baht/Rai) = 50 B.*
7. *labour costs for caring the crops (800 Baht/Rai) = 800 B.*

(T0 model did not use fertilizer so there was no cost for fertilizer application)

CONCLUSION

According to the research findings, it can be concluded as follows:

1. The fertilizer contained the most macro-nutrients was T4 model (Nitrogen, Potassium, and Phosphorus, respectively) and T5 model contained the most secondary nutrients (Sulphur, Calcium, and Magnesium, respectively).
2. From the vegetative growth analysis, the models that had the most effective vegetative growth development were T4, T5, T3, T2, T1, and T0, respectively. But between T4 and T5 models show no statistical significance.
3. The data on yields and yield components revealed that the maximum output production per Rai were ranked T4, T5, T3, T2, T1, and T0 models (1,313, 1,305, 970, 857, 775, and 428 kilogram/Rai). And there was no statistically difference between T4 and T5 in relation for producing similar amount of yields due to high amount of macro-nutrients, secondary nutrients, and micro- nutrients in the fertilizer and a balance of each nutrient.
4. The minimum total expenses per Rai were T0, T5, T2, T1, T3, and T4 models, respectively; however, T0 and T1 models had the lowest corn production costs per Rai whereas, T5 and T4

models had the lowest corn production costs per kilogram and the best return on investment.
5. T5 model should be promoted for sustainable agriculture as this type of fertilizer maximizes crop yields with the greatest financial return while providing a balance and complete range of nutrients, soil amendments and effective microorganisms.

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Research article

Land Use Assessment for Proposing Sustainable Development in El Jicaral, Mixteca Region, Mexico

SERGIO AZAEL MAY CUEVAS
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: m-mihara@nodai.ac.jp

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Abstract El Jicaral is an indigenous community of around one thousand inhabitants located in the Municipality of Coicoyán de las Flores, Mixteca Region, Mexico. This region is characterized for being one of the poorest regions in Mexico, with high levels of land degradation, deforestation and water shortages. Even though several studies have been undertaken to estimate the region's area affected by soil degradation, the findings derived from these studies cannot describe accurately the conditions in the community especially for scale differences, and hence appropriate sustainable farming practices are difficult to be proposed. For this reason, the objective of this study is to assess the present land degradation condition in the study area, using a satellite map obtained from Google Earth and through the overlaying of a mesh, for the identification and classification of several variables, namely vegetation density, slope, steepness and land use, to propose suitable farming practices for mitigating land degradation. The results showed that currently there is a severe degree of soil degradation in the community, reflected in the majority of cells of the mesh with very low and low values of vegetation density, and that most of them were also in slopes up to 16%. Also, it was observed that most of the studied area land use was dedicated for agricultural purposes, even in hillside terrains. So, it is necessary to implement farming systems taking into account this topographic factor, as well as socioeconomic and environmental ones.

Keywords land use assessment, sustainable development, Mixteca

INTRODUCTION

In the last decades, sustainable development has become a primary objective, as mentioned in the Johannesburg Declaration on Sustainable Development, adopted at the World Summit on Sustainable Development (WSSD) (United Nations, 2002). This created a continuous need for accurate information on landscape changes. With the present technologies, these changes can be observed in photographs of as practically in any places in the Earth. This is important for developing environmental management and planning strategies at different scales in terms of sustaining those resources, which provide important economical goods and services (Hammad and Tumeizi, 2012).

Such strategies for environmental management also are intended to mitigate the current situation of land degradation that could be defined as the processes derived from human activities which lead to a reduction in either the biological productivity or biodiversity, as well as in the current and/or future capacity to sustain human life (Oldeman, 1998).

In Mexico, several studies have been carried out to estimate the country's resources situation, including land degradation (Semarnat, 2008). However, the results obtained cannot be compared due to differences in methodology and scale. According to the Mexican Secretariat for Environmental Protection, Natural Resources and Fisheries (SEMARNAP in Spanish), the two most recent studies are the Assessment of soil loss due to hydric and eolic erosion in Mexico, scale 1:1,000,000 (Semarnat-UACh, 2003) and Assessment of soil degradation caused by man in Mexico,

scale 1:250,000 (Semarnat-CP, 2003). However, these studies cannot describe accurately the conditions in the research site, especially for scale differences, and hence appropriate sustainable farming practices are difficult to be proposed.

STUDY SITE

For this research, the community of El Jicaral, located in the Mixteca Region was selected. Mixteca region is compounded by three states: Puebla, Guerrero and Oaxaca. The Oaxacan Mixteca (Fig. 1) is a region comprising 19,583 km^2, 8 districts, 165 municipalities, and 1,419 villages. Of its nearly 500,000 inhabitants, 68% live in rural areas and 35% belongs to one of several indigenous groups, including the Mixtecas (predominant), the Triqui, the Chochomixtecos, the Amuzgos, and the Tacuates. This region is characterized as being one of the poorest regions in Mexico, with high levels of land degradation, deforestation and water shortages (Martínez and Altieri, 2006).

El Jicaral (Fig. 2) is an indigenous community with around 1,000 inhabitants, whose spoken language is Mixteco. The main crops are rain-fed corn, chili and beans. Due to the uneven topography of the region, the upland fields are mostly situated in hillsides, being prone to land degradation processes.

Fig. 1 Mixteca Region, Mexico

Fig. 2 Land degradation in El Jicaral

OBJECTIVE

The objective of this study is to assess the present land use condition in the study area, using satellite maps obtained from Google Earth and through the overlaying of a mesh for the identification and classification of several variables, namely: vegetation density, slope and land use. In doing so, the objective is to be able to propose suitable farming practices for this community, in the hope that it could be spread throughout the region.

METHODOLOGY

Through the use of digital maps obtained from Google Earth software, a mesh was constructed above the community of El Jicaral, which is located in the coordinates 17º 07'34.56" Latitude North, and 98º11'48.9" Longitude West. Cells dimensions were 50 meters by 50 meters, covering an area of around 0.5 km^2 (Fig. 3).The digital photography used for this research was taken in November 19th 2010.

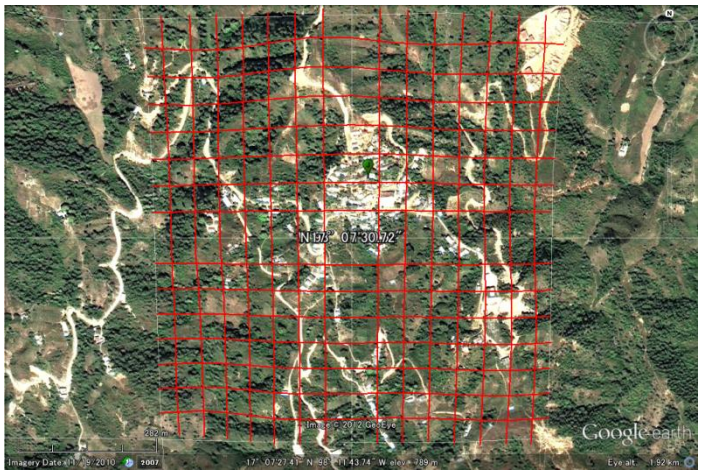

Fig. 3 Mesh projected in El Jicaral community

The Haversine formula of spherical trigonometry was used to calculate the distance between two points in the mesh using coordinates. This formula estimates the shortest distance over the earth's surface, ignoring any hills, Eq. (1).

$$harvesin\left(\frac{d}{r}\right) = haversin(\emptyset_2 - \emptyset_1) + \cos(\emptyset_1)\cos(\emptyset_2)\, harvesin(\lambda_2 - \lambda_1) \qquad (1)$$

In Eq. (1)*harvesin* is the Harvesine function, Eq. (2).

$$harvesin(\theta) = sin^2\left(\frac{\theta}{2}\right) = \frac{1-\cos(\theta)}{2} \qquad (2)$$

In Eq. (2)*d* is the distance between the two points along the sphere; *r* is the radius of the sphere, ϕ_1 and ϕ_2 are the latitude of point 1 and point 2 respectively, and λ_1 andλ_2 are longitude of point 1 and point 2, respectively.

After the mesh was projected in the study field, the elevation value of every intersection was obtained. Knowing the distance between intersections, the steepness and slope in every cell was calculated. Furthermore, with the mesh defined, vegetation density as well as land use values were assigned to every cell.

RESULTS AND DISCUSSION

Steepness and slope: Steepness (ΔL) is the difference of elevations between two points. In every cell there are four intersections, so the steepness was calculated choosing the highest value and the

lowest value among these four intersection points and then making the subtraction of these two values, as shown in Fig. 4. Then with the values of steepness, and already knowing the distance between the two points chosen (Δd) the value of slope was calculated, as shown in Fig. 5.

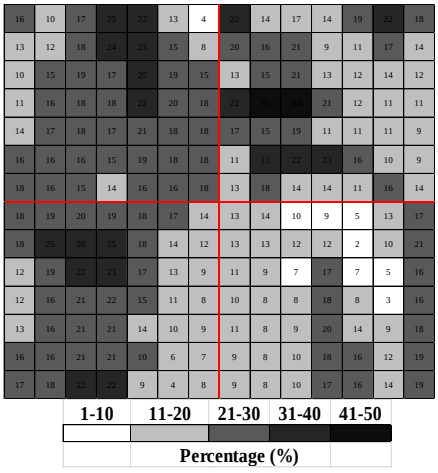

Fig. 4 Steepness values (m)

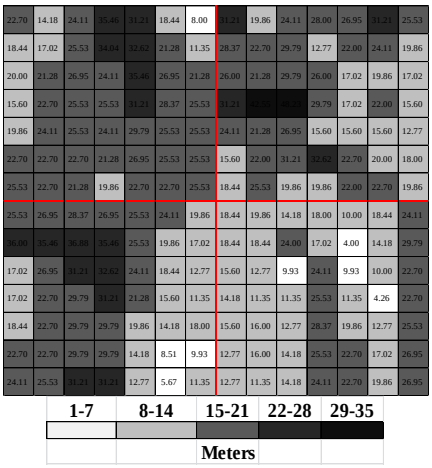

Fig. 5 Slope values (%)

The average slope value for the mesh was 21.9%. The maximum value was 48.3% and the minimum was 4%.

Vegetation density: Using the mesh projected in the research area, for every cell of 50 meters by 50 meters, a value was assigned, according to the density of vegetation observed. The values were from 1 to 5, being 1 the lowest vegetation density value and 5 the highest (Fig. 6).

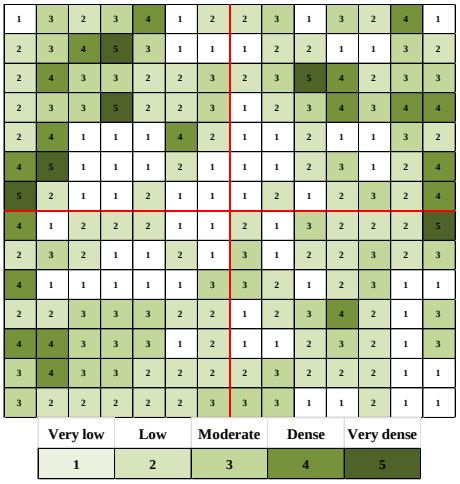

Fig. 6 Vegetation density in the study site

In the community of El Jicaral it was observed that most of the research area presented very low and low vegetation density.

Land use: The classification of land use was also carried out in the research area. As in vegetation density, values for land use were assigned to every cell according to direct observation of the digital map. The values are as follows: 1 Farmland, 2 Human settlements, 3 Water sources, 4 Forest and 5 Wasted lands (Fig. 7). Most of the area land use corresponds to farming activities, despite the steepness of the relief.

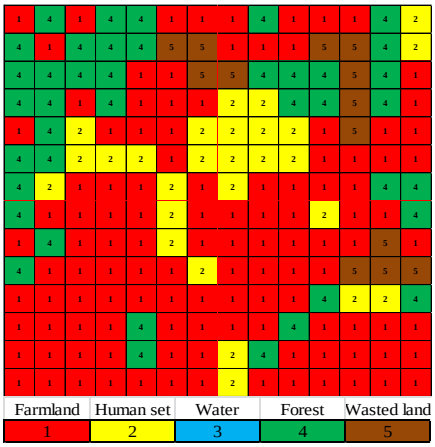

Fig. 7 Land use assessment in the research site

Land degradation: Moreover, overlapping of the Vegetation, density mesh and the Slope mesh was conducted, for determining the level of land degradation in the study site. According to Feras (2007) slopes greater than 16% are not suitable for field crops. So, taking into account this value, a mesh was projected where slopes are bigger than 16%, and where vegetation density was very low and low, as shown in Fig. 8.

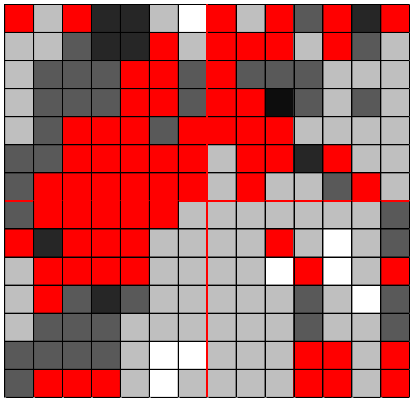

Fig. 8 Land degradation by slope and vegetation density

Cells in red indicated the areas where a high land degradation process is occurring, where slopes are bigger than 16%, vegetation density is low and agriculture is being conducted. It means that more than 35% of the study site is coming under this phenomenon.

The slope values and vegetation density variables were compared (Table 1).

Table 1 Relation between vegetation density and slope variables

Vegetation density value	Number of cells	Average slope values (%)
1	58	21.16
2	66	21.32
3	47	22.52
4	19	23.41
5	6	26.95

The highest number of cells presented a low vegetation density value, with 66 of the total of 196 cells of the study area, followed by the lowest value of vegetation density, with 58 cells. So, it could be said that there is a high level of land degradation, reflected in these data.

When comparing vegetation density mesh to land use mesh, it can also be observed that one

cause that lowest vegetation density values are predominant because most of the community area is being used for conducting farming practices in hillsides.

So, as can be observed in the land degradation mesh, more than third of the research area is under a high land degradation degree. Even of this fact, still farming practices are conducting, such as maize, beans and chili cultivation as well as shepherding of goats.

CONCLUSION

Through the present analysis of the research area it can be concluded that the land degradation is serious in El Jicaral community, where the vegetation cover is low and where land use is mainly for agricultural practices in hillsides. For this reason, a suitable farming system should be proposed, for mitigating land degradation, taking into account, socioeconomic and environmental factors, such as topography, climate, production and land-owning systems, public policies and markets.

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Research article

Gender Partiality in Land Ownership and Water Distribution in Rural Tanzania

YUMIKO TANAKA*
Institute of Social Sciences, The University of Tokyo, Tokyo, Japan
Japan International Cooperation Agency (JICA), Tokyo, Japan
Email: Tanaka.Yumiko@jica.go.jp

EIJI YAMAJI
Graduate School of Frontier Sciences, The University of Tokyo, Tokyo, Japan

Received 14 December 2012 Accepted 30 January 2013 (*Corresponding Author)

Abstract The social and economic impact of modernisation processes of agriculture is diverse in rural sub-Sahara Africa.With the introduction of modern agricultural technology, such as high yield varieties, irrigation infrastructure and water distribution, paddy yield increased in Lower Moshi Irrigation Scheme (LMIS) in the Kilimanjaro region in Tanzania. The major aim for developing LMIS was to reduce rural poverty through improving food security and income from paddy production. It was partially achieved, however, generated controversial effects of unequal land and water distribution. In Tanzania, 84% of the female labour force is engaged in agriculture, consisting of about 50% of the total agricultural labour force. However, female farmers have limited access to and control over land and water due to pre-existing social and customary practices, as well as limited participation in the decision-making processes. Land ownership is a condition for obtaining a membership in the water association. And water is becoming scarce due to climate changes, encroachment on the forests and conflicts between upper-stream and down-stream. The main objective of this paper is to analyse relationships between women's land ownership and water distribution through a case study of modern irrigation project. The research methods used are literature review, semi-structured interviews with male and female farmers, and statistical data analysis of landholdings. Main results of the study are: 1) the number and share of female land ownership increased in the last 25 years, however, the social and gender partiality about land inheritance and ownership are still persistent which prohibit female farmers from equal access to irrigation water, 2) changing regulations and practices of water users associations to be more gender-responsive lead into more equitable and impartial water distribution.

Keywords gender partiality, land ownership, water distribution, modern irrigated agriculture, Kilimanjaro, Tanzania.

INTRODUCTION

Land has a central value for people in sub-Sahara African countries providing a source of identity, food security and income, and constitutes an asset of cultural and spiritual significance as well as increasing market commodity (Benjaminsen and Lund, 2003). As land becomes scarce and acquires economic value, a demand for more individualised and formalised land ownership rights increases. An evolutional theory of land rights has been debated by researchers on land tenure system in Africa leading to the criticisms that it is un-automatic for rural societies to "evolve" from informal/customary practices, and successfully adopt formal/statutory laws (Platteau, 1996). Rural women, subsistence farmers and pastoralists are most unlikely to be guaranteed for the security of land tenure if the formal land titling is provided (Yngstrom, 2002; Odgaard, 2003). The development agencies argued that the farmers become more productive and efficient provided with the formal land titles and would increase investment in agriculture production. However, it is unclear under what specific conditions the security increases, especially for female farmers and

small landholders.

In Tanzania, the Land Act 1999 guaranteed the gender equality in legally acquiring and owning the land through registration and having the land title. The Village Land Act 1999 provided for women to be involved in decisions regarding the use and disposal of village land through equitable representation in the village land councils. The Land Act No.2 of 2002 established Land Tribunals regulating the assignment of at least 43% of women as tribunals, and Land (Amendment) Act 2004 allowed women to mortgage their land on the same basis as men.

In reality, however, women tend to lose customary land and water rights along with land commoditisation processes and modernisation of irrigation systems (Upperman, 2000; Englert, 2008). The customary rights of water are closely associated with land rights. Since the efficacy of land laws has been dismal and women are continuously excluded from accessing and owning the land, the discriminatory decision-making processes and inheritance practices, dominated at the household and community levels, need to be scrutinised (Mascarenhas, 2007). Given that 84% of the female labour force is engaged in agriculture, consisting of 50% of the total agricultural labour force, knowing how to secure land and water rights with substantive effects for female farmers needs to be examined.

OBJECTIVE

The main objective of this study is to analyse the relationships between women's land ownership and water distribution and find a new perspective for changing gender partiality through a case study of Lower Moshi Irrigation Scheme (LMIS) project in the Kilimanjaro region in Tanzania.

METHODOLOGY

Methodologies adopted in this study include: 1) literature reviews; 2) analysis of 1,845 sampled farmers based on dispersed lists of landholders between 1987 and 2013 kept by the Lower Moshi Irrigation Association (LOMIA) and LMIS office, which the author consolidated and analysed; 3) interviews with farmers (8 persons in 2011 and 42 persons in 2012), local government officials, LMIS office staff and Japanese experts. The first fieldwork was conducted in July 2010, the second in November 2011 and the third in August-September 2012.

RESULTS AND DISCUSSION

The LMIS is located at a distance of 15 to 20 km in the southeast of Moshi town in the Kilimanjaro region. It was developed with financial and technical assistance by the Japanese government. The irrigation facilities were handed over to the Tanzanian government after completion in 1987. The irrigated area for paddy is about 1,100 ha in total. There are 5 divisions (Upper Mabogini, Lower Mabogini, Ru ya Kati, Chekereni and Oria), consisting of 45 blocks with about 3000 plots in total (Fig. 1). Each block is about 10ha to 30ha. Average plot size is 0.3ha. The average paddy yield increased from 1.5-2.0 tons/ha to 6-7 tons/ha as a result of the project.

Based upon the data obtained from the LOMIA lists of landholders, it was found that the female farmers consist of 21.1% of total numbers (390 females out of 1,845 landholders), and they owned 16.8% of the total plots. Therefore, it was found that an overall gender gap exists in land ownership. As shown in Fig.2, the frequency distribution of landholdings indicates that average size of the female-owned plot is more concentrated towards the smaller size than those of male farmers meaning that female farmers are more clustered at the subsistence levels.

One block each from Upper Mabogini, Lower Mabogini and Chekereni was selected for this study. The selection criteria are: 1) the blocks belong to the up-stream with plenty of irrigation water, mid-stream with rotationally distributed water and down-stream with acute water shortage; 2) the share of female landholding exceeds 20% of the total block of landholders; 3) the share of female landholding areas exceeds about 20% of the block area; 4) the average size of female landholding is less than 3,000 m^2, meaning that the majority consists of small-holders.

In all the blocks studied, the number of female landholders increased, as well as their share as shown in Fig. 3. However, data of Lower Mabogini in 1987 was unavailable. Female's share reached to almost 50% in Upper Mabogini and 57% in Lower Mabogini in 2013. The female share of the total landholding areas also increased in all the blocks as shown in Fig.4. It reached up to 51% in Upper Mabogini and 44% in Lower Mabogini. The changes in the average size of the plots owned by farmer poses a somewhat different trend from the previous figures as shown in Fig.5. Only in Upper Mabogini the average size of the plots owned by females had increase, whereas in the other two blocks it decreased between the year 2008 and 2013. In the case of male farmers, it decreased in all the blocks. The average size of the plots owned by farmers had also decreased meaning that the segmentation of land has been progressed in all the blocks.

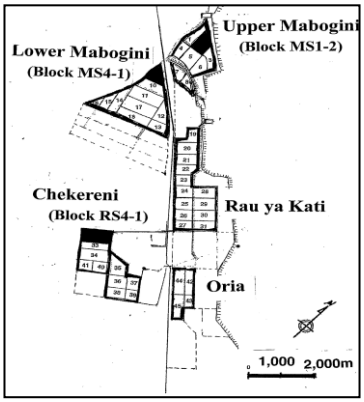

Fig. 1 Divisions in LMIS and three blocks studied

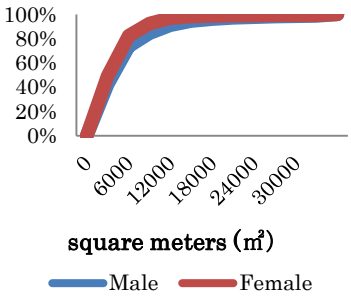

Fig. 2 Frequency distribution of average landholding size per farmer in LMIS

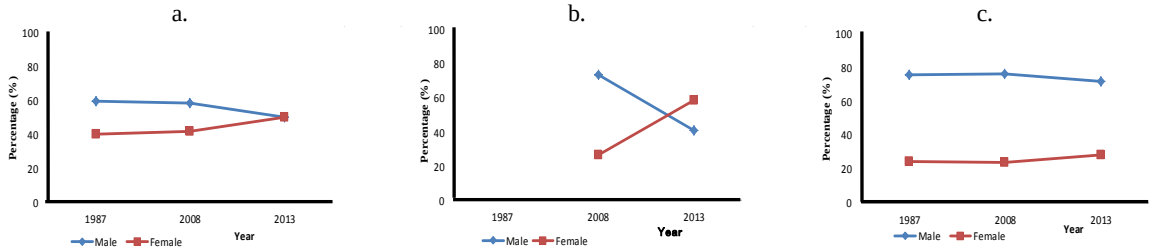

Fig. 3 Share of total landholders by gender

a. Upper Magobini (up-stream), b. Lower Mabogini (mid-stream), and c. Chekereni (down-stream)

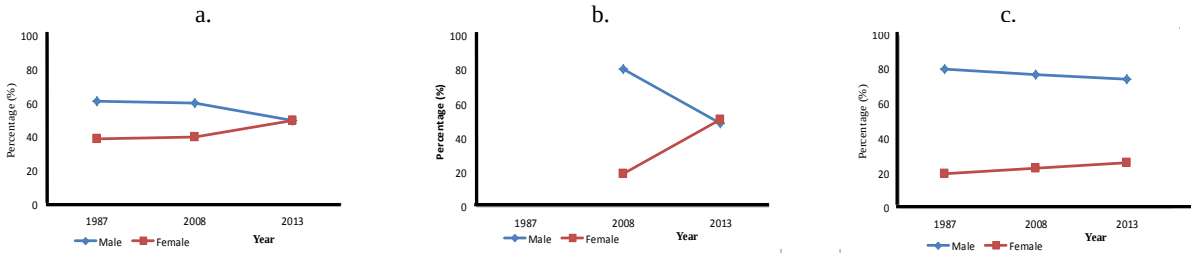

Fig. 4 Share of total landholding area by gender

a. Upper Magobini (up-stream), b. Lower Mabogini (mid-stream), and c. Chekereni (down-stream)

The changes in female holding plots in Upper Mabogini, Lower Mabogini and Chekereni are shown in Fig. 6, 7, and 8, respectively.

The share of female land owners, the number is increased in all 3 blocks in LMIS as indicated above. It reached nearly half in the case of Upper Mabogini and Lower Mabogini, indicating "feminisation of agriculture" is taking place, however, the changes have been rather slow in Chekereni. More female farmers are engaged in paddy production today, whereas men are breaking

away for alternative sources of income. On the other hand, the average size of landholding declined in all the blocks. This means more numbers of female farmers became landholders but held a much smaller size plot, except in Upper Mabogini, where the average size of female landholding slightly increased.

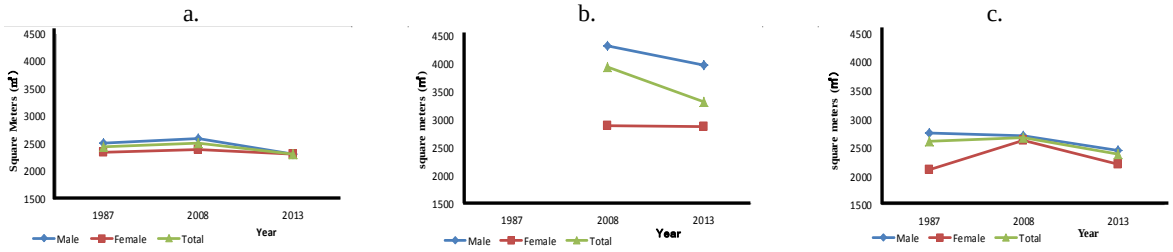

Fig. 5 Average plot size owned by a farmer

a. Upper Magobini (up-stream), b. Lower Mabogini (mid-stream), and c. Chekereni (down-stream)

Fig. 6 Changes in female owned plots in Upper Mabogini (up-stream) from 1987 to 2013

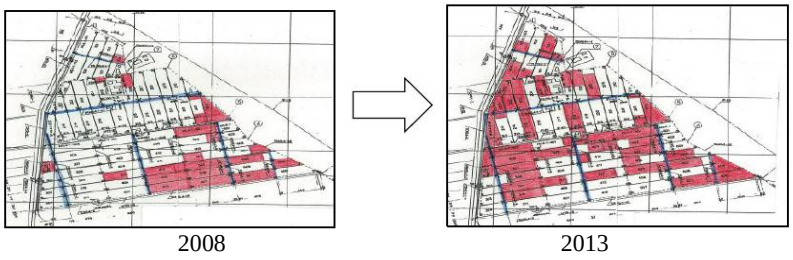

Fig. 7 Changes in female owned plots in Lower Mabogini (mid-stream) from 2008 to 2013

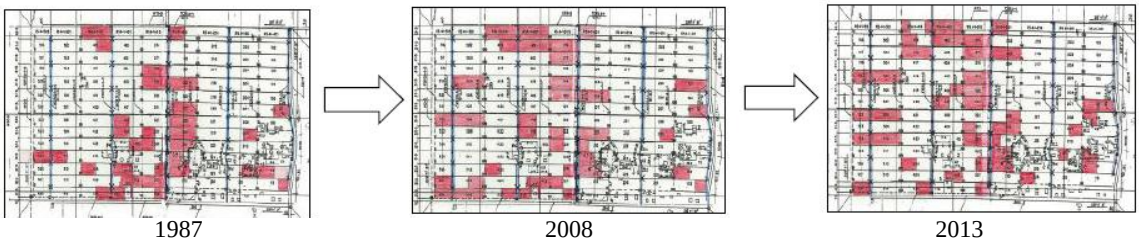

Fig. 8 Changes in female owned plots in Chekereni (down-stream) from 1987 to 2013

The socio-economic features as well as the difference in views about water rights of Upper Mabogini, Lower Mabogini and Chekereni are shown in Table 1. If women have more access to education, information and networking, they are less bound by traditions and attending LOMIA meetings and speak out about their views as seen in Upper Mabogini and Lower Mabogini. Some women groups organised themselves into collective farming using rented plots. With their earnings, they even purchased the plots. They are also active in engaging in non-farm income-generating activities. On the other hand, women in Chekereni down-stream face extreme difficulties with obtaining water. They pay water fees to LOMIA, but unable to access water. They face difficulties in physically fighting over water with male farmers and going out at night waiting for their water

turn. Thus, they have to pay extra amounts to send some men to secure water at night. They complained about unfair distribution of water, but if they are widows and do not have sons, their voices are unheard in the negotiations and meetings. Although, in principle the water rights are attached with landholding rights, the landholding rights do not automatically guaranteed to female farmers with securing water rights. They get more marginalised when water gets scarce.

Table 1 Main features of three irrigation blocks studied

	Upper Mabogini (Up-stream)	Lower Mabogini (Mid-stream)	Chekereni (Down-stream)
Geographical conditions	Surrounded by a river and spring, restricted for area expansion.	Originally flat upland, so expansion was easy.	Arable land became unavailable for new comers by 1980s.
Water situation and paddy cultivation	Due to plenty of water available, they continued cultivating paddy twice a year since 1987.	Water is not enough. Paddy cultivation is rotational, once in 2~3 years. They alternately grow maize.	Due to acute water shortage since 2008, they stopped cultivating paddy. Instead, they grow maize and beans in the plots today.
Social features	Early settlers. Little support by government as it is near Moshi town. Many live in the town and have alternative income sources.	Multi-ethnic groups migrated into the area. The tradition is not so strong, and women inherit and purchase the land.	Migration started in early 1970s. Government provided support. Now the most impoverished area. Local governance is weak.
Landholdings	Mostly small farmers, with a few large holders.	Many large holders, as land was cheap and abundant.	Mostly small holders under collective farming (*Ujamaa*).
LOMIA (water association)	People are not interested in LOMIA. But recently, leaders taking initiatives for collective repair works of infrastructure.	LOMIA is relatively well functioning, and farmers, both men and women, follow the water distribution calendar.	Due to acute shortage of water, severe disputes occur within the blocks and between mid- and up-streams. LOMIA is not working.
Ideas about water conflicts and distribution	Most men and women think they have customary rights and priorities to use water as they are up-stream, and down-stream should grow maize. However, renters, labourers and young owners think the water distribution should be rotational, and one woman renter even thinks that they should skip one season in Upper Mabogini.	The block leader and some women think the water should be used rotationally. One woman land owner even thinks the water distribution should start from the down-stream, Chekereni, since they are suffering most from water shortage.	Most men and women think that the up-stream does not have priority rights to water and water should be used rotationally in all LMIS. Majority think that water should be distributed equally. Women and widows have great disadvantages for negotiating with watermen and accessing water, especially at night to get water turns.
Women's activities and groups	Most women live in the town. They have better access to education and information, and individually actively engaged in economic activities.	Women groups are active in income-generating activities and collective paddy cultivation in rented plots.	Only churches and mosques organise small women's groups. Women are busy working as wage labourers in other places. Not attending village meetings.

Source: Field interviews undertaken by the author.

"Ujamaa" is collective farming and villagisation policy introduced by government in the 1970s.

Women can obtain agricultural land but have to go through difficult processes. The ways they obtain land are mainly by inheritance from father (occasionally mother or family members), by inheritance from husband, by purchasing with own money, and in earlier days during 1960s and 1970s by allocation through official institutions such as colonial government, collective farm system, etc. The main ethnic groups in LMIS are Chagga and Pare. In Chagga tradition, land is the source of identity, providing cultural and spiritual values. It has been and still is only the male members who inherit their family and clan's land, as women get married outside of the clan member. It is shameful for men without land, thus leading into fragmentation of arable land after generations. With the enactment of Marriage Laws (1971 and 2002) along with women's groups movement, such practices are gradually changing, however, still persistent in their discourse on landholdings.

Women's landholding is mostly relational. The widows can inherit husbands' land today, however, mostly before passing them onto their sons. They are unable to sell family and clan's land, but can sell self-acquired land after marriage. In addition to the cumbersome bureaucratic procedures and money cost to formalise the land title, they are afraid that such an action may cause unnecessary suspicion among the sons and family members, and as a result they may lose the usufruct rights. They know that if they keep quiet about the formal rights, they can continuously use the land. As long as one can count on the good will of village offices and community members who they know in the village, the security of customary land rights might be guaranteed. However,

women are also aware of the constraints and risks of such situations.

LOMIA allows only the land owners to be a member and attend the meetings. The renters and labourers are usually excluded though the majority are women who are engaged in the major part of cultivation and maintenance of irrigation facilities. Female landholders are called for the meetings when their labour contributions for irrigation maintenance are required and water fees need to be collected. Women are more willing to talk about water allocation issues between up-stream and down-stream and sharing water resources as shown in Table 1. However, their participation in LOMIA activities is non-active. There are only 3 women out of 28 central board members of LOMIA and they are only serving as treasurers.

CONCLUSION

The main findings of this study are: firstly, although the number and shares of agricultural land owned by females was increased from the past 25 years, it is not automatically considered a gain for women. In order to secure land rights, LOMIA should provide legal consultations and information to women so that they can easily register their names as landholders; secondly LOMIA should allow both of husbands and wives as well as cultivators participation in decision-making processes for water distribution. Women and cultivators (renters and labourers) are more open to talk about sharing water between up-and down-streams, which would lead into creating new and more impartial systems for water distribution; thirdly, the Lower Moshi irrigation office should prove technical guidance on saving water in up-stream with proper infrastructure maintenance, which women farmers are already involved and thus their knowledge and views may lead to more appropriate maintenance means. As some interviewed women commented, if they will get more chances to get involved in meetings and decision-makings, they can speak out and share their ideas.

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Research article

Changes in Surviving Microorganism in Cow Manure with Adding Lime Nitrogen

YUTA ISHIKAWA
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: m-mihara@nodai.ac.jp

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Abstract Pathogenic bacteria known as *E. coli* may survive in cow manure and may efflux from upland fields where cow manure was applied. So, treating of *E.coli* through fermentation process has been focused. It has been considered that air drying method was effective method for decreasing *E.coli*. However, this treatment may possibly eliminate not only pathogenic bacteria but also useful bacteria for decomposition. This study aimed to investigate the changes in number of *E.coli*, coliform bacteria and general bacteria during the fermentation of cow manure with adding lime nitrogen (nitrolime). Samples used were fresh cow dung, 2 weeks and 12 weeks fermented manure. Lime nitrogen was added to all three types of dung samples then were kept in incubator within 14 days. Sampling, stirring and supplying of physiological saline were conducted. Based on the experimental results, there was a significant decrease in *E.coli* and coliform bacteria in cow manure after adding of lime nitrogen; however there was no decrease in general bacteria. It was observed that controlling to pH 9.0 in cow manure samples was appropriate for decreasing *E.coli* and coli form bacteria during cow manure fermentation with minimum damage to general bacteria. Therefore, it was concluded that treating of cow manure by adding lime nitrogen, especially controlling to around pH 9.0, is an effective strategy for sterilizing pathogenic bacteria such as *E.coli* and other coliform bacteria with minimum damage to general bacteria.

Keywords *Escherichia coli*, general bacteria, lime nitrogen, cow dung, pH

INTRODUCTION

Big amounts of cattle dung has been produced in farms. The point of view of organic agriculture, making manure was considered as proper treatment. However, bulk production of manure may possibly contain immature fermented manure. In addition, the pathogenic bacteria known as *Escherichia coli* (*E.coli*) or coliform bacteria may survive and remain in immature fermented manure (Chun-Ming et al., 2005; Indira et al., 1998). Especially, cow dung has an amount of *E.coli* than other cattle dung (Nakazawa and Sameshima, 2002). These bacteria may survive in soil (Islam, M et al., 2005) and may be released from grazed land and upland field applied with immature fermented manure (Mishra et al., 2007; Yagura et al., 2006; Ishikawa and Mihara., 2010). The efflux of *E.coli* causes water pollution or contamination of potable water sources affecting human health (Tamura et al., 2006; Mishina et al., 2007).

So, treatments to sterilize cow dung of *E.coli* during fermentation process were focused. Some treatments as air drying treatment (Saito and Mihara, 2010) were carried out. However, air drying treatment has possible affect to not only *E.coli* or coliform bacteria but also general bacteria (Ishikawa and Mihara, 2011). On the other hands, it was reported by Minato et al., (2001) that pH control by lime nitrogen adding treatment, it decreases not only *E.coli* but also beneficial bacteria. However, beneficial bacteria which affect fermentation of manure change in fermentation stage. So, it is necessary to observe the surviving of microorganisms in lime nitrogen adding treatment.

This study aimed to observe the survival of several microorganisms such as *E.coli,* coli form bacteria and general bacteria under lime nitrogen adding treatment.

METHODOLOGY

Cow dung and fermented manure used in this experiment were collected from Fuji Farm, a cattle farm of Tokyo University of Agriculture located in Shizuoka Prefecture (Fig.1). There were three types of cow dung collected for this experiment, fresh cow dung, 2 weeks, and 12 weeks fermented manure with water contents at 76%, 75% and 68% respectively. In addition, cow dung and manures contained 90%, 89% and 86% of organic matter. The colony forming units (cfu) of *E.coli* were 20×10^6 in cow dung, 1×10^3 in 2 weeks fermented manure. In 12 weeks fermented manure, *E.coli* was not observed. Also, the colonies of coli form bacteria was 1×10^5 cfu/g in cow dung and 0 cfu/g in 2 and 12 weeks fermented manures. The number of general bacteria was 128×10^6 in cow dung, 236×10^6 in 2 weeks fermented manure and 93×10^6 in 12 weeks fermented manure**.**

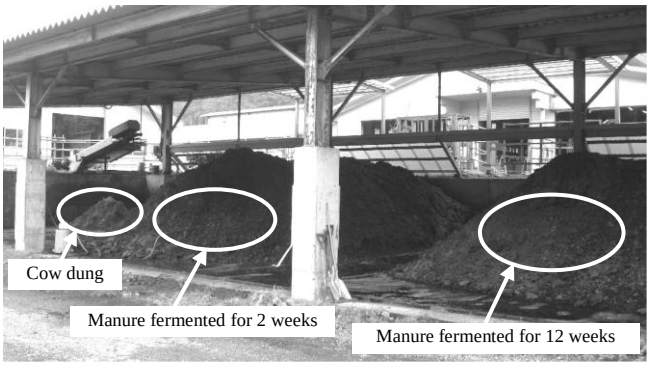

Fig.1 Situation of cow dung and manure

Table 1 Properties of cow dung and fermented manure

	Period of fermentation	*E.coli* (cfu/g)	Coliform bacteria (cfu/g)	General bacteria (cfu/g)	Water contents (%)	Organic matter (%)
Cow dung	0 days	20×10^6	1×10^5	128×10^6	76	90
Manure	2 weeks	1×10^3	0	236×10^6	75	89
Manure	12 weeks	0	0	93×10^6	68	86

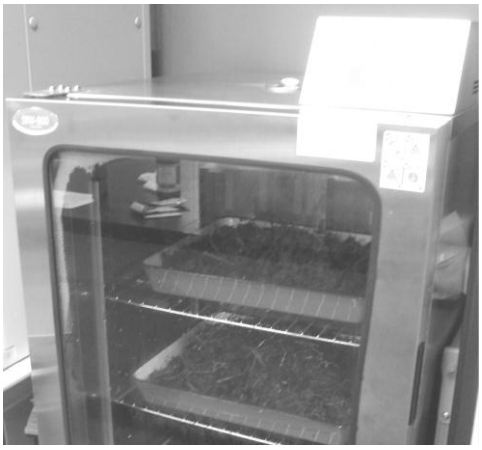

Fig. 2 Situation of incubator

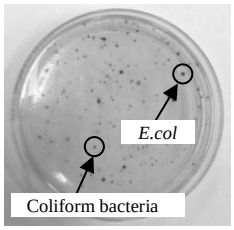

Fig. 3 Colonies of *E.coli* and coliform bacteria

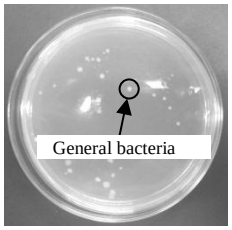

Fig. 4 Colonies of general bacteria

Both of cow dung and manure at 3 kg were mixed after adding 60 g of lime nitorogen. Then, they were put in incubator at 37 degree temperature for 14 days (Fig. 2). At 4th, 7th, 11th, 14th day, sampling, stirring and supplying of physiological saline were conducted.

The number of *E.coli*, coliform bacteria and general bacteria in sample were measured through laboratory experiments. The analysis of *E.coli* and coliform bacteria was carried out through counts of colonies on XM-G agar medium as shown in Fig.3. The analysis of general bacteria was carried out with general agar medium (Fig. 4). In addition, the pH in cow dung and manure were measured through laboratory experiments.

RESULTS AND DISCUSSION

The changes in the number of *E.coli* in each sample were summarized in Figs. 5-7. In cow dung, *E.coli* decreased after lime nitrogen was added then, *E.coli* was not observed. Based on the results of variance analysis, significant difference was observed. In 2 weeks fermented manure, *E.coli* was decreased after lime nitrogen was added as well as cow dung. However, significant difference was not observed. In 12 weeks fermented manure, *E.coli* was not observed during experiment.

Changes in coliform bacteria were shown in Figs. 8-10. In cow dung, coliform bacteria were sterilized by lime nitrogen adding treatment as shown in Fig. 8. Moreover, it showed a significant difference of 99% between before lime nitrogen adding and after. In addition, coliform bacteria were not detected from 2 weeks and 12 weeks fermented manure. Therefore, it was considered that the adding of lime nitrogen is an effective treatment to decrease pathogenic bacteria as *E.coli* or coliform bacteria. Figs. 11-13 show changes in general bacteria. In both of samples, it showed a tendency that the number of general bacteria was not decreased by adding of lime nitrogen. Based on results of variance analysis, significant difference was not observed during experiment. Therefore, it was considered that general bacteria which contain beneficial bacteria are not affected by lime nitrogen adding treatment.

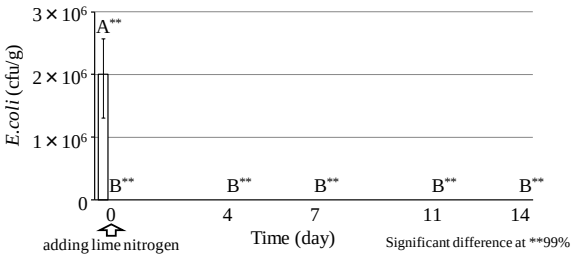

Fig. 5 Changes in *E.coli* (cow dung)

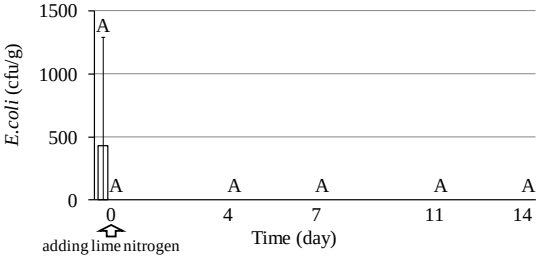

Fig. 6 Changes in *E.coli* (2 weeks fermented manure)

The pH in cow dung and manure are indicated in Fig. 14. In all of samples, pH was increased to around 9.0. It was reported that *E.coli* or coli form bacteria can survive from pH 4.4 to 9.0 (Nakanishi and Maruyama, 2009). Furthermore, based on a report of Fujita (1993), proper pH for fermentation of manure is 8 to 10. So, it was considered that pH controlling to around 9.0 is able to decrease *E.coli* and coliform bacteria without sterilize general bacteria which contain beneficial bacteria**.**

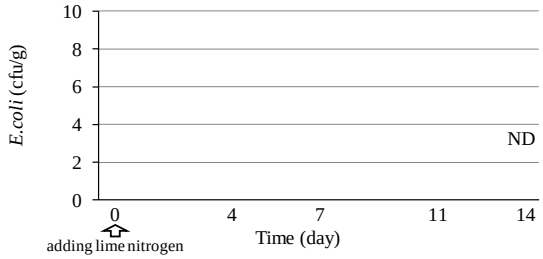

Fig. 7 Changes in *E.coli* (12 weeks fermented manure)

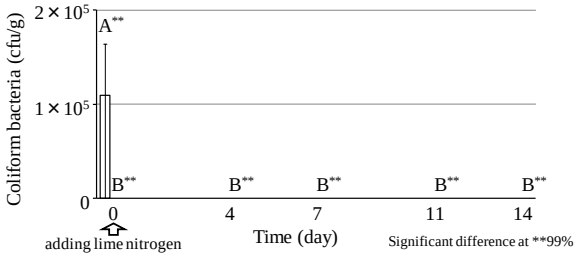

Fig. 8 Changes in coliform bacteria (cow dung)

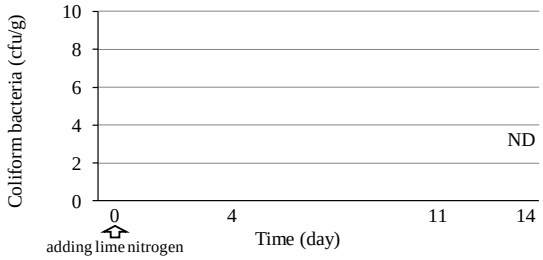

Fig. 9 Changes in coliform bacteria (2 weeks fermented manure)

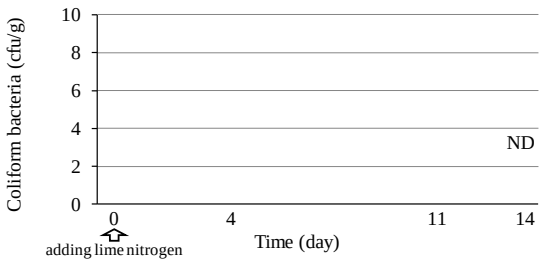

Fig. 10 Changes in coliform bacteria (12 weeks fermented manure)

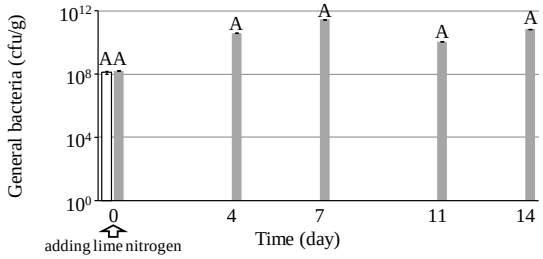

Fig. 11 Changes in general bacteria (cow dung)

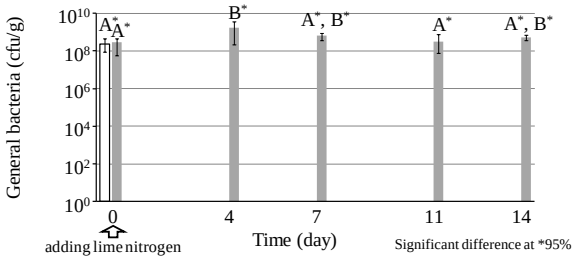

Fig. 12 Changes in general bacteria (2 weeks fermented manure)

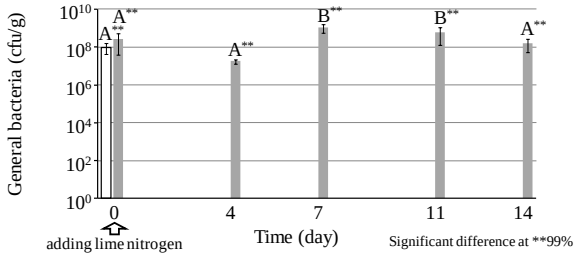

Fig. 13 Changes in general bacteria (12 weeks fermented manure)

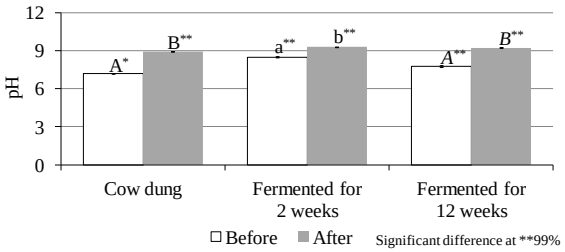

Fig. 14 Changes in pH of manure

CONCLUSION

This study aimed to observe the survival of *E. coli*, coli form bacteria and general bacteria under lime nitrogen adding treatment in cow dung, 2 weeks and 12 weeks fermented manure.

Based on experimental results, *E. coli* was decreased after lime nitrogen addition treatment. Moreover, there was a significant difference observed. Also, coli form bacteria were sterilized by lime nitrogen as well as *E. coli*. On the other hand, lime nitrogen has not affected the number of general bacteria which contain beneficial bacteria.

In addition, as the results of pH, there were tendencies that pH was increased to around 9.0 which were proper for decreasing *E. coli* or coli form bacteria with minimum damage to general bacteria.

Therefore, it was concluded that the pH control to around 9.0 using alkaline as lime nitrogen is an effective treatment for decreasing pathogenic bacteria in fermentation process.

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Research article

Resource-based Alternative Approach on Rice Bug *(Leptocorisa oratorius* Fabricius*)* Management for Food Security and Bio-safety

MARINA A. LABONITE*
Research and Development Center, Bohol Island State University, Philippines
Email: mtalabonite@yahoo.com.ph

Received 17 December 2012 Accepted 6 May 2013 (*Corresponding Author)

Abstract: In the Philippines, rice bug is a serious menace at reproductive stage of rice causing qualitative as well as quantitative losses resulting in yield reduction by 14% (PGCPP-BPI-MAF, 1986). Thus, chemical pesticides become an instant management strategy in rice culture for many decades until even after users realized its adverse effects on environment and human health. Though effective, various reports are made on pesticide residues in food, soil, water, air and overall environment causing health problems (Magallona, 1985). These problems are more than lessons from the technology. Hence, the need to seek for an effective technology that also reduces input costs while assuring supply of safe and nutritious food for man and all useful organisms, tapping common yet underutilized pest-repellent plant species. The Hindu (2002) reported that companion planting with repellent and trap crops is among the safe but sure ways to manage the insect pests of crops. Repellents are plants with strong natural aroma that can ward-off insect pests away. This experimental research determined the usefulness of resource-based alternative approach on rice bug management using four repellent plant species. A two-factorial randomized complete block design was employed with sites and repellent species as factors. The indigenous repellents tested in three replicates per site were: Bamboo (*Bambusa levis* L.), Erect Shell (ES) Ginger Plant (*Catimbium haenkei* L.), Malubago (*Hibiscus tiliaceus* L.) and Sand Ginger (*Kaempferia galanga* L.) with one control treatment as check. The statistical analysis revealed that the repellents tested were all effective in reducing rice bug population and infestation compared to the control, however, Bamboo and Sand Ginger are the most significantly effective. Findings imply that resource-based approach using repellents is efficient in reducing rice bug population and infestation, thus, it is valuable in preventing its yield loss in producing safe food and in making the rice agro-ecosystem safe for the useful organisms.

Keywords resource-based alternative approach, pest management, food security, bio-safety, chemical approach in pest management, repellents

INTRODUCTION

Rice grain is an important human food in many parts of the world but the plant is a host of various insect pests like rice bugs. Heinrich (1985) observed that rice bugs nymphs are more active feeders than adults but the latter cause more damage as they feed for a longer period of time. Feeding may contaminate grains with pathogens that cause discoloration or pecky rice of impaired quality and susceptibility to breakage during milling. To avoid this, farmers resort to pesticide sprays when rice bugs are in a damaging stage and state.

However, the World Bank (2005) warned that if mismanaged, most pesticides can lead to crop losses and pose a risk to human health and the environment. This includes the cost incurred due to pesticide clean-up, cost related to human health and cost incurred due to increase in pesticide resistance in insects and disease vectors and destruction of natural enemies of pest species, that may result in lost value in agricultural produce. Hence, there is a need for an alternative approach that assures safe and nutritious food for man and all useful organisms.

Mihindo (2002) asserted that humankind has become more conscious on the fragility of the earth in the face of technological development. The conventional farming technology has precipitated many of our problems as people are left with a depleted and abused environment and deepening moral apathy. Success in development is more likely to be achieved when traditional knowledge systems are fused with modern technology.

Among the indigenous, safe but sure ways to manage insect pests of crops is companion planting with repellent crops (Hindu, 2002). Repellents are plants with chemical properties to ward off pests away. However, no data are available that show the effectiveness of these species to rice bugs, hence, this study was done.

The experiment aimed to determine the effects of indigenous repellent species on rice bug population, infestation and yield of rice. Being proven effective, these plant genetic resources shall be conserved and utilized as an alternative approach on rice bug management for food security and bio-safety.

OBJECTIVE

The main idea of this research was to determine the usefulness of a resource-base alternative approach using indigenous repellent plant species on rice bug management. Specifically, the study was aimed for the following objectives:

1. To assess the usefulness of *Bambusa levis* L., *Catimbium haenkei* L., *Hibiscus tiliaceus* L. and *Kaempferia galanga* L. in resolving rice bug infestation
2. To identify the repellent species that is significantly effective in minimizing rice bug population and infestation
3. To evaluate the effect of indigenous repellents on the yield of treated crops and
4. To find out the interaction of factors particularly the site and repellent species on the infestation of rice bugs.

METHODOLOGY

Participatory on-farm experimentation was employed with the cooperation of farmers in four municipalities with natural growth of repellent species: Bilar, Pilar, San Miguel and Tubigon in Bohol, Philippines. A two-factorial randomized complete block design (RCBD) with three replicates was adopted. Sites and the botanicals are the two factors studied. Four indigenous repellent species were tested with one control treatment as check with no repellents used. The repellent Bamboo (*Bambusa levis* L.) locally named Butong; Erect Shell (ES) Ginger Plant (*Catimbium haenkei* L.) or Tagbak; Malubago (*Hibiscus tiliaceus* L.) or Mabago; and Sand Ginger (*Kaempferia galanga* L.) or Kiso were used.

The rice crop host of the rice bug was grown following recommended cultural management practices except on pest management. To confine the rice bug/test pest and facilitate data collection that measure the effectiveness of the repellents, a mesh net enclosure at 1.5 m high was established in all plots in four sites before heading stage of rice started.

Data collection was done weekly in all plots in four sites in four consecutive weeks. The data gathered were rice bug (nymphs and adults) population, number of infested grains per panicle using 10 randomly selected panicles and the yield of rice in kilograms at 14% moisture content per plot per block. To determine the significance between the treatments, all data gathered were analyzed using analysis of variance (ANOVA). The same data were subjected to further test of significance using Tukey's Honest Significant Difference (HSD) Test.

RESULTS AND DISCUSSION

Usefulness of repellent species in reducing rice bug population

The average population of rice bugs is presented in Fig. 1. It reveals a fluctuating trend. The data imply that Bamboo was very effective and useful in reducing the rice bug population, followed by Sand Ginger, ES Ginger Plant and Malubago as the least effective. Though Malubago was less effective, data still indicated that it has much lower rice bug count than the Control.

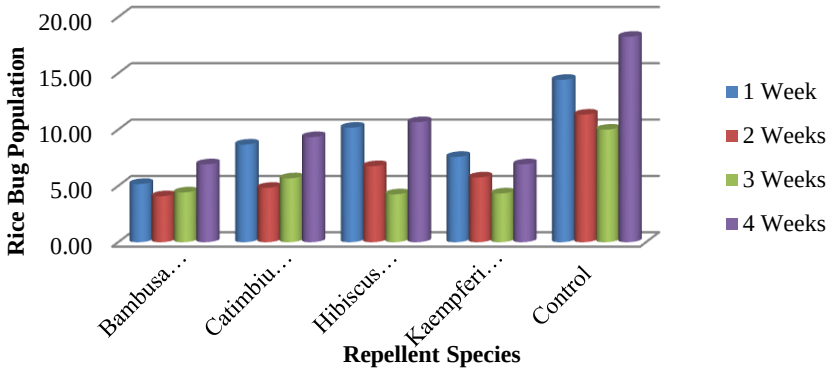

Fig. 1 Average rice bug population per repellent species in all sites

The ANOVA on the rice bug population gives a highly significant difference between repellents, between sites and in its interactions. This means that rice bug population in the experiment was affected by the significant effects of each repellent used and by the varied conditions of the study sites.

Table 1 Tukey's HSD Test on rice bug population as affected by repellent species

Repellents		RICE BUG POPULATION							
		1st Week		2nd Week		3rd Week		4th Week	
		Subset		Subset		Subset		Subset	
		1	2	1	2	1	2	1	2
Bamboo	*B. levis*	5.17		4.08		4.42		6.92	
Sand Ginger	*K. galanga*	7.58	7.58	5.75		4.33		6.92	
ES Ginger	*C. haenkei*	8.67	8.67	4.83		5.66	5.66	9.33	
Malubago	*H.tiliaceus*	10.17	10.17	6.75	6.75	4.25		10.67	
Control			14.42		11.33		10.00		18.25
Significant		0.276	0.083	0.507	0.095	0.905	0.120	0.168	1.000

** Means within the same subset are not significant to each other.*

Table 2 Tukey's HSD Test on rice bug population as influenced by site

Sites	RICE BUG POPULATION								
	1st Week		2nd Week		3rd Week		4th Week		
	Subset *		Subset *		Subset *		Subset *		
	1	2	1	2	1	2	1	2	3
Bilar		11.53		11.33	2.80		7.40		
Pilar	8.47	8.47	5.53			11.39			16.73
San Miguel	3.00		4.13		4.60			11.87	
Tubigon		13.80	5.20		4.13		5.67		
Sig.	0.096	0.107	0.776	1.000	0.620	1.000	0.601	1.000	1.000

** Means within the same subset are not significant to each other.*

Table 1 and Table 2 show the Tukey's HSD Test of significance on the rice bug population. Table 2 shows a similar weekly trend of significantly lower rice bug population for Bamboo-treated crops ranging with only 4.08 to 6.92 bugs over the other repellents and the control which have

higher average count ranging 10.00 to 18.25 bugs. The two Ginger species are also showing lower bug population with 4.33 to 7.58 for Sand Ginger; and 4.83 to 9.33 bugs for ES Ginger Plant compared to the control. Table 3 illustrates the significant and constant influence of San Miguel site on the effectiveness of the repellents in reducing rice bug population ranging from 3.00 to 11.87 bugs compared to other sites, though Tubigon and Pilar follow the trend while Bilar's influence on the effectiveness of the repellents came only on the last two weeks.

Effective repellents in minimizing rice bug infestation

The rice bug infestation in terms of average number of rice bug-infested grains per site per repellent is presented in Fig. 2. The data indicate that rice bug infestation was consistently low in the Bamboo-treated plots and consistently high in the Control plots. This implies that Bamboo is a very effective controlling species for rice bug, and thus, can be used in its management while producing a safe food and securing the agro-ecosystem for all life forms. The data also disclosed that in all sites, Bamboo is an effective repellent for rice bug management as it reduced its infestation better than the other species wherever it was. However, the other three repellent species gave better protection than the Control.

Table 3 shows that rice bug infestation in repellent-treated crops is significantly different compared to the Control at 5% level. However, the difference in infestation between sites is highly significant at 1% level, so do with the interactions of the species and sites. This analysis implies that the degree of effectiveness of the repellents is not only governed by the inherent quality of each species itself but also by the site where the repellents are used. Therefore, the efficiency of the species depends on the area where it will be used as also shown in Fig. 2 where *B. levis* has significantly reduced bug infestation in Pilar, San Miguel and Tubigon but not in Bilar while *K. galanga* gave better protection to rice in Tubigon and San Miguel but not as effective as in other sites, thus, one species will not work efficiently in all areas.

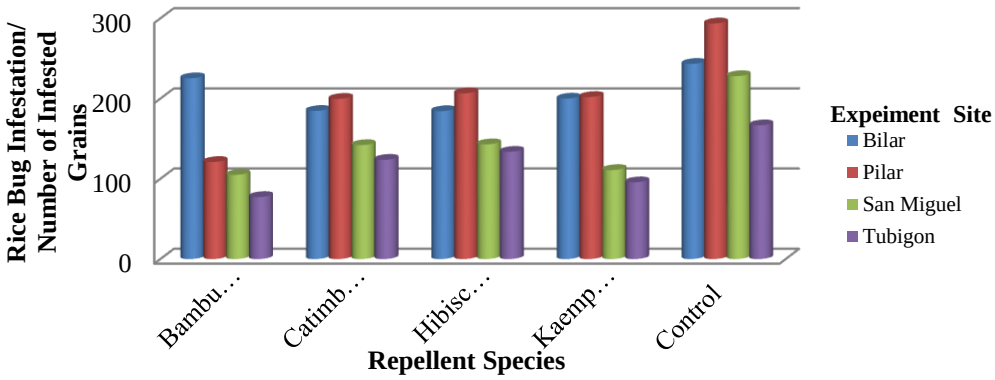

Fig. 2 Average rice bug infestation per repellent species per site

Table 3 The ANOVA on the rice bug infestation per repellent per site

Sources of Variation	F-Value	Significance
Repellent Species	7.669	*.003
Site	12.733	**.000
Repellent Species x Site	761.972	**.000
C. V. = 16.20%		

** significant at 5% level* *** highly significant at 1% level*

The Tukey's HSD Test on rice bug infestation shows that all repellents had significantly lower infestation compared to the control. As to site, Rice bug infestation was significantly lesser in San Miguel and Tubigon than in Pilar and Bilar implying that rice bugs activity is also influenced by rice environments.

Influence of the repellent species on yield of rice

Both nymphs and adult bugs suck the milky white endosperm of rice grains at milking stage. The removal of milky sap usually results in smaller grains causes yield reduction. Figure 3 shows that in every site, rice plants treated by each species produced closely similar yield but untreated plants had lower harvest. Findings impart that the use of repellent species can improve rice yield via the protection against bugs it provided the crop.

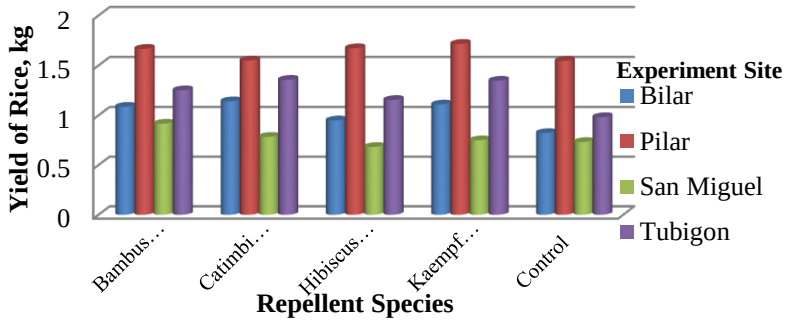

Fig. 3 The average yield of rice, in kilograms, per repellents species per site

The analysis of variance on yield in Table 4 shows a significant degree of difference in yield between repellent species but a highly significant variance between sites, and on the interaction between site and species. This implies that yield was significantly influenced by site factor and by the repellents themselves. It also indicates that rice yield differed depending on the site and on the repellent species.

Table 4 Analysis of variance on rice yield of test crop

Sources of Variation	F-Value	Significance
Repellent Species	4.559	*.018
Site	88.931	**.000
Repellent Species x Site	3659.681	**.000
C. V. = 7.21%		

** significant at 5% level* *** highly significant at 1% level*

The results of the Tukey's HSD Test on yield of test crop revealed that among repellent species, ES Ginger Plant and Malubago are not significantly different to each other and the Control, but these had significantly lower in yield than those with Bamboo and Sand Ginger.

The test also illustrates a highly significant degree of difference in yield between sites. The result also imparted that aside from the effects of the repellents used; the site factor somehow caused a significant difference on the yield of the crop as rice is a site-specific crop.

CONCLUSIONS

Based on the data gathered in this experiment, the following conclusions were made:

1. Bamboo (*Bambusa levis* L.), ES Ginger Plant (*Catimbium haenkei* L.), Malubago (*Hibiscus tiliaceus* L.) and Sand Ginger (*Kaempferia galanga* L.) are useful in resolving rice bug infestation, these can be an alternative approach in rice bug management.
2. All the four repellent species are effective in reducing rice bug population and infestation compared to the control, however, Bamboo and Sand Ginger are the two most valuable species.
3. The effect of the repellent species on the yield of the treated crops was significantly higher especially for Bamboo and Sand Ginger but those with ES Ginger Plant, Malubago and the control had similar lesser harvest.

4. There was a significant interaction of between the repellents and sites on the infestation of rice bugs as evidenced by the effect of Bamboo that significantly reduced bug infestation in Pilar, San Miguel and Tubigon but not in Bilar. It is showing that its repelling performance of Bamboo is not only the function of the species but also of the site.
5. Since Bamboo and Sand Ginger are significantly effective for rice bug management, these repellents should be conserved for food security and bio-safety. To promote conservation, it should be used, protected and domesticated.

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Research article

Characteristics of an Agricultural Innovation and Incentives for Adoption: Rhizobium in Cambodia

ROBERT J. FARQUHARSON*
The University of Melbourne, Melbourne, Australia
Email: bob.farquharson@unimelb.edu.au

ROBERT J. MARTIN
University of Battambang, Battambang, Cambodia

BRUCE MCCORKELL
NSW Department of Primary Industries, Tamworth, Australia

J. FIONA SCOTT
NSW Trade and Investment, Tamworth, Australia

EL SOTHEARY
Cambodian Agricultural Research & Development Institute (CARDI), Phnom Penh, Cambodia

CHAN PHALOEUN
Cambodian Agricultural Research & Development Institute (CARDI), Phnom Penh, Cambodia

HENG SOPHORS
Cambodian Agricultural Research & Development Institute (CARDI), Phnom Penh, Cambodia

SREY SINATH
Cambodian Agricultural Research & Development Institute (CARDI), Phnom Penh, Cambodia

CHEACH MONIDA
Cambodian Agricultural Research & Development Institute (CARDI), Phnom Penh, Cambodia

SVAY SINARONG
Cambodian Agricultural Research & Development Institute (CARDI), Phnom Penh, Cambodia

BO SOKUN
Cambodian Agricultural Research & Development Institute (CARDI), Phnom Penh, Cambodia

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Abstract In this paper we consider whether the processes of farm-level change and adoption of new technologies in Cambodia can be related to the adoptability characteristics of a technology. The literature posits that technologies can be assessed in terms of relative advantage, compatibility, complexity, trialability and observability. Other socio-economic factors may also be important in the adoption process. We test these propositions among commercial upland farmers in north-west Cambodia for rhizobium inoculation of legume seeds to increase crop yields. In promoting this technology the objective is to increase farm income and help to reduce poverty and improve food security. We surveyed farmers who have been involved in a project testing and demonstrating rhizobium inoculation (along with other technologies) and statistically analyzed the results. We found that, with respect to their rhizobium-adoption intentions, relative advantage (incentive) is the predominant characteristic, with observability also being important. Other socio-economic characteristics in their adoption, intentions included whether they grew legumes, the source of first contact, the period since the technology was introduced, and the size of farm. That the innovation demonstrated high relative advantage was

confirmed by separate economic analysis of the likely return on investment for rhizobium in these upland farming systems. Using an approach of assessing adoptability characteristics prior to release provides a basis for developing and screening technologies for successful adoption, rather than trying to adapt ill-suited (in terms of these characteristics) technologies after the event. Such an approach is likely to be more efficient for project sponsors to achieve desirable change.

Keywords new technology, adoptability, relative advantage, rhizobium, Cambodia

INTRODUCTION

There are many constraints to improved crop production for upland farmers in Cambodia (Farquharson et al., 2006). Overcoming such constraints by development and adoption of new technologies or improved farm management techniques can lead to increased farm income to alleviate poverty and improve food security.

Typical economic and social constraints in these upland regions can include small farm sizes and lack of suitable facilities and machinery (i.e. economies of scale are not available and cost of production relatively high), availability of technologies or improved management techniques, levels of education and management or technical expertise, availability and cost of credit, availability of farm inputs of assured quality, marketing and transport options for farm products, adverse prices of inputs and outputs and options or incentives for adding value on farms (e.g. through on-farm storage). And poverty itself may be a trap in poor countries (Sachs, 2005) where natural, built and human capital can be very low.

Because any improvement must be considered in a farming systems context (McConnell and Dillon 1997), where many constraints may be limiting, it may be difficult for a farmer to observe the full expression from any particular change. However, the fertility of soil, and thus the nutrient level available to plants, is an important constraint to crop growth anywhere in the world. In north-west Cambodia many soils have recently been cleared of forest and are still relatively fertile for agricultural use. However, continued cropping without replacement of soil nutrients is unsustainable (e.g. for Cambodia see Martin et al., 2012); and long-term soil fertility decline has been observed in other places (e.g. for Australia see Dalal and Mayer, 1986).

Martin et al. (2012) report activity of farm-level trials, extension activities and farmer adoption intentions for rhizobium in Cambodian upland regions. In this paper we investigate rhizobium inoculum of legume seeds as an innovation or technology by considering adoptability characteristics.

UPLAND CROPPING SYSTEMS IN CAMBODIA

Production of rain fed crops such as maize and soybean has rapidly expanded in north-western Cambodia after reintegration of the former Khmer Rouge began in 1996 (Anonymous, 2004), although soybean production has declined since 2005. The area is mountainous and most of the cultivated areas have rich soil of volcanic or limestone origin. However, in the space of 10 years, crop yields are now declining and soils are being eroded and degraded by excessive cultivation and burning. The main crops grown in the upland areas of Battambang/Pailin, according to area sown, are maize (red corn), soybean, mungbean, sesame and cassava.

There was a rapid expansion in the area sown to maize in Battambang/Pailin between 2005 and 2009 but since 2009 the area of maize has declined and the area of cassava has correspondingly increased. The area sown to soybean, mungbean and sesame has also declined. This is indicative of a trend towards an over-reliance on production of maize and (more recently) cassava with the potential to lead to soil degradation and fertility decline.

Unlike Cambodian lowland rice producers, who are often at subsistence levels in their operations, the upland farmers in the regions studied by Martin et al. (2012) are primarily commercial as indicated by surveys conducted within the project. This has implications for their

farm objectives and response to innovations. The regions studied were those of Martin et al. (2012).

OPTIONS TO INCREASE CROP YIELD

Options to increase crop yields include better varieties, certified seed, improved agronomic practices, reduced tillage, better weed and pest control, fertilizer application and legume crop rotations. Biological nitrogen (N) fixation by crop legumes is a key process in agriculture and inoculation of legume seeds with rhizobia can increase the effectiveness of legume growth and the N-supplying capacity of the soil (Herridge, 2005).

Pin et al. (2009) demonstrated that rhizobial inoculation can replace N fertilizer for mungbean, peanut and soybean at a much reduced cost and reduced environmental impact. The results were comparable to those obtained in other countries. Significant increases in grain yields of mungbean (7%), peanut (15%) and soybean (12%) were obtained by rhizoidal inoculation and the response was equal to (soybean) or better than (mungbean, peanut) application of 40 kg N/ha. Inoculation increased the number of nodules per plant by 23% for mungbean, 39% for peanut and 66% for soybean. Rhizoidal inoculation was included in on‐farm demonstrations of improved technologies in collaboration with Provincial Department of Agriculture staff as well as non‐government organizations. Early results indicate that farmers are interested in inoculation but lack of understanding, access to rhizobium and the ability to adopt the technology. The purpose of this demonstration was to give farmers 'hands‐on' experience and practice in rhizobial inoculation.

ON-FARM RESEARCH AND EXTENSION

On-farm experiments and demonstrations with rhizobium inoculation were carried out at Samlout district in Battambang Province, north-west Cambodia between 2008 and 2010. In 2010, twelve on−farm rhizobium inoculation demonstrations of soybean and sixteen demonstrations of rhizobium inoculation for peanut were held. The objectives were to implement on‐farm demonstrations of rhizobium inoculation of peanut and soybean; to measure the effect of inoculation on nodulation, growth and seed yield of the crops; and to determine the impact of inoculation on farmer's cash income through gross margin (GM) and partial budget analysis.

In 2010, rhizobium inoculation increased the average soybean kernel yield by 15% from 2.944 to 3.379 t/ha. Peanut kernel yield was increased by 12% from 3.493 to 3.920 t/ha. Rhizobium inoculation increased the crop gross margin (GM) for soybean by 4% from US$884 to US$916/ha. For peanut, the GM increased by 15% from US$1,869 to US$2,148/ha.

From the farmer's point of view the economically important measure is the return on investment for funds used in a new technology (CIMMYT, 1988). How does the likely return compare to the opportunity cost of funds? Economic analyses by Farquharson et al. (2006), Farquharson et al. (2008)and (Scott, 2008) have shown relatively high returns on investment for rhizobium, depending on the price at which inoculums can be delivered to the farm gate.

ADOPTABILITY OF TECHNOLOGOES AND RESEARCH QUESTION

Rogers (2003) distinguished and gives the effort of studying the characteristics of adopters and the properties of an innovation influencing the rate of adoption. He developed a classification scheme describing the perceived attributes of innovations. Five different attributes were proposed by Rogers (2003): relative advantage (the degree to which an innovation is perceived as being better than the idea (or practice) it supersedes); compatibility (the degree to which an innovation is perceived as consistent with existing values, past experiences and needs of potential adopters); complexity (the degree to which an innovation is perceived as relatively difficult to understand and use); trialability (the degree to which an innovation may be experimented with on a limited basis); and observability (the degree to which the results of an innovation are visible to others).

Pannell et al. (2006) discussed adoption of innovations through a cross-disciplinary lens, where a dynamic learning process is related to the achievement by the farmer of landholder personal goals. They considered that innovations are more likely to be adopted if they have a high relative advantage and are readily trialable. The research question addressed in the Cambodian study was how rhizobium as an innovation is assessed by potential innovators in terms of Rogers' five attributes. The hypothesis tested was that adoption intentions were related to these innovation attributes and other factors and, if so, which innovation attributes were most important.

METHODOLOGY

A survey questionnaire was developed for individual farmer interviews asking about their personal circumstances (e.g. age, farm size, crops grown, and farming experience), their previous exposure to rhizobium (i.e. workshops attended, village trials) and whether they would adopt rhizobium. Their responses to Rogers' (2003) five attributes, were assessed in categorical forms (i.e. Yes/No/Undecided). The survey was conducted in four villages of Samlout district in June 2011 by researchers from the Cambodian Agricultural Research and Development Institute (CARDI). The survey questions were translated and recorded in Khmer.

A logistic model (e.g. see Askar et al., 2006) was developed to test statistically the determinants of adoptability of a technology such as rhizobium. The data were also analyzed with log-linear models that examined whether the responses of farmers were independent of their personal circumstances and experience of rhizobium. Logistic regression analysis was used to analyze adoption intentions and the importance of innovation attributes.

RESULTS

The total number of farmers interviewed was 59, out of which 57 were deemed suitable (Table 1). Of these, 46 indicated that they would and 11 that they would not adopt rhizobium. Results for the significance of innovation characteristics are shown in Tables 2 and 3.

Table 1 Farmer interview numbers by villages, June 2011 Samlaut

Village	Kantout	Sre reach	Beong Run	Kampong Touk	Total
Interviews	14	16	11	16	57

Table 2 Statistical importance of rhizobium innovation characteristics

Decision to adopt rhizobium by farmers according to	Statistical significance
Relative advantage	**
Compatibility	NS
Complexity	NS
Trialability	NS
Observability	*

*Significance: <0.001 '***', <0.01 '**', <0.05 '*', <0.10 '.', >0.10 'Not Significant (NS)'*

Relative advantage was highly significant and observability moderately significant, whereas the other characteristics were not significant (Table 2) in the adoption intention decision. For other factors influencing adoption intentions, the source of first contact and whether farmers grew legumes were highly significant, the period since rhizobium was introduced and size of farm was moderately significant, a farm workshop was not very significant.

DISCUSSION

When donors fund integrated farm-level projects there is an opportunity to conduct activities including agronomic trials; on-farm demonstrations and field days; economic analysis of technologies, management changes and farming systems; and social analysis of farmer

characteristics interacting with difficult and dynamic learning and change processes. In this paper we report on work which considered the characteristics of innovations as perceived by farmers after they had experienced such project activities where the technology was introduced and demonstrated. These activities provided a basis for an objective consideration of the adoption decision.

In terms of innovation characteristics, relative advantage was most important and observability was also highly significant. With respect to relative advantage Pannell et al. (2006, p.1415) noted that 'among those farmers with a focus on profit, the farm-level economics of a proposed practice will be important'. The ability to observe the new technology perform in real-farm situations is also highly important. Thus relative advantage and observability were found to be most important to these commercial farmers.

Of the other socio-economic factors influencing adoption the farmers responses indicated that a trusted source of information and (for rhizobium inoculation) whether they grew legumes were important. The size of farm and period of time to consider the technology were also important, but not gender or age of these farmers.

Table 3 Statistical importance of other factors

Decision to adopt rhizobium by farmers according to	Statistical significance
Gender of farmer	.
Period since rhizobium was introduced	*
Source of first contact	**
Observing locally	NS
Attended a rhizobium workshop	NS
Age of respondent	NS
Size of farm	*
Presence of off-farm work	NS
Grow legumes	**
Attended farm demonstrations	NS
Attended farm workshops	.
Years of experience farming in Samlout	NS

*Significance: <0.001 '***', <0.01 '**', <0.05 '*', <0.10 '.', >0.10 'Not Significant (NS)'*

If adoptability is important in generating successful farm-level outcomes (and successful project outcomes) then a process of assessing the characteristics of technologies or innovations prior to their promotion to the farming community may be valuable to project funders and sponsors. The innovation attributes assessed in this paper have been incorporated into a screening process (called the ADOPT tool) for this purpose (see Kuehne et al. (2011). More widespread use of such a tool could be advantageous to research funders and sponsors.

CONCLUSION

The Cambodian upland farmers exposed to the rhizobium inoculation technology for legume seeds assessed this technology in terms of five important characteristics suggested by the literature for successful innovations. A survey and statistical analysis showed that relative advantage was the most important trait for adoptability. An existing tool (ADOPT) to predict outcomes according to these traits is available. Perhaps project funders who do not already do so, could consider testing such a tool to augment project development processes and improve the probability of project success.

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Research article

The Concept of Sustainable Development in Indonesian's Forest Law (Case Study: Tesso Nilo's National Park in Pelalawan Regency, Riau Province, Indonesia)

Sri Wahyuni A Kadir*
Islamic University of Riau, Pekanbaru, Indonesia
Email: sri_wahyuni6969@ymail.com

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Abstract Tesso Nilo National Park has a forest area approximately 153 000 hectares located in the 4th district in Riau Province, Indonesia. The park is one of eight blocks of natural forests at Pelalawan Regency in Riau Province. With its rich resources, it provides benefits for the economic development of the people and community. While the mobility of people from the other side, interests of forestry potential is so high, resulting in the emergence of bad things to the preservation of forests and the environment of the forest resource itself. In line with rapid population growth and increasing demand for wood, plantations and agricultural land expansion, and excessive timber industry practices coupled with the level of exploitation of forest resources on a large scale, through large scale cultivation without any effort adequate conservation and rehabilitation, as well as policy issues that are less supportive of forest conservation and forest law enforcement failures increased the level of deforestation or forest loss. The study used survey research involving observation. Population sampling was done by purposive sampling or selection of a deliberate consideration of respondents where actors consisting of three different stakeholder groups on the basis of formal and informal institutions. The group was the Government, Society, and other groups that were not incorporated in the two previous groups. The factors that specifically affected the implementation of Forest law are as follows: unfinished boundaries, lack of quality and quantity of personnel, existence of tenure and encroachment, inconsistent land use designation, existence of settlements in the region, uncontrolled logging or timber theft, fire hazard, overlapping with plantation, weak oversight of the access road around region, and lack of coordination among relevant agencies. Governments need to improve the coordination system to each relevant agency to carry out protection and conservation of the Tesso Nillo forest areas as well as enforcing in the law against any encroachment and violations under the legislation.

Keywords environment, environmental law, forest, forest law

INTRODUCTION

Tesso Nilo forest is surrounded by four conservation areas namely Kerumutan Wildlife Reserve, Bukit Tigapuluh National Park, Mount Rimbang Baling Wildlife Reserve and Nature Reserve. Clearing of forests for other uses have been cut off. Connectivity between Tesso Nilo forest and these conservation areas formed a landscape area of 3 million hectares called Tesso Nilo landscape of Bukit Tigapuluh. The landscape is associated with biological corridors and buffer zones which consist of natural forests, production forests, and timber and oil palm plantations, including farming communities. The mechanism of protection using the landscape approach allows wildlife to move more freely while providing a large survival support system.

In the last 30 years timber for Indonesia has achieved the highest revenue from the export of natural resources. Nevertheless, excessive felling, deforestation and the conversion of remaining forests continue to plantations. The forest fires in Indonesia are a man-made environmental disaster. The reasons are firstly found directly in Indonesia but also in the development of global markets, because the raw materials, must give way to forests of Indonesia for their production (pulp, rubber, palm oil), commercial products worldwide (Sri Wahyuni, 2006).

Since 1982, Indonesia has a legislation to protect the environment, but their application and monitoring for various reasons, is flawed. Thus, the environmental legislation can be characterized as inadequate and confusing, and it seems to lack a certain determinant and transparency in the enforcement of laws. Although the Indonesian government Agenda 21, the Program of Action of the environmental conference in Rio in 1992, has committed to integrate environmental concerns into all policies and to pursue a policy of sustainability. It is subject to a high degree of economic conflicts of interest, Forestry, according to the Forestry Law Number 41 Year 1999, is a system that has to do with the management of forests, forest lands, and forest products organized in an integrated manner. Forest is a unitary form of landscape ecosystems biological resources, dominated by trees in their natural environment. The two cannot be separated. Forest area is a specific area or a designated area and assigned by the government to be protected as permanent forests. State forest is a forest that is on land which is not encumbered land rights. Private forest is a forest that is on land encumbered land rights. Indigenous forest is a country forest in the territory of indigenous peoples. Production forests are forests that have the principal function of producing forest products. Protected forests are forest areas that have basic functions as protection of life support systems to manage the water system, preventing floods, controlling erosion, preventing sea water intrusions and maintain soil fertility.

In line with rapid population growth and increasing demand of wood, plantations and agricultural land expansion; excessive timber industry practices coupled with the level of exploitation of forest resources on a large scale cultivation without any effort of adequate conservation and rehabilitation; policies that are less supportive of forest conservation and forest law enforcement failures increased the level of forest loss.

On July 3, 2007 Governor of Riau issued Decree No. Kpts: 271.a/VII/2007 about the formation of response teams and land encroachment and expansion in Tesso Nilo National Park with tasks to:

1) Make the steps on handling forest encroachment and its implementation in accordance with their respective authority.
2) Identify the perpetrators of forest encroachment and seek alternatives after exiting from Tesso Nilo forest.
3) Make efforts in accelerating the process of expansion of Tesso Nilo National Park in the Department of Forestry
4) Make a plan and implement the Tesso Nilo forest rehabilitation in collaboration with relevant agencies.

The findings of this study include how is Riau Province government policy towards the concept of sustainable development of Indonesian's Forest Law considering the case of Tesso Nilo's National Park in the Pelalawan Regency.

OBJECTIVE

Tesso Nilo National Park has a forest area approximately 153 000 hectares located in the 4th district in Riau Province, Indonesia. The park is one of eight blocks of natural forests at Pelalawan Regency in Riau Province. With its rich resources, it provides benefits for the economic development of the people and community. While the mobility of people from the other side, interests of forestry potential is so high, resulting in the emergence of bad things to the preservation of forests and the environment of the forest resource itself. In line with rapid population growth and increasing demand for wood, plantations and agricultural land expansion, and excessive timber industry practices coupled with the level of exploitation of forest resources on a large scale through large scale cultivation without any effort, adequate conservation and rehabilitation, as well as policy issues that are less supportive of forest conservation and forest law enforcement failures increased the level of deforestation or forest loss.

METHODOLOGY

The study is a survey research descriptive analysis of means. This is an in-depth study on the protection and conservation of the Tesso Nilo forest area during the previous and the present time. In accordance with the development of the field, the nature of this study will be flexible to follow the pattern of thought and the final analysis of results so as to provide an explanation of the past, an explanation of what now is being held on that are expected to answer the problem. The population and sample selection is done by purposive sampling where respondents are three groups of stakeholders: from formal and informal institutions: the Government, the Society, and the other group which consists of those that do not belong to the two previous groups.

RESULTS AND DISCUSSION

The current policy includes the Governor of Riau policy as an instrument of law. The resolver is difficult to implement due to a variety of issues and problems especially in answering some of the main interests which include: protecting the forest, rationalizing utilization of resources, resolving uses and conflicts and reaching a balance between the interests of society and developing, while providing protection to the potential existing resources. In connection with the policy of the Governor of Riau and implementation according to Law No. 41 year 1999, Article 46 states that: "Forest protection and nature conservation aimed at keeping the forest, so that protection, conservation functions and production functions are achieved in an optimal and sustainable degree".

1. The type of stakeholders classified in terms of institution, tenure or ownership of natural resources and attitude show two levels: the formal and the informal institutions. From these two levels of four different stakeholder groups of institution: the Government, Public, Private or corporate and other groups are those that are not incorporated in the three previous groups.
2. Based on the control and the possession of the land around Tesso Nilo forest, two groups of stakeholders were identified, namely the main or primary stakeholders and secondary stakeholders.
3. Based on Stakeholder's Attitude
   Stakeholder's groups can also be distinguished by its attitude towards the Tesso Nilo forest conservation. There were three stakeholder categories namely: Support Groups, Opposition Groups and the Opportunists.
4. Support Group
   Support groups are stakeholders who are committed to the preservation of the Tesso Nilo forest without any desire of commercial gain of exploiting it. There are 15 institutions that supported the Tesso Nilo forest which include the Central Government through the Ministry of Forestry, NGOs working in the field of conservation, local government, the Press in Riau, Institutions of Higher Education, Research and others.
5. Opposition groups
   Usually based on economic interests and opportunity. There are nine institutions into opposition. These opposition groups tend to oppose the Tesso Nilo forest conservation because the presence of conservation efforts will disrupt their opportunity to exploit the forest resources for economic benefit.
6. Opportunist groups
   Matters concerning the management of forests can be seen from the articles such as following: Article 4 of Forest Law Number 44 Year 1999 which states that “all the forests within the territory of the Republic of Indonesia, including natural resources contained therein under the state's overall prosperity for the people. Forest control by any State referred to in paragraph (1) authorizes the government to: Set up and take care of everything related to the forest, forest, and forest products. Determine the status of certain areas as forest area or forest area as a non-forest area, and regulate and establish legal relations between the people with the forest and set up legal actions concerning forestry. Forests by the State shall respect the customary law, as long as it exists and its existence is recognized and does not conflict with national interests”.

From the above description is concluded that the of Law Number 22 Year 1999 on local government by Forest Law No. 41 Year 1999 on the harmonization of forest seen in terms of forest management with the authority that is in the hands of government (central government), but provisions of article 10 of Law Number 32 Year 2004 regarding Regional Government which replaced Law Number 22 Year 1999 on the same thing, there is an existence of disharmony in the case of forest administration. Judging from the article 10 of Law No. 32 Year 2004, that only covers government affairs, foreign policy, defense, security, justice, monetary and physical, and religion, thus implied intent that forest management be submitted to the Government, but the Law Number 41 Year 1999 regarding Forestry and Forest Administration has not changed ,still remains with the government (central government). This raises a contradiction in terms of forest administration authority.

Natural resources and environmental accounting includes the calculation of all natural resources and environment, both used and not used in the production process. Natural resources and environmental accounting includes the calculation of stock reserve and natural changes of assets that have economic value (Sherafy and Lutz, 1989).

In gaining a clear illustration of the economic purpose of natural resources accounting, especially in its relationship to economic policy formulation and development planning, both monetary and physical accounting must be conducted. Due to the difficulties in finding a unit of measurement for all sectors and types of natural resources, the compilation of natural resources are considered important and strategic (Sherafy and Lutz 1989; Pearce et.al. 1989).

Forests are numerous suppliers of renewable raw materials and commodities. Through its function of protecting watersheds and soils is base-existence of many industries. The tropical hardwood products that were exported in 1986 by tropical countries represented, only 3% of the wooden total degradation in developing countries. However, most of these exports come from the rainforests of a small number of tropical countries, where they constitute a very large share of wood degradation. This was particularly the case in the eastern tropics (Siegenthaler/Oeshger, 1987).

The genesis of the concept of sustainable development is commonly reported to the 1987 Brundtland Report, which contains the well-known definition of "sustainable development" as: development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987).

In an era of increasing economic globalization, the traditional environmental and social challenges seem to have gained a new dimension which must be taken into account. However, pursuant to the Johannesburg Declaration, "the rapid integration of markets, mobility of capital and significant increase in investment flows around the world has opened new challenges and opportunities for the pursuant of sustainable development (Massimiliano Montini, 2008).

The complexity of the concept of sustainable development is well known. Due to its vagueness and often perceived irreconcilable nature of its basic pillars, namely the economic, environmental and social dimensions, the concepts of sustainable development is still denied the recognition of the status of a "legal principle" by most scholars and by the relevant practice of States, although this does not render its role less pivotal in contemporary international as well as national law (Lowe, 1999).

From this analysis, all the main difficulties related to the recognition of the role of a legal principle to the concept of sustainable development, such as, first of all, the uncertainty to its legal content as well as the absence of adequate criteria for its justifiability, are clearly outlined. Starting from this analysis, a similar though even more incisive approach was then proposed in a seminal article by Vaughan Lowe, which stated that the argument that sustainable development is a norm of customary international law, binding on and directing the conduct of States, and which can be applied by Tribunals, is not sustainable (Lowe, 1999).

Government regulation number 34 year 2002 is on Forest and Forest Management Planning, Forest Utilization and Forest Use Zone, which is the implementing regulations of Law Number 22 Year 1999 regarding Regional Government (Autonomous Region). Forest governance and forest management planning, forest use, and use of forest area are a part of forest management. Furthermore, forest management is a part of forest management with the authority of the Central

Government. This means that the activities of forest governance, forest management planning, forest use and forest use is the authority of the Central Government. Thus, the licensing arrangements for the utilization of forest wood in natural forests and plantations is given by the Minister of Forestry on the recommendation of the Regent / Mayor and the Governor as set out in PP (Government Regulation) No.34 year 2002. However, this has been adjusted to the legislation in the field of Local Government (Law No. 22 of 1999).

Although Law No. 41 year 1999 as if themselves to the authority of the central government. However, PP (Government Regulation) Number 34 year 2002 has been adjusted. As a follow-up submission to the central authority of the local area utilization permit, environmental services business license, the license of utilizing non-timber forest products, and permit harvesting of timber and non timber has been delivered and given to the area (Regent / Mayor) if that located in within the district / city. Likewise, if located in the area of Trans regency / city in one province the authority is granted to the Governor. But if the forest is located in the province to permit cross-utilization it's still remaining in the hands of the Minister of Forestry. For the unity and equality policies in the treatment of contour system of forest ecosystems, the policy for granting permits to utilization of forest products, in PP (Government Regulation) 34 year 2002 is still on hold by the government, in this case the Minister of Forestry. Access to information and public participation are essential building blocks for sustainable development. This prepares citizens to become informed decision makers, offering a basis for stimulating creative solutions to environmental, social and developmental problems, and providing a foundation for building consensus on critical priorities. Governments and institutions governed by transparency, openness, accountability and community participation are more capable of reconciling the needs of present and future generations, balancing private and public interests, and harmonizing economic development with social and environmental needs. Thus, improved access to information and participation in decision-making will more likely lead to overall sustainable development (Wahyuni, 2011).

CONCLUSION

1. The factors that specifically affect the implementation of Decree No. 271.a/VII/2007 Governor of Riau in the protection and conservation of the Tesso Nilo forest areas as follows:

a. Aspects of Management
- Boundaries are not yet complete (how about uncompleted or unfinished delineation of boundaries?)
- Lack of quality and quantity of personnel
- Lack of quality and quantity of facilities and infrastructure

b. Aspects of the Area:
- The existence of tenure and encroachment (how about prevalence of encroachment)
- The land use designation is inconsistent with that of oil palm, rubber and acacia, etc.
- The existence of settlements in the region
- There is still logging / timber theft (how about unresolved logging practices)
- Prone to fire (vulnerability to fire hazards)
- Overlap with plantation

c. Weak oversight of the access road
Lack of coordination among relevant agencies, it is seen from: 1) National Self-Help Program (Prona Self-Help) Budget 1998/1999 by the Office of the National Land Indragiri Hulu in the region that issued the certificate on behalf of the Tesso Nilo forest, Plantation

2. Government needs to improve the coordination system with each relevant agency that carry out protection and conservation of the Tesso Nilo forest areas as well as enforcing the law against any encroachment and violations under the legislation.
3. In anticipation of the issue and application of empirical authority in the field, a recommendation can be submitted to the Central Government to conduct an evaluation or revision of several laws and regulation relating to the protection and conservation systems taking legal action in case of

violation and encroachment in Tesso Nilo forest, as well as avoiding overlaps of authority in the field with the drafting of forest area management, in line with the spirit of autonomy.

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Research article

The Nitrogen Runoff Characteristics in Agricultural Watersheds after Enforcement of Animal Waste Regulation

TOSHIMI MUNEOKA*
Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan
Email: muneoka@obihiro.ac.jp

YURI YAMAZAKI
Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan

SACHIYO WAKOU
Department of Agriculture, Forestry & Fishery, Ibaraki Prefectural Government, Ibaraki, Japan

MOTOKO SHIMURA
National Agriculture and Food Research Organization, Western Region Agricultural Research Center, Farming Systems and Agro-Environmental Technologies Research Division, Hiroshima, Japan

KUNIHIKO YOSHINO
Faculty of Engineering, Information and Systems Division of Policy and Planning Sciences, University of Tsukuba, Ibaraki, Japan

OSAMU TSUJI
Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan

TOSHIO TABUCHI
Former professor of the University of Tokyo, Tokyo, Japan

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Abstract In this study, the characteristics of nitrogen in river water at the normal water level were examined for a period after the enforcement of animal waste regulation. The differences in agricultural land use in the two study sites in Eastern Hokkaido were taken into consideration. In 35 watersheds in the two areas, the total nitrogen (T-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N) and ammonium nitrogen (NH_4-N) concentrations, and the river discharges were investigated. A total of 7 investigations were carried out during the period from late May to late November 2005. In the Tokachi area (24 watersheds), the main land uses are upland and dairy farming. In the Nemuro area (11 watersheds), the main land use is large-scale dairy farming. Irrespective of the land use in the watershed, when the proportion of the agricultural land was about 20% or lower, the value obtained by adding the standard deviation to the annual mean T-N concentration of river water in many investigated watersheds was 1.0 mg/L or lower. When watersheds whose proportion in the agricultural land was 65% or higher were examined, there were some whose values obtained by adding the standard deviation to the annual mean T-N concentration were close to 10 mg/L. Decreasing trends were not identified in the nitrogen concentration in river water investigated in the first year after enforcement of animal waste regulation. From the viewpoint of water quality conservation, it is effective to appropriately adjust the use of chemical fertilizers in the cropland in the watersheds and to encourage dairy farmers to practice appropriate management of livestock manure.

Keywords nitrogen runoff, agricultural land use, animal waste regulation, water quality conservation

INTRODUCTION

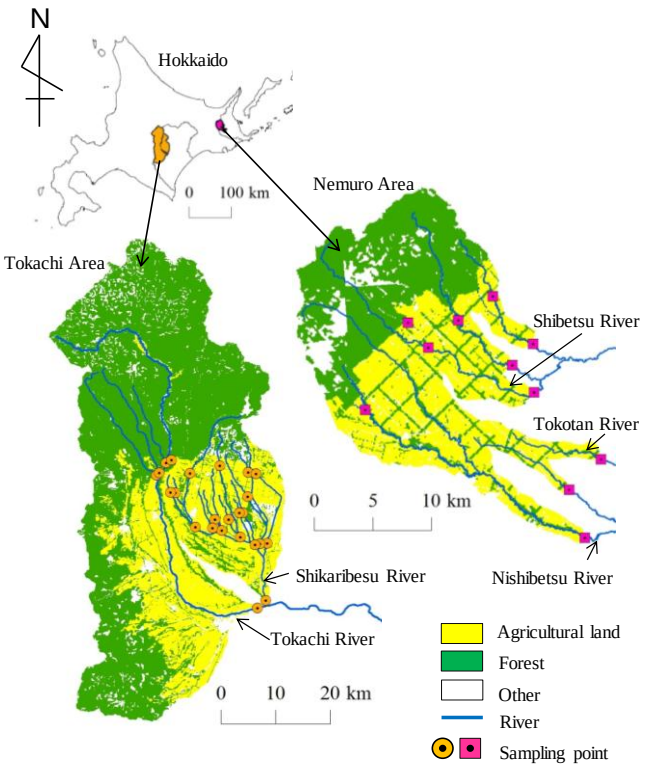
Japan is in the Asian monsoons region. In Eastern Hokkaido, where large-scale farming has been conducted under harsh climatic conditions, nitrate pollution of the local water system has been pointed out. The concentration of nitrate nitrogen in river water and the extent of agricultural land use in an investigated area were reported to have a positive correlation (Tabuchi et al., 1995; Woli et al., 2002; Woli et al., 2004; Muneoka et al., 2012).

Tabuchi et al. (1995) investigated the nitrate nitrogen concentration in river water and the agricultural land use in each area in Eastern Hokkaido in the summer of 1992. Yamazaki et al. (2013) conducted a long-term observation on the relationship between nitrate nitrogen concentration in river water and agricultural land use in the Tokachi and Nemuro areas based on the observation results of Tabuchi et al. (1995). Their observation revealed that in some of the watersheds where the nitrate nitrogen decreased in the summer of 2004 relative to the summers of previous years, the nitrate nitrogen actually increased significantly in 2005, and the increasing trends continued in successive years. On the contrary, there have been few studies that observed the seasonal fluctuation of the river water quality in agricultural watersheds immediately before and after the enforcement of animal waste regulation (Kato et al, 2006).

The present study examines the characteristics of nitrogen that flowed into river water at the normal water level in two areas in Eastern Hokkaido in the first year after the enforcement of animal waste regulation. The study focuses on the differences in agricultural land use between the two areas.

METHODOLOGY

The maps of study sites are shown in Fig.1. The Tokachi area, which has 24 watersheds on the Tokachi River system and the Shikaribetsu River system (No. 1 to 24), is located in the



Sampling Point	River name	Bridge name	Area (km^2)	Land use (%) Agricultural land	Forest
Tokachi area					
1	Tokachi	Oojika	632	1	94
2	Penkenai	Pennai	23	0	98
3	Penkenikorbetsu	Penkenikorobetsu	48	2	96
4	Penkenikoro	Minamiiwamatsu	72	2	97
5	Tokachi	Nakajima	1798	21	70
6	Shikaribetsu	Urimaku	217	4	91
7	Sikanosawa	Kikuchi	5	83	13
8	Kamihoronai	Kamihoronai	3	88	12
9	Shikaribetsu	Momiji	256	13	81
10	Minami1sen	Nakashikakann2gou	13	72	17
11	Iketo	Minamisawa	9	95	2
12	Pankebibaushi	Kousui	27	90	7
13	Urimaku	(no bridge)	9	13	66
14	Poronai	(no bridge)	3	90	7
15	Urimaku	Mutsu	49	58	32
16	Penkeutorei	Honnmaki	3	88	11
17	Pankeutorei	(no name)	5	93	6
18	Pankeutorei	Komadome	17	65	25
19	Penkechin	Okuyama	26	22	49
20	Ponchin	Kamimaki	13	75	18
21	Penkechin	Isami	63	46	33
22	Pankechin	Sinnei	10	52	32
23	Pankechin	Taneuma	72	72	15
24	Shikaribetu	Kunimi	667	48	45
Nemuro area					
A	Kanjiushi	Yourouushi	11	4	71
B	Keneka	Minori	41	7	81
C	Keneka	Hakuyou	82	32	57
D	Shibetsu	Nagori	54	3	91
E	Shibetsu	Kamisibetu	82	22	72
F	Masu	Masukawa	10	32	64
G	Masu	Kenebetsu	28	49	46
H	Tokotan	Houtoku	12	81	14
I	Nishibetsu	Kousai	19	10	60
J	Nishibetsu	Nishisyunnbetsu	149	54	32
K	Pononnebetsu	Akashi	19	73	21

Fig. 1 Outline of the Tokachi and Nemuro areas

northwestern part of the Tokachi General Sub prefectural Bureau, and it is an area with upland and dairy farming. The Nemuro area, which has 11 watersheds on the Shibetsu River system, the Tokotan River system and the Nishibetsu River system (A to K), is located in the western part of the Nemuro Sub prefectural Bureau, and it is an area mainly of dairy farming. In both of these areas, large-scale farming has been operated, and there have been no considerable changes in agricultural land use in either area since 1985.

In year 1981 to 2010, the annual mean air temperature and the yearly precipitation were 5.9℃ and 840.7 mm at Komaba in the Tokachi area, and 5.4℃ and 1158.0 mm at Nakashibetsu in the vicinity of the Nemuro area. Both areas have a relatively cold climate with less rainfall.

The investigation of the river water quality was conducted at the normal water level at 35 sampling points. Electric conductivity (EC) and water temperature were measured at sampling points. Discharge was also measured on the rivers in small watersheds (21 to 24 samples per month). Analysis for some water quality components were done after the field investigation. The total nitrogen (T-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N) and ammonium nitrogen (NH_4-N) concentrations were used as indices in this study. The 7 investigations were carried out during the period from late May to late November 2005.

The GIS software application ArcGIS Desktop (Ver. 10, ESRI) was used for analyzing land use in the study sites. The data were "rivers", "watershed boundaries" and "detailed land use mesh" from digital national information to determine the proportion of agricultural land in watersheds. The detailed land use mesh (100 m × 100 m) shows 11 types of land uses; however, we redefined the mesh into the three items of "agricultural land", "forest" and "other". The proportion of agricultural land was determined for each watershed by overlaying the watershed map created for the sampling points on the detailed land use mesh.

RESULTS AND DISCUSSION

In Japan, there are two major water quality standards that use nitrogen as indices. "The Environmental Standards Concerning the Protection of Human Health" specifies the highest acceptable combined concentration of NO_3-N and NO_2-N as 10 mg/L. Some standards with "The Environmental Standards Concerning the Conservation of the Living Environment" specify the highest acceptable concentration of T-N as 1.0 mg/L.

For an examination of the characteristics of the seasonal fluctuations in nitrogen concentration of river water at 35 sampling points in the two investigated areas in 2005, the annual mean nitrogen concentration and the standard deviation are shown in Fig.2 (a), (b).

The T-N concentration in river water in the two areas was compared using the coefficient of variation (standard deviation divided by the mean). The values for the Tokachi area (24 sampling points) were 12% to 77% and those for the Nemuro area (11 sampling points) were 7% to 27%. The range of seasonal fluctuation of T-N concentration in river water was smaller in the Nemuro area than in the Tokachi area.

Among the all sampling points, the number of sampling points where the sum of annual mean T-N concentration and the standard deviation were 1.0 mg/L or lower was 7 points in the Tokachi area and 6 points in the Nemuro area. The proportion of agricultural land in the watersheds in these areas were <1 - 22% in the Tokachi area and 3 - 32% in the Nemuro area. It was found that irrespective of the land use differences, if the proportion of agricultural land was 20% or lower, the nitrogen concentration in the river water in many watersheds was 1.0 mg/L or lower.

Differences were clearly found in the characteristics of the fluctuations in nitrogen concentration between the two areas when the value of T-N concentration in the watersheds exceeded about 3.0 mg/L. There were some sampling points in the Tokachi area whose values for T-N concentration and standard deviation combined were close to the 10 mg/L, specified in "The Environmental Standards Concerning the Protection of Human Health". At 5 sampling points (No.11, 14, 16, 18 and 20) among the above 14 points, the coefficient of variation was 30% or greater. These five watersheds had features that are in common, such as small areas of 3 - 17 km^2 and a high proportion of agricultural land of 65% - 95%. In the Nemuro area, however, only one watershed

had the T-N concentration and standard deviation combined that exceeded about 3.0mg/L. For this watershed, the coefficient of variation was 13%, which was relatively small, the area was 23 km^2, and the proportion of agricultural land was 81%.

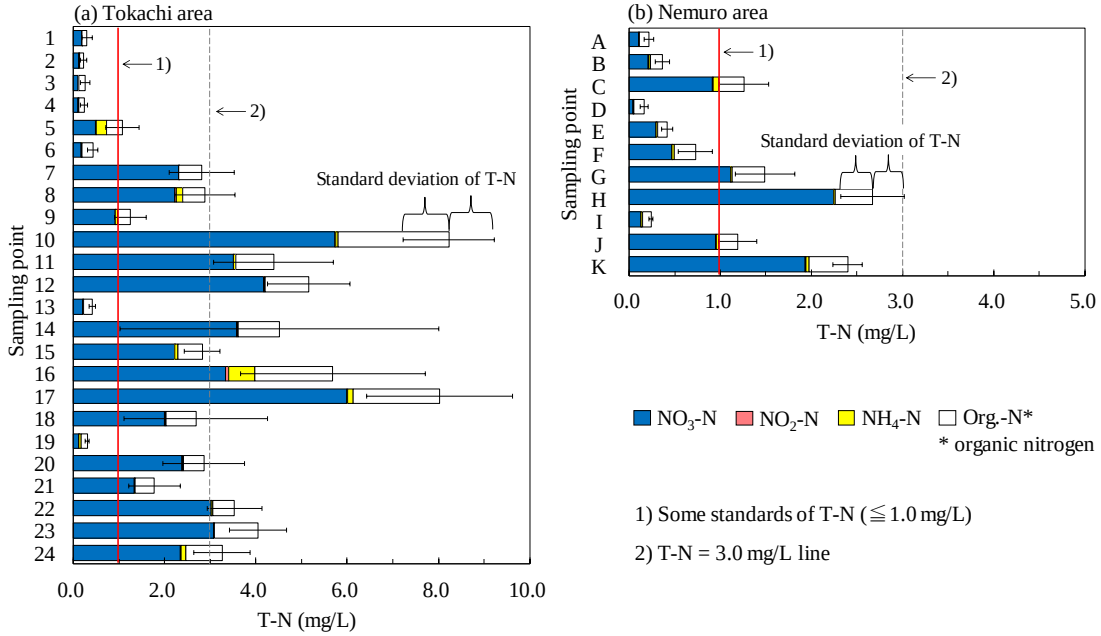


Fig. 2 The annual mean nitrogen concentration and the standard deviation of the river water in the watersheds in the Tokachi and Nemuro areas

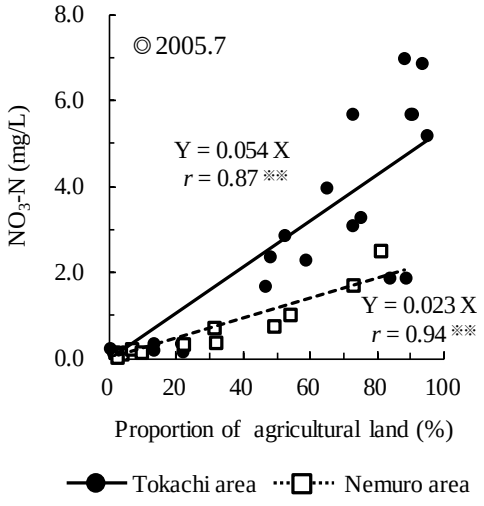
Fig.3 shows the regression lines and the calculated coefficients of correlation, which indicate the relationship between the NO_3-N concentration in river water and the proportion of agricultural land in the watersheds. The NO_3-N was used as the index on this study, because T-N in the river water mainly consisted of NO_3-N in general.

The relationship between the NO_3-N concentration in river water (Y) and the proportion of agricultural land in the watershed (X) is expressed as $Y = aX$. The slope "a", which indicates the impact factor (IF) value, for the both areas in 2005 were 0.026 - 0.054 in the Tokachi area and 0.020 - 0.029 in the Nemuro area. When two watersheds, one from the Tokachi area and the other from Nemuro area, that had similar proportion of agricultural land were compared, the NO_3-N concentration in the river water at the similar investigation period tended to be higher in the Tokachi area. The IF in the Tokachi area showed particularly high values that exceeded 0.050 from July to September.

When the coefficient of correlation *r* for both areas was examined by using the NO_3-N concentration as the index, *r* for the Tokachi area were $0.67^{※※}$ - $0.89^{※※}$, and that for the Nemuro area were $0.94^{※※}$ - $0.96^{※※}$. These coefficients are all positive and significant at the 1 percent level. The correlation was constantly higher in the Nemuro area throughout 2005.

As discussed above, comparison between the annual mean nitrogen concentrations in river water in the two areas in the first year after the enforcement of animal waste regulation (2005) showed that the nitrogen concentration was relatively low and stable in the Nemuro area, while it was high and varied greatly in the Tokachi area.

In the Nemuro area, agricultural land use had been unified into grassland, and the major loading source of water contamination derives from livestock manure. Therefore, it can be assumed that the seasonal variation in the nitrogen concentration of the river water was relatively small and had a high correlation with the proportion of agricultural land in the watershed.



Investigated month	NO_3-N (mg/L) [Y = a X] Tokachi area a*	Tokachi area *r*	Nemuro area a*	Nemuro area *r*	N.B
2005.5	0.028	0.69 ※※	0.020	0.95 ※※	
2005.6	0.026	0.67 ※※	0.020	0.95 ※※	
2005.7	0.054	0.87 ※※	0.023	0.94 ※※	◎
2005.8	0.051	0.89 ※※	0.024	0.95 ※※	
2005.9	0.052	0.84 ※※	0.028	0.96 ※※	
2005.10	0.041	0.73 ※※	0.025	0.95 ※※	
2005.11	0.042	0.76 ※※	0.029	0.96 ※※	

* The impact factor (IF)
※※ significance of 1%

Fig. 3 Relationship between the NO_3-N of the river water and the proportion of agricultural land in watersheds in the Tokachi and Nemuro areas

In the Tokachi area, land use was for dairy farming and the farming of various upland crops. In addition to livestock manure, the loading source includes chemical fertilizers that were applied in large quantities to the upland fields. It is assumed that the use of chemical fertilizers contributed to the higher concentration of nitrogen in river water and that the larger range of seasonal variation in the nitrogen, concentration was attributable to the use of chemical fertilizers during the peak season of agricultural farming.

CONCLUSION

By focusing on the difference in agricultural land use in the watersheds of two areas in Eastern Hokkaido, the nitrogen outflow characteristics were examined for river water at the normal water level at 35 sampling points in the two areas. The examinations found that, in the first year after the enforcement of animal waste regulation (2005), the nitrogen concentration in river water in the two areas showed different behavior depending on the differences in agricultural land use. In the Tokachi area, the nitrogen concentration in river water tended to be high in many watersheds. In small watersheds with a high proportion of agricultural land, the nitrogen concentration in river water during the summer period (July to September) showed great increases. To conserve the water environment by decreasing the concentration of nitrogen in river water, it is necessary to control nitrogen loading during the summer seasons not only by promoting appropriate use of chemical fertilizers in croplands but also by encouraging individual farmers to practice appropriate management of livestock manure.

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Research article

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

TRAN BA LINH*
Can Tho University, Vietnam
Email: tblinh@ctu.edu.vn, linh.tranba@ugent.be

WIM CORNELIS
Ghent University, Belgium

SARA VAN ELSACKER
Ghent University, Belgium

LE VAN KHOA
Can Tho University, 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.

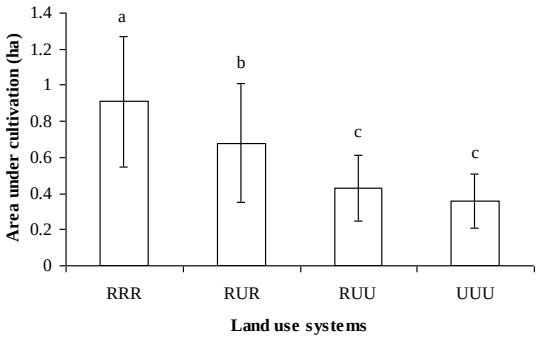
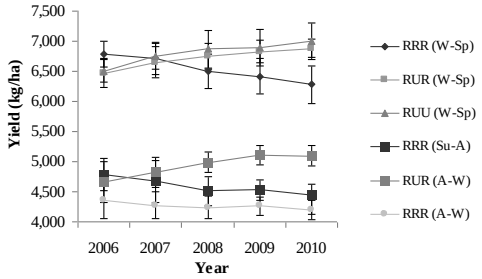


Fig. 1 Average area under cultivation per farmer (ha) for the different land use systems

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.

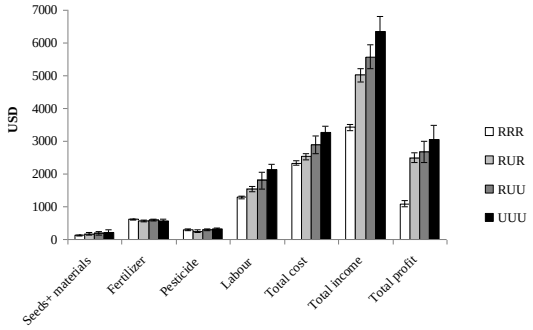


Fig. 3 Cost and income for the different land use systems (in USD)

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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Research article

Determinants of Sugarcane Productivity in Pakistan (1981-2011)

ANWAR HUSSAIN*
Pakistan Institute of Development Economics (PIDE), Islamabad, Pakistan
Email: anwar@pide.org.pk

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Abstract The paper evaluates the impact of water availability, fertilizer consumption and credit disbursement on sugarcane productivity in Pakistan using time series data over the period 1981-2011. The data has been taken from Economic Survey of Pakistan, Agricultural Statistics of Pakistan and National Fertilizer Development Corporation (NFDC). The study estimates log-log model using ordinary least square method. For checking the stationarity of the time series data, Augmented Dickey Fuller (ADF) test is used. The empirical findings reveal that the yield elasticities of water availability, fertilizer consumption and credit disbursement are 0.16, 0.14 and 0.04 respectively. It is recommended that water availability should be ensured by the government at the grass root level for higher sugarcane productivity. The farmers should be given support in consumption of fertilizer. Micro Agriculture credit should be given for sugarcane farmers for purchasing the inputs, technology and high yielding varieties.

Keywords sugarcane, productivity, water availability, agriculture credit

INTRODUCTION

Sugarcane is one of the important cash crops of Pakistan and is the important source of the livelihood of the poor community in rural areas. It is used for industries like sugar, chipboard, and paper. Looking over the statistical picture of sugarcane crop, its share in value added of agriculture and GDP are 3.4 percent and 0.7 percent, respectively. In the year 2008-09, the area under sugarcane crop was 1029 thousand hectares which was lower by 17.1% as compared to the year 2007-08. The production of the sugarcane was 50.00 million tons as compared to production of 63.9 million tons in the year 2007-08, showing 21.7% decrease against the year 2007-08. The deteriorating situation was mainly due to water shortages and shifting of the area for the cultivation of rice crop. The lack of in time payments to the farmers by the sugar mills was also the major factor (Government of Pakistan, 2009).

Sugarcane production showed significant fluctuations in the past. In 1960-61, the total area under sugarcane crop was 388 thousands hectares which has been increased to 1029 thousands hectares in 2006-07. On the other hand, in 1960-61, the total sugarcane production was 11641 thousands tonnes which has been increased to 54742 thousands tonnes in 2006-07. The total credit disbursement in the agriculture sector in Pakistan was Rs.103.78 million in 1960-61 which has been increased to Rs. 168830.46 million in 2006-07. The total fertilizer off-take in 1960-61 was 31.40 thousand nutrient tonnes, which has been increased to 3672 thousand nutrient tonnes in 2006-07 (Government of Pakistan, 2007).

The recent statistics reveals that the area under sugarcane crop is 988 thousands hectares in the year 2010-11 which is higher against the year 2009-10 of 943 thousands hectares. Similarly the sugarcane production also improved in the year 2010-11 against the year 2009-10. The production of the sugarcane in the year 2009-10 and 2010-11 was 49,373 thousand tones and 55,309 thousand tonnes respectively. It is also interesting to note that sugarcane yield in kilograms per hectare has also been increased to 55,981 kilograms per hectare in the year 2010-11 as compared to 52,357 in

the year 2009-10. Agriculture production in general and particularly sugarcane production can be increased through applying appropriate agricultural input policy. The major agriculture inputs mainly credit disbursement, area under cultivation, water availability and fertilizer which matter much.

A very limited researchers conducted studies about the econometric analysis of different aspects of sugarcane crop. Ulveling and Fletcher (1970) estimated Cobb-Douglas production function using input elasticities as a quadratic function of a capital intensity index and determined the rate of returns to scale through incorporating the cost function. Alcantara and Prato (1973) conducted study in Brazil in which they estimated the returns to scale for sugar mills farms. The findings revealed that the elasticities for labor, land, fertilizer, pesticides and machinery/equipment were 0.340, 0.285, 0.351, 0.113 and -0.089 respectively. They recommended for government to increase the efficiency in sugarcane industry and focusing on expansion of sugarcane farms. Bhatti and Yanagida (1990) developed a supply response model and empirically estimated standard regression procedures. The principal factors affecting sugarcane supply response were the official procurement sugarcane for sugarcane paid at the sugar mill gate, the scale of operation and the relative returns to alternative uses of sugarcane.

Farooq et al. (1999) outlined the possible causes of wide spread cultivation of a non-recommended, high yielding but low in sucrose contents sugarcane variety i.e. Co-1148. It has created different problems for both the farmers and sugar mills. Ali et al. (2000) conducted study about fertilizer-use efficiency and cane yield under different nitrogen levels and weed management practices in spring planted sugarcane. He pointed out the average fertilizer use efficiency (FUE) to be 36.10 in weed-free crops compared with 21.94 in weedy crops, with corresponding yields of 99.87 and 75.94 t/ha. FUE ranged between 150 and 225 kg N/ha. Yadav and Yaduvanshi (2001) studied that the yield of millable cane from the planted sugarcane was affected by fertilizer N rather intercropped green manuring or plant arrangement. He observed that whether it is the plant cane or the ratoon crop, the quality of cane juice is not affected in either case. The organic carbon content and available N in the soils have been increased by residues from the green manures and N fertilizer treatments. Chattha et al. (2001) evaluated the effect of different production factors on the yield of 15 sugarcane cultivars in Punjab, India. The factors were mainly planting methods and date, soil amendments, irrigation and plant protection. Results revealed that sugarcane yield improved by 21.96% through trench planting, by 43.75% through effective weed control, by 34.50% through the integrated use of press mud and fertilizers, by 26% through skip furrow irrigation and by 50% with urea application by drilling. Through proper weed management he also observed 32% improvement in ratoon crop.

Muhammad, et al. (2001) observed that non-adoption of recommended agricultural technologies was the responsible factor for the low per hectare yield of crops. The data were collected from 191 sugarcane growers selected through stratified random sampling technique from 16 villages selected by using multistage sampling method. The data suggested that awareness and adoption of sugarcane production practices were very poor. Lack of awareness of recommendations appeared to be the major cause of non-adoption. Nixon and Simmonds (2004) investigated the impact of fallowing and green manuring on soil conditions and the growth of sugarcane in Swaziland. He observed that yields were improved from 129 tonnes per hectare to 141–144 tonnes per hectare after fallowing and green manuring. He also assessed positive relation between root length and air-filled porosity. Hussain et al. (2006) made economic analysis of sugarcane production in Pakistan using time series data ranging from 1990 to 2002. Their findings revealed that Pakistan has no comparative advantage in producing sugar at export parity prices although plays role as import substitution. Gana (2008) evaluated the sustainability of organic fertilizer on sugarcane production in Nigeria. He conducted experiments using plots with and without fertilizer application. The findings revealed that application of organic and inorganic fertilizers matters in sugarcane production.

Fernandez1 and Nuthall (2009) conducted a study in the Central Negros area, Philippines on sources of input use inefficiency through data envelope analysis. They have taken individual farms in which same type of input-output were used for which the mean relative technical, scale and overall technical efficiencies were determined and these indices were found as 0.7580, 0.9884 and

0.7298, respectively. The findings further revealed that technical inefficiency was the major source of overall inefficiencies as compared to scale effect. It was also found that farmer's age and experience, access to credit, nitrogen fertilizer application, soil type and farm size were positively associated with overall technical efficiency. Niamatullah et al (2010) assessed the impact of price of fertilizer and agriculture credit on sugarcane acreage in Khyber Pakhtunkhwa over the period of 1991-92 to 2007-08. Their findings revealed that price of fertilizer and agriculture credit were the influencing factors for sugarcane acreage.

OBJECTIVE

The significance of the sugarcane crop in the economy of Pakistan cannot be ignored. Unfortunately, there is dearth of studies over the issue under consideration. The present study will bridge this gap and attempts to estimate the impact of water availability, fertilizer consumption and credit disbursement on sugarcane productivity in Pakistan using time series data over the period 1981-2011.

METHODOLOGY

According to the classical economist, output (Q) is a function of labor (L) and the relationship is expressed as: $Q = f(L)$

The neoclassical economist added the capital (K) component in this production function, taking the form: $Q = f(L,K)$

In non-linear form, the relationship is expressed as:

$$Q = AL^{\alpha}K^{\beta}e^{\mu} \quad (1)$$

This is the conventional Cobb-Douglas (1928) production function. α and β are the output elasticities of labor and capital respectively. 'A' is the rate of technology and μ is the random term, satisfying all the usual assumptions. Taking natural logarithm to both sides, the equation becomes:

$$\ln Q = \ln A + \alpha \ln L + \beta \ln K + \mu \quad (2)$$

This model can be estimated by applying the ordinary least square method.

The model not only shows the input output relationship but also gives information about the rate of returns to scale.

The concern of this study is to evaluate the impact of major determinants of sugarcane productivity in Pakistan, so the following model is estimated using the ordinary least square method:

$$\ln(SY_t) = b_o + b_1 \ln(WA_t) + b_2 \ln(FC_t) + b_3 \ln(CD_t) + \mu_t \quad (3)$$

Where

SY = Sugarcane yield (Kgs/Hectare) in Pakistan

WA = Water availability[1] (million acre feet) in Pakistan

FC = Fertilizer consumption for sugarcane crop (000 N/T) in Pakistan

CD = Credit disbursement[2] (Rs. in million) in Pakistan

't' is the time period and μ is the random term satisfying all the usual assumptions.

The data on these variables has been taken from Economic Survey of Pakistan, Agricultural Statistics of Pakistan and National Fertilizer Development Corporation (NFDC).

[1] The crop specific water consumption data is also not available; therefore, it has been obtained by multiplying the water availability for Kharif (season) crop by its corresponding weight. The weights used were obtained dividing the area under sugarcane crop by total cropped area.

[2] The data on crop wise credit disbursement is not available. This variable is constructed by multiplying the total credit disbursement by weights and the weights have been obtained by dividing the area under sugarcane crop by total cropped area.

For checking the reliability of the regression results, equation-3 has been checked for econometric properties. Augmented Dickey-Fuller (1981) test has been used for checking the stationarity of the data[3]. Variables which were non-stationary at level have been made stationary after taking first difference and second difference. To detect the long-term relationship among the series, the Cointegrating Regression Durbin Watson (CRDW) test[4] of Sargan and Bhargawa (1983) has been used. Furthermore, to check the stability of the coefficients, the cumulative sum and cumulative sum of square residuals have been plotted. A statistical package Eviews is used for deriving the results.

RESULTS AND DISCUSSION

The results given in table 1 showed that the water availability for sugarcane crop has the highest elasticity (highest contribution towards sugarcane yield) as compared to other determinants. A one percent increase in the water availability for sugarcane crop increases sugarcane yield by 0.16 percent. The coefficient of WA is statistically significant at 5% and 10% level of significance. Water availability is the crucial policy variable for policy makers in Pakistan. The worsening situation of water availability may be a serious threat for sugarcane yields in future. Because, the water availability has declined from 100 million acre feet in the year 2007-08 to 80 million acre feet in year 2009-10 (Economic Survey of Pakistan, 2010).

Table 1 Regression results of the determinants of sugarcane productivity

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	9.45	0.13	73.52	0.00
ln (WA)	0.16	0.07	2.290	0.03
ln(FC)	0.14	0.04	3.819	0.00
ln(CD)	0.04	0.01	3.072	0.01
R-squared	0.87	Adjusted R-squared		0.86
F-statistic	61.62	Prob(F-statistic)		0.00
Durbin-Watson stat	1.57			

The yield elasticity of FC and CD are 0.14 and 0.04 respectively. These coefficients are also statistically significant and show positive impact on sugarcane yield. Fertilizer also place importance because its consumption reduced from 340.77 thousands, NT in the year 2001-02 to 314.64 thousands NT in the year 2010-11 (Economic Survey of Pakistan, 2011). Among the other factors, fertilizer supply is important which is continuously affected by ongoing power crisis. The availability of the compressed natural gas, shortage of electricity, destructive rains in Sindh Province and increasing prices of fertilizer also supplemented the issue.

Credit disbursement issue if tackled well, can enhance sugarcane productivity. The small farmers not only are deprived from receiving the loans but also these are not given at the time when it is required for purchasing farm inputs. Further the total supply of agriculture credit reduced by 6.5% and 6% in the years 2009-10 and 2010-11 respectively (Economic Survey of Pakistan, 2011).

In addition, agriculture research and development (R&D) expenditures[5] can also increase sugarcane productivity through introducing high yielding varieties. In Pakistan, it is 0.59% of the total GDP in the year 2008 as compared to 2-3% in developed countries (Pakistan Council for Science and Technology, 2009). According to World Development Report (2008), developing countries invest only one-ninth of what industrial countries put into agriculture R&D as a share of agriculture GDP.

[3] The Akaike Information Criterion (AIC) has been used to select the optimum ADF lag.
[4] It is used to test the null hypothesis that the value of *d* is equal to 0.
[5] Due to non availability of data, the variable R&D expenditures is not included in the model. Similarly, having too many complications with using climatic variables, these have not been incorporate in the model.

The overall test of significance, depicted by the value of F-statistics, favors the model. The fit is also good shown by the high value of R-square (0.87). The Durbin Watson statistics shows that there is no serious problem of auto correlation.

The ADF test results shows that ln(SY) and ln(WA) are stationary at level while ln(CD) and ln(FC) have been made stationary after taking the first difference (Table 2). This may provide some doubts to have spurious regression. But the Durbin Watson value 1.57 (Table 1) evidences that the variables included in the model are cointegrated. Because this value exceeds the critical values provided by Sargan and Bhargawa[6].

Table 2 ADF test results for stationarity (including both intercept and trend)

Variable	I(0)		I(1)		
	Test Statistic	Critical value 5%	Test Statistic	Critical value 5%	Results
Ln(SY)	-4.05[0]	-3.50	-	-	I(0)
ln(WA)	-4.04[0]	-3.51	-	-	I(0)
Ln(FC)	-1.91[0]	-3.53	-6.72[0]	-3.53	I(1)
ln(CD)	-1.98[1]	-3.50	-5.69[0]	-3.50	I(1)

The cumulative sum (CUSUM) and cumulative sum of square (CUSUMSQ) plots show stability in the coefficients of the model estimated. Both the plots (Fig. 1 and Fig. 2) fall within the critical bounds of 5 percent representing that the model is stable structurally.

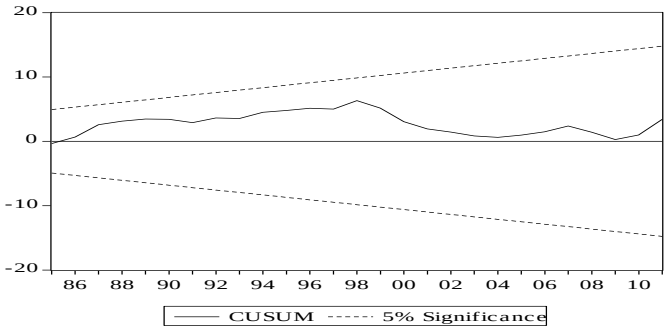

Fig 1 Plot of cumulative sum of recursive residuals

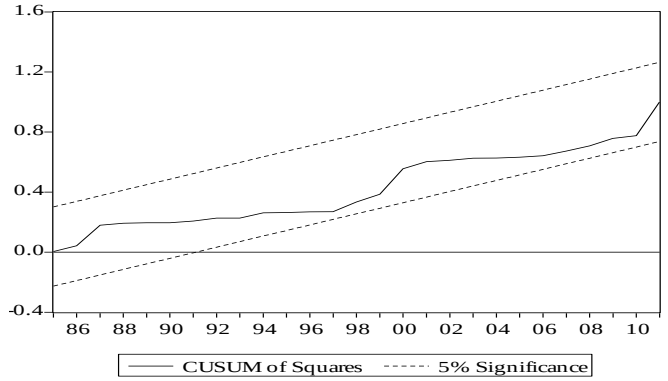

Fig 2 Plot of cumulative sum of square residuals

[6] According to Sargan and Bhargawa (1983), the critical values at 1%, 5% and 10% level of significance are 0.511, 0.386 and 0.322 respectively, for testing the null hypothesis that the value of *d* is equal to 0.

CONCLUSION

It is concluded that the policy variables, water availability, fertilizer consumption and credit disbursement have positive and significant impact on sugarcane productivity. It is recommended that the government should make efforts to increase water availability which is becoming worsening in Pakistan. This may create problem for food security in general and particularly for sugarcane productivity in future. The policy options for this can be increasing investment in the water and irrigation system. Agriculture micro credit programs should be improved to assist sugarcane farmers in purchasing the inputs and high yielding varieties. Agriculture R&D expenditures must be increased for ensuring higher productivity. It is also worth mentioning that sugarcane productivity can also be increased through appropriate sugarcane input-output policy, farm subsidies, technology etc but due to data availability constraint, these have not been included in the analysis.

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Research article

Food Security and Socio-economic Impacts of Soil Salinization in Northeast Thailand

AUNG NAING OO
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Email: ano1972@gmail.com, chulee_b@kku.ac.th

CHULEEMAS BOONTHAI IWAI*
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

PATCHAREE SAENJAN
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

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Abstract This study aimed to assess the impacts of soil salinity on the crop production system and to describe the food security and social and economic conditions in the salt-affected areas of Northeast Thailand. Ban Nong Na Woaw, Ban Phon Sim, and Ban Som Sanuk, all in the Northeast region of Thailand, were purposely selected because they had different salinity levels and different ecosystems. Random sampling method was used to select 90 households from the three villages and both quantitative and qualitative data were collected from January to June 2012 using a questionnaire, semi-structured interviews, and direct observation. Data were analyzed by means of descriptive methods. In all studied villages, the production system of rice among the farmers was not much different. Farmers used organic fertilizers and farmyard manure to alleviate salinity in their rice field. There were different types of agricultural and non-agricultural activities in the three studied villages practiced by the farmers in order to improve food security of their families. The average of rice yields was very low, about 1.5 ton/ha. The main income source was agricultural work among rural households. Domestic animals raised by most farm households in all villages were cattle, buffalo, pigs, chicken and crickets for home consumption and sale. In addition to salinity effects, periodic droughts, the heavy reliance on monsoons, lack of financial capital and low inputs uses were the other major constraints for the farmers in all villages. This finding suggests that farmers need to be advised to use farmyard manure and green manure in order to reduce salinity. But equally important is correct application and the timely use of urea fertilizer, better weeding, timely harvesting and proper threshing and winnowing. Since rice is the main source of livelihood for the farmers, extension agencies should provide farmers with financial and technical assistance such as salt tolerant rice varieties, knowledge and improved technologies.

Keywords salinity, food sufficiency, livelihood

INTRODUCTION

Soil salinity has become a serious problem throughout the world and around 20% of the world's cultivated land are affected (Sumner, 2000). In Northeast Thailand, approximately 17 % of the land is salt-affected due to salt bearing rocks (Land Development Department, 1991). mainly in Nakhon Ratchasima, Khon Kaen, Roi Et and Mahasarakham provinces (Department of Mineral Resources, 1982). Soil salinity has been accelerated by human activities such as deforestation, irrigation, salt-making and construction of roads and reservoirs (Mitsuchi et al., 1986). It has been one of the most important issues for local farmers who live in Northeast Thailand. Decreasing soil productivity caused by salinization has led to social tension, unemployment and reducing incomes of all social groups. Large-scale soil salinization affects many families in the area with small land holdings. Soil

salinization must also be seen as a human problem rather than one concerned solely with the destruction of ecosystems. While people are the main agents for salinization, they are also its victims.

Northeast Thailand has about 9.3 million hectares of agricultural land, of which approximately 7.9 million hectares are used for rainfed farming (Office of Agricultural Economic, 1998). Up to 75% of this land is devoted to rice, but the planted area varies considerably from year to year, mainly because of uneven water availability and salinity affected land (Arunin, 1984; Yuvaniyama et al., 1996). Besides, the soils in Northeast Thailand are characterized as universally infertile because of their light texture and low inherent nutrient contents (Jirapornchaeroen, 1993). The low fertility of sandy soils in the region coupled with frequent drought, degradation and salinity has been accounted for the low yield (Kabaki et al., 2003) and consequently leads to the problem of food insecurity for the farmers.

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996). The entire livelihood system of Northeast Thailand is farm-based. Farmers continue to make their living from manual trade and agriculture. Rice, cassava, and corn are the main crops grown under rainfed conditions by practicing traditional cultivation system, and rice is the staple crop of most farm households in the region. Due to certain constraints, low productivity has brought poverty leading to the lowest per capita income in this region of the country. Their dependency on agriculture and lack of knowledge on management might have caused problems of salinization which has a severe effect on soil fertility and crop productivity. Therefore, it requires an investigation in order to get a solution to this problem for a better livelihood of future generations. Much research work has been done on the management of salt-affected soils in Northeast Thailand. However, insufficient research has been undertaken on an evaluation of the food security and socio-economic aspects in salt-affected areas of this region. Yet rice sufficiency is the key to survival in Northeast Thailand as rice forms the greatest portion of daily food consumption for subsistence farmers. Therefore, this study aimed to assess the impacts of soil salinity on the crop production system and to describe the food security and social and economic conditions of the salt-affected areas of Northeast Thailand.

METHODOLOGY

Site selection

This research project was conducted in villages at Khon Kaen, Kalasin and Mahasarakam provinces in Northeast Thailand. The three selected study villages where farmers grow crops in salt-affected soils were Ban Nong Na Woaw, Khon Kaen Province; Ban Som Sanuk, Mahasarakam Province; and Ban Phon Sim, Kalasin Province, all in the Northeast region. These study sites were purposely selected because they have different salinity levels and different ecosystems.

Research design

Qualitative research is best known for the validity of its findings while quantitative research is strong in reliability, and both have strengths and weaknesses (Babbie, 1999; Dawson, 2002). In this study, the typical design was started out with a qualitative part including documentation and in-depth interview. The information from this part helped to develop the tool, a structured questionnaire, for the quantitative study. The quantitative cross sectional study was employed to get information about individual cognitive behaviors and household's socio-cultural and economic characteristics whereas the qualitative approach included in-depth interviews, focus group discussions, and meetings. It was used to gain the in-depth understanding about the situation, problems, causes of the problems, and needs. Therefore, both qualitative and quantitative research methods were used in this study and emphasis was given to the qualitative method.

Research tools

Research methods used in this study include a small questionnaire, semi-structured interviews, and direct observation. The small questionnaire was used in collecting quantitative data. Semi-structured interviews were used in collecting qualitative data and separate guidelines for key informants and household informants were used. This was because holding a well-prepared interview guide in hands, semi-structured interviews are more likely to cover all sub-topics of interest, and thereby reducing the potential risk of missing data. Direct observations were made in order to validate information given by informants (IFAD, 2002).

Data collection and analysis

For data collection and analysis, the interview and information collection process was used as follows: (i) key informant interview and group interview in village level (ii) household level in-depth interview and (iii) observations. Qualitative data was supported by documents and materials relating to the topics covered by the study and the quantitative component of the study. Field notes were converted into detailed notes each day in the field soon after completing all interview sessions of the day. Missing or contradictory information were noted down and verified the following day. When the entire data collection process was completed, descriptive methods were used in data analysis. Quantitative data was analyzed by applying descriptive statistics (mean, percentage, etc) with the help of Microsoft Excel.

RESULTS AND DISCUSSION

The characteristics of the households in the three studied villages in salt-affected areas of Northeast Thailand are shown in Table 1.

Table 1 Characteristics of the study households in the three studied villages in salt-affected areas of Northeast Thailand

Characteristics	Ban Nong Na Woaw (High salinity level)	Ban Som Sanuk (Moderate salinity level)	Ban Phon Sim (Low salinity level)
Sample household	30	30	30
Average age of respondents (year)	56.9 (39 ; 79)	56.3 (35 ; 76)	52.2 (27 ; 70)
Education (%)			
Primary school	60	60	50
Secondary school	40	40	50
Average household size (person)	4.0 (2 ; 6)	3.9 (2 ; 6)	4.6 (3 ; 8)
Landless households (%)	30	20	26
Average labors (person)	2.4 (1 ; 5)	2.6 (1 ; 5)	2.6 (1 ; 5)
Average number of dependents (person)	1.6 (0 ; 5)	1.6 (0 ; 4)	2 (0 ; 4)
Average cultivated area (hectare)	2.4 (0 ; 5.8)	2.1 (0 ; 5.6)	1.8 (0 ; 5.3)

Parentheses show minimum and maximum.

Rice production in the studied villages

As a staple food crop, rice has been grown in the three studied villages for generations. Due to the salinization, limitation of water resources, low soil fertility, high cost of capital investment for land preparation such as sowing, seedling, equipment, chemical fertilizer, pesticide, transportation and high cost of labor, the rice productivity is quite low. This situation has made the farmers face the problem of food insecurity. The villagers mentioned that the expenses of agricultural inputs have increased every year, especially fertilizer and pesticide.

In all studied villages, the production system of rice among the farmers is not much different. However, most farmers use urea fertilizer, but most of them cannot use the recommended dosage, 50kg N/ha, plus compound fertilizer. They use different brands of compound fertilizer with different organic ratio ingredients and various prices depending on the capital accessibility.

There are two varieties of rice grown in the studied villages namely Khao Dawk Mali 105 (KDML 105) and Kor Khor (RD 6), which are non-sticky and sticky rice, respectively. KDML 105 is named as Jasmine rice because its natural aromatic scent is similar to that of jasmine flower. KDML 105 is high quality rice and one of the promising economic crops for Northeast Thailand. Its demand is very high because of its better eating and cooking quality. RD 6 is grown and consumed in the Northeast Thailand region, especially in rural areas. In all studied villages, farmers grow RD 6 rather than KDML 105 because they like RD 6. It was mentioned that RD 6 is for household consumption, whereas KDML 105 is for sale.

Village food security

Despite the fact that Thailand produces more than enough food to meet domestic needs and is a major food exporter, abundant food supplies do not automatically translate into abundant food for the poorer groups of Thai society. Based on group interview in each village, there are different types of agricultural and non-agricultural activities in the three studied villages practiced by the farmers in order to improve food security of their families. Generally, there are different agricultural activities such as rice, cassava, corn, eucalyptus, etc. and non-agricultural activities such as retailer shop, daily labor, salt-making, but not all households get involved in those activities. It was noted that most of agricultural activities in the three villages are similar.

Socio-cultural conditions

Culture, beliefs and religious activities: All villagers are Buddhists and they strongly believe in Buddha's teachings. They value the ordination ceremony when their son or grandson becomes a novice monk. All of the temple donations are based on agricultural income. In a year when the weather conditions are favorable for high productivity of crops, their standard of living is better so they can use the surplus for donations. All of the families do their social, cultural and religious activities after harvesting their cultivated crops. At that time, they can use their crop products and also cash from selling these crops for donations. In the activities, the old persons and village headman play an important role. Even though the village headman has full authority, he shows respects to the old, honorable persons and follows the guidelines and suggestions from them. For the religious activities, monks play very important role in the village. In some social and cultural problems, monks can give the final decision for the village. Seasonal religious festivals are held under the guidance of the monks and elder person.

Economic conditions

Crops and livestock: The major crop grown in the three study villages is rainfed rice, but some farmers grow eucalyptus, cassava and corn. In all villages, no vegetables are grown in their fields, but they are grown in their home garden for household consumption. In all villages, rainfed rice is grown during the rainy season but there is no irrigated rice in the dry season. Domestic animals raised by most farm households in all villages that are cattle, buffalo, pigs, chicken and crickets for home consumption and sale.

Salt production: In the case of Ban Nong Na Woaw, some villagers make salt from the highly salt-affected soil. The old villagers reported that salt production had begun in a primitive manner for household consumption. In this method, the white crust of salt collected from the soil surface is dissolved into water and filtered. The dissolved salt then is crystallized by boiling. This salt-making is done in the off-farm season.

Occupation and income: The village economy is based on agriculture in all studied villages. Most

households in all villages are farm households, and very few households do non-farm work like government officials, public health workers, agricultural input retailer or small shopkeeper. The major source of income for the farm households in all villages is the cultivation of crops and keeping domestic animals like cattle and pigs also make a contribution to household income. Apart from the expenses on basic needs, household income is also spent on such social occasions as traditional festivals. They also spend certain amount money on their children's education, health, transportation, clothing, lightening, kitchenware, house maintenance, donation and personal use. In most cases, farm work is done using family labor, but hired labor is common during peak seasons like transplanting and harvesting of the crops.

Table 2 Comparison of soil salinity level, average rice yield and average household's income among all studied villages in the year 2011

Village	Salinity level [#] (EC_e, dS m^{-1})	Average rice yield (ton/ha)	Household's income (US$/year)	Source of income
Ban Nong Na Woaw	High (>4)	1.56	2096	Farm-based, Non-farm
Ban Phon Sim	Moderate (2-4)	1.56	1935	Farm-based
Ban Som Sanuk	Low (<2)	1.62	2258	Farm-based

[#] *Topark-Ngarm (2010) ; EC_e (Electrical conductivity of the saturation extract)*

According to the group discussion, in all villages, the average of rice yields is very low about 1.56 ton/ha (250 kg/rai) (Table 2), as compared to other parts of the country (average of 2.9 ton/ha in the central region and 1.8 ton /ha in the Northeast region) (Office of Agricultural Economic, 1998). This low yield might be due to the salinity, low soil fertility and sandy texture soil. The main source of household income was farm-based. This study found that the average income of households from Ban Phon Sim village was the lowest amount when compared to other villages. In contrast, the average income of households from Ban Nong Na Woaw was the highest. The average income of household from Ban Nong Na Woaw was higher even this village has high salinity levels when compared to Ban Phon Sim village which has moderate salinity level because their average productive land areas are more than other villages. Besides, this village is not too far from the township (Ban Phai Township) and hence, farmers can access improved technology from agricultural service and other agencies and supplement to their income also come from other non-agricultural activity such as salt-making and waged labor.

CONCLUSION

The three studied villages face enormous widespread soil salinity as a consequence of soil and water resource degradation. Also, rising water tables resulting from deforestation have caused water-logging problems in many areas. The collected information shows that despite difficulties, farmers are continuing their efforts for the management of salinity to produce field crops. In order to alleviate salinity in their rice field, they apply organic fertilizer and farmyard manure such as cattle manure and chicken waste. However, the average of rice yields is very low about 1.5 ton/ha (250 kg/rai). In addition to salinity effect, periodic droughts, the heavy reliance on monsoons, lack of financial capital, low inputs uses are the major constraints for the farmers in all villages.

There are different types of agricultural and non-agricultural activities in the three studied villages practiced by the farmers in order to improve food security of their families. Domestic animals raised by most farm households in all villages are cattle, buffalo, pigs, chicken and crickets for home consumption and sale.

This finding could suggest that farmers are advised to use farmyard manure and green manure in order to reduce salinity, correct application of urea fertilizer, the timely use of urea fertilizer, better weeding, timely harvesting and proper threshing and winnowing. Since rice is the main source of livelihood system, development extension agencies should provide farmers with financial and technical assistance to make available salt tolerant rice varieties, knowledge and improved technologies in order to increase food sufficiency. Every project to be implemented in these villages should pay more attention to the most vulnerable landless and small farmer households.

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Research article

Development without Conformity: Impacts of Large-Scale Economic Development on Indigenous Community Livelihoods in Northeastern Cambodia

BAROMEY NETH*
Royal University of Phnom Penh, Phnom Penh, Cambodia
Email: baromeyneth@yahoo.com, neth.baromey@rupp.edu.kh

SAM OL RITH
Royal University of Phnom Penh, Phnom Penh, Cambodia

MAKOTO YOKOHARI
The University of Tokyo, Tokyo, Japan

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Abstract Large scale economic development (LSED) has undergone rapid policy and sectoral reform in Cambodia. LSED is expected to generate revenues to support economic growth and development at both macro and micro levels. Yet, it is questionable about benefits and risks of such natural resource-consumptive and extractive development for the host areas, especially indigenous people (IP). IP communities in Northeastern (NE) Cambodia are vulnerable to such development. This region has been put under agricultural economic land concession, forest concession, and mining concession. The conversion of forestlands and farmlands into commercial cash-crop and agro-industry plantations as well as logging and mining zones has led IP communities to have limited access to land and natural resources. This caused to reduced livelihood capabilities (resources, knowledge and skills, activities, and protective security) and distressed cultural diversity and integrity and socio-demographic fabric of IP. By using sustainable livelihood approach/framework (SLA/F), this paper aims to investigate IP livelihood problems and identify LSED opportunities and strategies in Northeastern Cambodia and their impacts on IP livelihoods.

Keywords large scale economic development, SLA/F, indigenous communities, community capabilities, integrated economic and community development

INTRODUCTION

Growth, conservation, ownership rights, poverty reduction, capacity, equity, empowerment, participation, collaboration, precautionary approaches and governance considerations are embedded in most conceptualizations of sustainable development (Bryant and White, 1982; Agyeman et al., 2003; Bouapao, 2005). These considerations have placed importance on rural community development in order to reduce the imbalance caused by urban-oriented growth mechanism which generates dichotomy between rural and urban areas (Hirsch, 1987). The concept of rural community development allows (poor or marginalized) rural communities to participate in and benefit from economic growth and development. Their participation allows them to improve their economic and social lives and intervene in resource redistribution and consumption for the betterment of their quality of life and conservation (Chamber, 1983; Hirsch, 1987; Buller & Wright, 1990; Bouapao, 2005).

Successful community development needs to be grounded on the three pillars of sustainable development, while equitable access to and sustainable utilization of community resources should not be overlooked (Roberts, 1979; Green and Haines, 2001; Blackstock, 2005; Ashley and Maxwell, 2001). Yet, economic imbalance, social inequality and marginalization of the poor usually trigger over exploitation of resources, although over-consumption of natural resources is central to the

challenge of sustainable community development. Environmental injustice and economic inequality in rural development cause more poor people suffer from loss of livelihood assets, opportunities, and traditional knowledge. This happens when developers and planners do not pay much attention to local social structure/system and immediate needs of communities (Agyeman et al., 2003).

There are many factors that affect community livelihoods (capabilities, assets, and activities) and community enthusiasm to accept changes in their livelihoods, as well as the dynamic relationship between these. In response, the Sustainable Livelihood Framework (SLF) has been adapted by an increasing number of researches as a tool for analyzing complex livelihoods of people (Scoones, 1998; DFID, 1999; Ellis, 1998). The SLF is seemingly parallel to the Sustainable Livelihood Approach (SLA), and is used as a holistic, structural approach to identify influential factors that are centered on people and important in contributing to community livelihood diversification and livelihood sustainability supported by existing activities (Neth, 2008). The Department for International Development (DFID) (1999) and Carney (1998) articulated that this framework could be used by researchers, planners and developers who deal with a complex human subject, especially in rural areas, where people live in pressing social and environmental conditions. This tool helps these stakeholders with a range of perspectives and capacities to participate in structured and coherent study and deliberate over the factors that influence community livelihoods, their relative significance and the way in which these factors interact.

This paper uses theories and concepts of sustainable livelihood approach / framework (SLA/SLF), communal land management by modernized legal approaches and culture / right of indigenous community over resource access / use / management to discuss and produce research findings from a holistic analysis of literature, policy papers, reports of previous empirical studies, and primary data collected from fieldworks in Dak Dam commune.

OBJECTIVE

This paper aims to: (1) investigate indigenous community livelihoods by stressing their livelihood shocks, capabilities, and strategies; (2) identity of large scale economic development opportunities and strategies in Northeastern Cambodia; and (3) determine impacts of large scale economic development on indigenous community livelihoods.

METHODOLOGY

This study used both primary and secondary data. Documentary review and analysis were carried out with relevant theories, concepts and empirical facts from previous research findings as well as other sources. As part of a comprehensive, extensive study in NE Cambodia, Dak Dam Commune in Mondulkiri (MDK) Province was selected as a case study area due to its unique characteristics and irreplaceable condition as an overlapped concession area in the IPs communities which lead to complex IPs livelihood problems, overlapped mandate and conflict of interest, controversial government-company-community relations, dynamic land use change, and community responses based upon IPs collective knowledge and activism. The area has been put under many resource-extractive plans, ranging from commercial logging and community forestry (CFs) since in the late 1990s (McAndrew and Il, 2009), ELCs (economic land concessions) and mining license, since in the mid 2000s (Guttal, 2006; Neth *et al.*, 2011), and social land concession for communal land titling, since in the late 2000s (Neth *et al.*, 2011). Primary data were collected from several methods, such as: (1) household survey in the three villages (Pou Chhorb, Pou Andreng, and Pou Les); (2) in-depth interviews and focus group discussions with local authorities, village elders and IPs community leaders; and (3) expert interviews with reps of concerned institutions and academia.

Description of research site

Dak Dam is located in southeastern MDK province and administratively registered as one of the

two communes of O'Reang District. Despite being home to abundant natural wealth, Dak Dam possesses less cultivated land area than other communes in MDK. Yet, more than 73% of its total population is engaged in irrigated and non-irrigated rice farming. In addition, crop cultivation, such as corn, soya bean, mungbean, peanut, cassava, sweet potatoes and sesame also play crucial role in Dak Dam's rural production and local livelihood system (Neth *et al.*, 2011). Most of the agricultural activities in the area are rain-fed and depend largely on local traditional wisdom (ibid.).

The majority of the population belongs to Phnong ethnicity. Their occupations range from rice and crop cultivators to non-timber forest products (NTFP) collectors (including resin collection), hunters, and paid workers in nearby plantations (Neth *et al.*, 2011). A few Khmer households are also found to have settled in Dak Dam, most of who are newcomers from across Cambodia. These newcomers migrated into Dak Dam in search of agricultural land and business opportunities with highland indigenous communities who have less experience in business.

RESULTS AND DISCUSSION

Community livelihood problems

Indigenous people living in Dak Dam are seen to be very impoverished, vulnerable and susceptible to new economic development plans. Because of its large land area, easy access to the provincial township, fertile agricultural lands, and high mining resource potential, a vast part of Dak Dam's territory have been put under LSED plans. The extensive land conversion into agricultural and agro-industrial plantations and mining zones together with the influx of lowlanders, land speculation, and land encroachment have resulted in limited access to natural resources by the indigenous locals in Dak Dam. Forest resources and by-products have been main sources of their livelihoods for generations. Limited or the loss of access to these resources is not only translated into reduced livelihood capacity or livelihood loss, but it also affects local cultural diversity and integrity as well as the socio-economic, demographic and cultural fabric of the Phnong ethnicity.

Current environmental problems

The lack of representation within the provincial and national authorities together with language barriers makes the indigenous Phnong become a disadvantaged group in their own area. The geo-political conduct of the government and the growing interest of investors are often seen as lack of clarity and sensitivity to local culture and livelihoods. These leave local communities in Dak Dam at high risk of further violations, intimidations, livelihood loss, and socio-cultural corrosion. The designation of the area for macro-economic purposes by disregarding local needs, and the conclusion of concession agreements (between the government and companies) without consultations with local communities have triggered negative impacts on the locals as well as on the business environment. For the communities, on the one hand, these actions could be translated into complete contempt for local wellbeing, culture and livelihoods that depend upon available lands and resources. On the other hand, the companies have been reported to face constant disruption to their operations (e.g., the community shows resistance in the forms of public condemnation, strike and counteract) which could retard concession processes or even distress companie's properties and interests.

Community's system and right

Current LSED-oriented policies considerably affect local livelihoods and culture. This could set off declined community's capabilities (resources, skills, knowledge, activities, and rights), declined community livelihood strategies, and depletion of natural resources (land, water, and biodiversity). Especially, it weakens community's system (i.e., traditional management system) which eventually results in limited collectivity and community's customary rights.

At present, community's system and rights are being influenced by external and internal

factors. Externally, geo-politic development policies of the Royal Government of Cambodia (RGC) have shed light on agro-industrial plantations and mining activities in Dak Dam since in the early 2000s. These investments are conflicting with indigenous communities interests and reducing the extent of legal and legitimate communal land tenure and people's rights to use natural resources, especially forest resources. Moreover, the expansion of the investment lands on local ancestral land and sacred forests infringes on community's rights, and such disrespect of local culture sparks off constant changes upon local cultural norms and practices. The investment atmosphere in Dak Dam which is compliant with modern legalities and legitimacies has gradually provoked on-going conflicts with the customary norms practiced by local IPs. These conflicts are increasing over space and time, particularly on concessionary lands that overlap indigenous territories.

Nevertheless, several major internal factors are deforming community's system and limiting community's rights. They are: (1) informal rules (social capital); (2) alternation of basic religion and culture; and (3) poor institution of community which makes it more dependent on external assistance. Formal and informal social structures and relations formed in Dak Dam have been important in terms of providing social safety net, trust building, livelihood facilitation, conflict resolution and management, and reducing transaction costs of conventional economic activities. However, it is observable that the collective structures of social relations in Dak Dam has been changing when the increasing number of IPs want to have individual property rights over traditional communal lands.

Economic impacts of LSED

Despite stressing negatively, a minority of respondents also perceived agro-industrial and mining development as opportunities. Their primary attention is devoted to the possibilities for new jobs, such as mine workers, paid laborers in agricultural plantations, although such jobs often prove to be labor-intensive, low skilled, dangerous, less numerous, and less suitable to IP inhabitants. At present, because of the geo/socio-cultural conditions (land-based activities) and close proximity to the working areas, particularly in the adjacent plantations and bauxite mine, this is a good fit between such jobs and the living environment. Agro-industrial and mining development in Dak Dam also was remarked to have a possibility to inject capital flow for social development.

The concept of extractive exploitation of mineral resources and the agro-forestry environment are not perceived as economically attractive options for the majority of the IPs in Dak Dam. Local key informants and group discussants perceived current economic development in the forms of economic land concession and mining exploration activities as a negative change agent which can also lead to economic threats for the entire locality. Those who are mainly dependent on land and natural resources might be threatened by new geo-politic policies and land law via limited access and use rights of the IPs over available resources, while those with low income or limited livelihood alternatives might be pressured by rising costs of living.

The alteration of the IPs' economic system was perceived as an undesirable impact of current LSED which could impose burdens on vulnerable and poor community members, whose voices are often unheard. People were afraid that jobs created by current and future agricultural leases / land concessions and the mines may trigger greater influx of outsiders into the areas, let alone the low-skilled and unskilled IP inhabitants to have less ability to compete in new labor markets. Moreover, it was perceived that as natural resources extraction and conversion of agricultural lands into large scale agro-industrial lands continue to grow in capacity-intensity in Dak Dam, there would be loss of or limited capacity of the local economic systems to have proper adaptive economic strategies to tackle economic shocks.

Social impacts of LSED

Economic development in Dak Dam which somewhat favors local interests is found to have created a space for reconstructing local social systems. Key local informants hinted this issue in two ways. First, there is a healthier range of social patterns and options, which help change Dak Dam from

being a previously secluded and closed indigenous community to be a rapidly developing area. Constant interaction between Dak Dam's inhabitants and the outsiders, including lowland in-migrants, has contributed positively to new knowledge and technology transfer (especially in agricultural production) into the area. In addition, once the context of Dam Dak becomes widely open to the public, it brings in various interventions from state and civil society organizations in the forms of infrastructural and social services development and other socio-cultural outreach activities. Second, local IPs start to realize the substantive value of their traditional community laws and social capital which allows them to maintain their solidarity and cultural continuity against the intrusion of new state-driven development options.

Yet, it was found that community residents are aware of some instances of impacts occurred in Dak Dam. So far, increased contact with outsiders and the coming of unwanted development have caused various potential risks to the communities, including the risk of community disruption that has turned Dak Dam into large-scale industrial development zone. Such development is extinguishing the sense of community and social system which have often been ignored by in-migrants and external investors. In addition, respondents confessed that community's social values are being deteriorated by unfitting new cultures brought in by some newcomers, particularly workers of the agricultural plantations and mining companies. Some activities, such as sexual harassment, pre-marriage sexual intercourse between male workers and local female residents, abduction, and increased divorce rate due to abundance of indigenous wives, have to some extent demoralized IPs' socio-cultural value on one hand, while on the other hand they blemish local cultural norms and practices with regard to sexual interaction patterns.

Cultural impacts of LSED

It was found that the increased contact with mainstream industrialized cultures and gradual integration into cash economy during economic land concession and mining processes affect Dak Dam's indigenous cultures in several ways. First, it undermines cultural norms and practices, blurring cultural identity in Dak Dam. The invasion of commercial agricultural land and mining areas over traditional communal land has results in insecure community land tenure and reduction or discontinuation of traditional lifestyle and livelihood activities. The private intrusion into traditionally legitimate lands does not only affect local ownership over their agricultural and settlement land areas, but also cuts off sacred lands covering community spirit forests / sites and reduce locals' religious practices in Dak Dam.

Second, the isolated indigenous culture in Dak Dam becomes more increasingly vulnerable to current developmental contact through mining and agro-industry businesses and its subsequent impacts. Currently, there are two distinct cultures – indigenous culture and modern culture – which are clashing and transforming local traditional cultural systems. Indigenous culture is mainly based upon traditional community laws shaped by traditional norms and practices for generations, while modern culture follows modern public policies, laws and regulations of the RGC for developmental purposes. Modern culture is well-regarded and accepted by the majority of developers and planners with regard to problem solving approaches for land dispute, conflicts over natural resource access and use, and other development-driven issues. Therefore, this new cultural system is incessantly lessening power and status of leaders (community chiefs and village elders) of Dak Dam's native culture.

Environmental impacts of LSED

Despite some physical improvements and improved public services, almost all key interviewees expressed their disappointment with changes of natural landscape and environmental degradation in Dak Dam. The development-related growth over the last decade has resulted in constant dramatic change of the natural environment and biodiversity systems in the area. It was found that extensive forestlands have been cleared and converted into large agro-industrial plantations under agricultural leases or economic land concession policies, and are being disrupted further by current

mining operation plans. The loss of forestlands also leads to the demolishment of natural habitats, wildlife and plant species, as well as substantial forest non-timer forest products in which local communities depend on. Man-made disasters due to the heavy deforestation and the extraction of natural resources, including the soil-terrains, were perceived to have contributed to the existence of land and soil erosion, seasonal drought and flood, and other climate change related problems.

CONCLUSION AND RECOMMENDATIONS

This study offers a view of developmental conflicts that are caused by multiple development approaches and overlapping zoning systems. Especially, it reveals lives of vulnerable indigenous communities who are living in such conflicted areas and under multi-dimensional pressures. It is found to be an affected case from large scale development policies since this commune has been explored and exploited by a number of companies, as well as being under a variety of LSED schemes. Dak Dam case presents an intense resource curse situation. IP's lives have been miserable despite living amid the rich natural resources. The sources of their livelihoods have been constantly invaded by external forces for the favor of LSED. The age-old cultural systems and social norms have also been repeatedly violated beyond tolerance. It's also found that at present the IP communities have only hope for survival and maintenance of their traditional wisdom and age-old culture lie with their security of communal land rights, forestlands, and sacred places/forests. These insurance mechanisms have also been found to be in jeopardy.

A number of key recommendations need to be taken into serious account by governmental, non-governmental, and private institutions. These include: (1) improve security mechanisms for communal land rights, forestlands, and sacred places / forests; (2) improve capacity building and advocacy programs; (3) strengthen legal, institutional, and policy supports by higher level of authorities; (4) improve free, prior informed consent (FPIC) and environmental impact assessment (EIA) enforcement; and (5) improve land zoning system and land use planning.

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Research article

Toward Measuring the Vulnerability of Agricultural Production to Flood: Insight from Sangkae River Catchment, Battambang Province, Cambodia

CHINDA HENG
The Learning Institute, Phnom Penh, Cambodia

SOTHEAVIN DOCH*
The Learning Institute, Phnom Penh, Cambodia
Email: sotheavin@learninginstitute.org, sotheavin_doch@yahoo.com

JEAN-CHRISTOPHE DIEPART
The Learning Institute, Phnom Penh, Cambodia

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Abstract The study proposes an indicator-based analysis on the vulnerability of agricultural production to flood issues in a river catchment area. The study site is the Sangkae River catchment area located in the Northwestern region of Cambodia and the unit of observation is the commune. Flood hazards are not restricted to the downstream lowland Tonle Sap plain; the study also considers river overflow and run-off flood events occurring upstream in Sangkae River catchment. We address the concept of vulnerability in three dimensions (exposure, sensitivity and adaptation capacity) and operationalize it in a multi-level analytical framework.We first identify indicators relevant with each of the three dimensions of vulnerability. We then combine the standardized and weighted indicators into composite exposure, sensitivity and adaptive capacity indexes, which we analyze statistically and spatially with a geographic information system. We further integrate the indicators in a hierarchical cluster analysis to establish a typology of commune vulnerability across the catchment. The results of the study showed the link between the vulnerability of agriculture to flood and the different farming systems of rural communities.

Keywords flood management, vulnerability assessment, agricultural production, watershed management, Cambodia

INTRODUCTION

Cambodia is one of the most vulnerable countries to climate change in Southeast Asia (Yusuf and Fransico, 2009). The processes of climate change are complex and diversified but are mainly at play through the intensification of the water cycle (Huntington, 2006). Climate change increases the occurrences of extreme weather phenomena, such as heavy rainfall, flood, drought, storms, etc. (Solomon et al, 2007). The modification of rainfall pattern has affected the water level of Mekong River and Tonle Sap Lake (MRC, 2010). Due to the river run-off from upper Mekong River, the water level of the Tonle Sap is projected to increase from 1 meter to 2.3 meters by the year 2030 (Eastham et al., 2008).

However, flood is not a new phenomenon in Cambodia. Many parts of the country have flooding experiences every year, particularly in the central area of the country where floods are associated with the reversal of water in the Tonle Sap River and the flooding of the large Cambodian central plain. People have developed ways to practice agriculture and fishing, which are well adapted to this unique phenomenon. As Suon rightly put, floods are usually good for rice-based agriculture but their irregularity and unpredictability bring negative impact on agricultural production and rural livelihood systems (Suon, 2007). Major flood events, such as the one that

occurred in 2011, had for instance very serious consequences in the Cambodia economy. The loss of agricultural productions and degradation of physical infrastructures were worth over $400 million (CRED, 2011).

Over the last 10 years, Battambang has witnessed a dramatic agricultural colonization of peripheral forest areas. Forest cover has become the substitute for agro-industrial cash crops very rapidly, in a process fuelled by important internal immigration movements of people coming from the lowland densely populated areas (PMPSWG, 2011). The conversion of the upland evergreen forest areas into agricultural land is also very likely to affect the hydrological system and to increase surface and river water run-off (Kirsch, 2010). Future flood patterns are thus very likely to be modified by the combined effect of climate and land use change. These transformations are very likely to result in a change in agricultural production and the challenges at stake are important as agriculture is the main source of livelihood for a very large majority of Cambodian household living in the rural and who make up to 80% of the entire population (RGC, 2010a). Flooding may contribute to increased poverty in rural Cambodia and have serious consequences in terms of availability and accessibility to food (NAPA, 2006; Helmers and Jegillos, 2004).

Flood risk management has been considered as key priority for poverty alleviation and development of Cambodia (RGC, 2010b). Several institutions and committees have been established from national down to local level to respond to natural disasters (Committee for Disaster Management). In Battambang province, principles and concepts of Integrated Water Resources Management (IWRM) have been introduced for the management of water resources at the catchment level (Yem, et al., 2011) and integrated in the provincial spatial plan (PMPSWG, 2011). However, weak cross-sector coordination and the lack of tools to support decision-making have considerably impeded effective flood management (Eng, 2009). The involvement and participation of Battambang Provincial Spatial Planning Team in this research process can be viewed as a first step toward the design of a flood management, decision-making tool for provincial authorities.

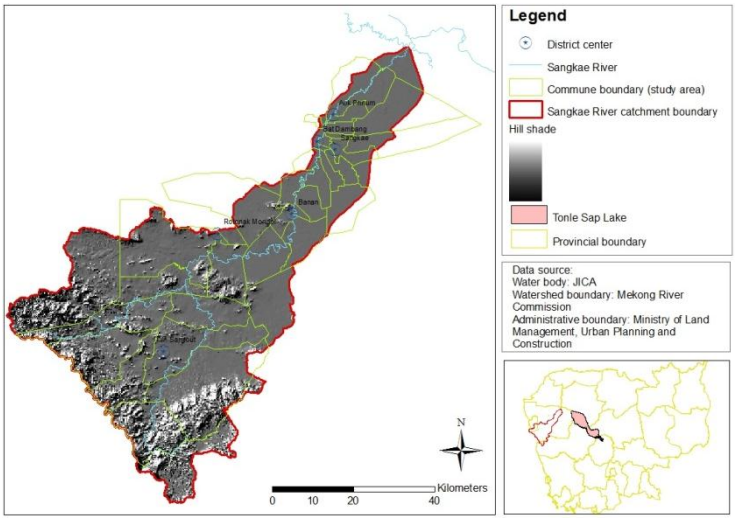

Fig. 1 Sangkae River catchment area

OBJECTIVE

The study aims to achieve two things. First, we aim to understand the vulnerability of agricultural production in Sangkae River catchment area and second, to provide recommendations to improve flood management as part of an integrated water resource management system.

METHODOLOGY

Conceptual framework

The concept of vulnerability of social and environmental systems has a history of several decades. One of the best known definitions was formulated by the International Strategy for Disaster Risk Reduction (UN/ISDR), which defines vulnerability as "the condition determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazard" (UN/ISDR, 2004). Originally envisaged in the context of natural disaster reduction, the concept of vulnerability was further developed with contributions made by climate change scientists (IPCC, 2001). Adger (2006) stresses that vulnerability is most often conceptualized as being constituted by components that include exposure to change or external stresses, sensitivity to change, and the capacity to adapt. Exposure comprises the degree, duration, and/or extent in which the system is in contact with a hazard, or subject to the change (Kasperson et al., 2005; Adger, 2006). Sensitivity is the extent to which a human or natural system can absorb impacts without suffering long-term harm or other significant state change (Adger, 2006). The system's coping capacity (Turner et al., 2003), or capacity of response (Gallopin, 2006), is also called adaptive capacity by the IPCC (2001); Adger (2006) and Smit and Wandel (2006). As noted by Smit and Wandel (2006), some authors apply "coping ability" to shorter-term capacity or the ability to just survive, and employ "adaptive capacity" for longer-term or more sustainable adjustment.

Following the IPCC framework, we address the concept of vulnerability of agriculture production to flood with three lenses: exposure, sensitivity and capacity of responses. While exposure refers to the occurrence, magnitude, and locations of the flood events; sensitivity concerns the impacts of the flood events on agricultural land and production in the River catchment. Capacity of responses deals with both the short-term coping mechanism and long-term adaptive strategy to respond to the flood impacts (Fig.2).

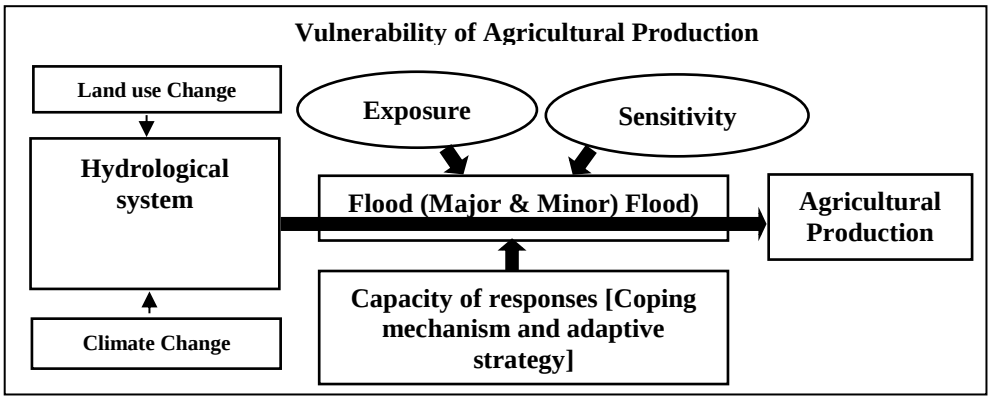

Fig. 2 Research conceptual framework

Helmers and Jegillos (2004) reported that there are two types of flood usually occurring in Cambodia: flash flood and central area flood. Flash floods result from heavy downpours upstream on the Mekong River and affect the provinces along the Mekong as well as in the southern areas of the country. The central area floods result from a combination of run-off from the Mekong and heavy rains around the Tonle Sap Lake (Helmers and Jegillos, 2004). We retain the central area flood as one separate type of flood. However, our study differentiates between river overflow flood (Sangkae river and its tributaries) and surface water run-off flood. The combinations of these floods are also considered (Fig. 3). As flood may not solely affect the down-stream part of the Sangkae River catchment (Tonle Sap flood plain), but also the up-stream part of the catchment; we decided to investigate flood in the whole Sangkae River catchment.

According to the Mekong River Commission, flood intensity is classified into three categories: minor flood, medium flood, and major flood, with frequency of occurrence of respectively every one, ten and twenty years (MRC, 2002). Our study focuses on two types of flood: normal flood considered here as a usual annual flood (minor flood according to MRC classification), and the severe 2011 flood, equivalent in magnitude to a medium flood according to MRC classification.

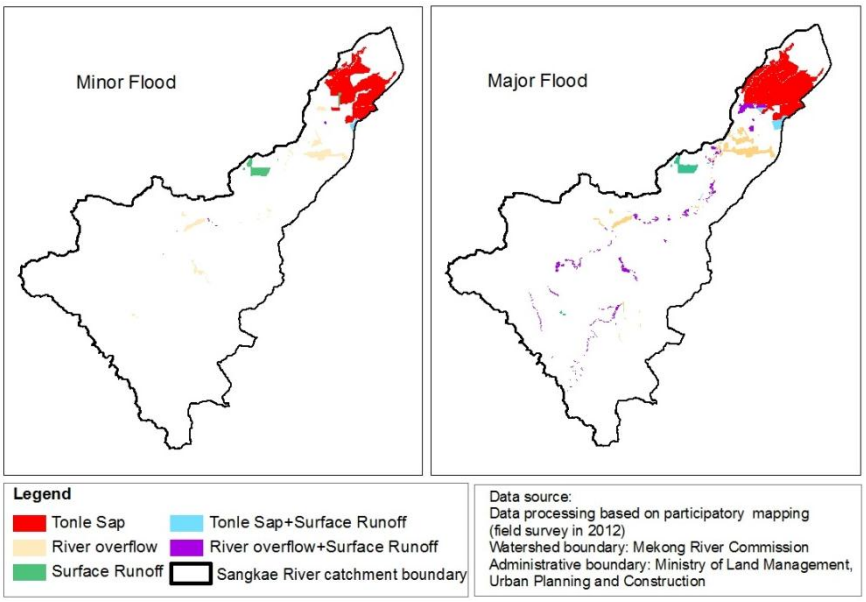

Fig. 3 Flood incidence in the Sangkae River catchment

Analytical framework

The assessment framework designed to approach, analyze and understand the vulnerability of agricultural production to flood in the study area is based on indicators. Each dimension of vulnerability (exposure, sensitivity and adaptive capacity) is measured through a number of indicators along several data sources (Table 1). The values of each indicator are standardized, weighted by a coefficient determined with local stakeholders and then combined into composite exposure, sensitivity and adaptive capacity indexes, which we analyze spatially with a geographic information system. We compute an overall vulnerability index by using the formula "Vulnerability = [(Exposure +Sensitivity)-Adaptive Capacity]". We further integrate the indicators in a hierarchical cluster analysis to establish a typology of commune vulnerability across the catchment, which we interpret by computing, for each vulnerability type, the mean values of each index.

Data collection and tools

Primary data collection on the vulnerability of agricultural production to flood was mainly carried out through commune workshops organized in each commune in 2012 with a group of 10-15 participants for each commune. These workshops started with a participatory flood mapping exercise focusing on the exposure and sensitivity dimensions of vulnerability. The mapping of flood areas in normal year (minor flood) and in 2011 rests on the knowledge of local authorities, as they are the main information providers. Aerial photos retrieved from the Google Earth Pro server (www.googlearth.com) covering the entire communal territory were printed on A0 size paper and were overlaid with plastic covers. The group of participants was invited to identify the main water ways and bodies in the commune as well as the agricultural land areas. They were then asked to map out the agricultural land affected by a usual flood and affected by the 2011 flood and for each

flood area, to provide information on the type of flood, their duration and their actual impact on the different agricultural productions. Lastly, a structured questionnaire provided data on the institutional capacity of the commune to adapt to flood. This included questions on i) the efficiency of the flood warning system, ii) the mobilization of self-help groups in case of flood, iii) the existence and efficiency of external support, iv) the allocation of communal funds for post-disaster management, v) the efficiency of the natural disaster management committee, vi) the provision and quality of training programs for farmers and how well these training programs address flood management and vii) the existence of farmer organizations in the commune.

In addition, secondary datasets were consulted to build a number of other indicators. The GIS provincial spatial planning database was useful to calculate indicators based on spatial layers: the agricultural land area and road density network (PMPSWG, 2011). The commune database provided useful updated statistical references for other indicators (http://db.ncdd.gov.kh/cdbonline).

Table 1 Survey analytical framework

Dimension	Indicators	Weight in overall composite index	Data source
Exposure	Major (2011) flood area size, expressed as a percentage of the total agricultural area in the commune	0.4	Commune workshop conducted in 2012
	Minor flood area size, expressed as a percentage of the total agricultural area in the commune	0.4	
	Major (2011) flood area size weighted by the duration of the flood and expressed as a percentage of the total agricultural area in the commune	0.2	
Sensitivity	Total agricultural land area expressed as a percentage of the total commune area size	0.3	Interpretation of Land sat satellite image (2010)
	Percentage of population involved in agriculture in the commune	0.1	Commune data base (2010 update)
	Major (2011) flood area weighted by impact on production and expressed as a percentage of the total agricultural area in the commune.	0.3	Commune workshop conducted in 2012
	Total cultivated area during flood period expressed as a percentage of total cultivated area in commune.	0.3	Commune data base (2010 update)
Adaptive capacity	Institutional capacity of commune	0.3	Commune workshop conducted in 2012
	Percentage of population in commune above poverty line	0.25	Commune data base (2010 update)
	Density of road network in commune	0.2	GIS-based calculation based on road information (2010)
	Literacy rate in commune	0.25	Commune data base (2010 update)

RESULTS AND DISCUSION

Annually, flood affects 252.83 km^2 of agricultural land area in the Sangkae River catchment. The flooded area in 2011 was 32% larger than the area flooded during a normal flood (Table 2). Among the three different types of floods, the Tonle Sap flood is by far the most important in terms of affected area size and duration, if compared with river overflow and surface run-off floods. However, the difference of flooded area size between a minor flood and the 2011 flood is proportionally much more important for a river overflow and surface run-off flood than for the Tonle Sap flood (54% against 25% increase).In the event of more frequent extreme flood events driven by climate change, our preliminary results suggest that flood management strategy in the catchment should pay greater attention to upper stream areas where floods hit and are likely to become more important in the future.

Exposure

There are several factors that determine the level of exposure of the communes; the topography, the origin of the flood and flood duration. Figure 4 shows that not only communes located in the Tonle Sap flood plain are exposed to flood. Some communes located in the middle and up-stream also have high exposure levels where the effects of river overflow are aggravated by surface run-off flood (Fig. 4). Second, flooding by Tonle Sap has a longer duration than both of the other types of flood (Table 2). This duration factor reinforces the high exposure levels of the down-stream communes.

Table 2 Flood impacts, duration and occurrence

Flood types	Agriculture flooded area (km^2)		Percentage of increasing flood area size	Duration (mean values in days)		Occurrence (mode of values)	
	major flood	minor flood		major flood	minor flood	major flood	minor flood
Tonle Sap (central area)	249.94	188.45	24.60	63.6	66.35	Sep-Oct	Sep-Nov
Direct river overflow	62.72	46.44	54.08	15.26	23.89	Aug-Oct	Sep-Oct
River overflow & Surface run-off	40.62	1.01		8.31	24.75	Jul-Nov	Aug-Sep
Surface run-off	16.88	16.93		32	40.25	Aug-Oct	Aug-Oct
Total	370.16	252.83	32				

Sensitivity

The factor being the most determinant in explaining the sensitivity of communes to flood is the possibility for the commune to diversify its agriculture production. We refer here to both the development of multi-cropping systems and the development of dry season production. The agro-ecological environment is of primal importance. The communes with high sensitivity are logically the communes in which agriculture land dominates in the land use. Amongst this group, the communes with little crop diversification besides the rain-fed rice are particularly sensitive. For the communes located at the down-stream of Sangkae River catchment where the agro-ecological environment allows for crop diversification and the practice of a dry season recession rice to avoid the flood peak period, the level of sensitivity decrease sharply even for commune which are located in the Tonle Sap plain. In the up-stream, the commune implements a multi-cropping system covering both dry and rainy seasons and are less sensitive to flood (Fig. 4).

Adaptive capacity

Down-stream communes have higher adaptive capacity (Fig. 4). This is due to the proximity with the city of Battambang, which greatly improves access to external intervention. The proximity of the city also offers opportunities of labor diversification away from agriculture, which can be considered here as an important adaptation strategy. We also noted that communes with extensive experience with floods have developed more efficient adaptation mechanisms and strategies. We also note important differences of adaptive capacity between communes that are located in the up-stream area of the catchment. What explains these differences is the relative capacity of the commune councils to mobilize resources internally and externally to address post-flood management.

Vulnerability

The interpretation of the multivariate statistical analysis of all indicators allows for the identification of five main types of vulnerability that we further ranked into five classes from “very low” to “very high” vulnerability (Table 3 and Fig. 4).

Table 3 indicates that exposure and sensitivity have a preponderant influence on the

vulnerability of agricultural production to flood. The exposure and sensitivity indices are positively correlated (Tab.3). However, exposure is more decisive in explaining the highest vulnerability level. However, the measures that need to be addressed to reduce the exposure implies heavy civil engineering works (dikes, riverbanks reinforcement), which are far beyond what the communes and communities can actually afford. In the upstream areas, measures to reduce exposure could be the terracing of steep land in a view to reduce water surface run-off.

Notwithstanding, the communes have more options and opportunities to reduce their sensitivity to flood: diversification of cropping systems, water storage systems and the parallel development of dry season agriculture are processes that could considerably reduce the vulnerability of agriculture to flood. Table 3 also indicates that the level of commune vulnerability is also quite influenced by the adaptive capacity. This is a domain where provincial, district, and commune authorities should prioritize their action. What is particularly needed is the establishment of an effective institutional platform where communes could formulate their need to improve flood management (pre/post disaster) and through which support and external assistance should be delivered. The watershed management committee may play this role.

Table 3 Commune vulnerability index

Commune vulnerability*	Overall exposure Index (mean of Z-score)	Overall sensitivity Index (mean of Z-score)	Overall adaptive capacity index (mean of Z-score)
Very low	Very low [-0.7323808]	Very low [-1.5983150]	Low [-0.3817778]
Low	Medium [-0.3817195]	Medium [0.4457365]	High [1.0304744]
Medium	Low [-0.7077337]	Low [-0.2380573]	Very low [-0.8889612]
High	High [1.1328966]	Very high [0.9314991]	Very high [1.0362228]
Very high	Very high [1.8084319]	High [0.6203428]	Medium [-0.2394899]

** Vulnerability classification made with a hierarchical cluster analysis (Ward's method)*

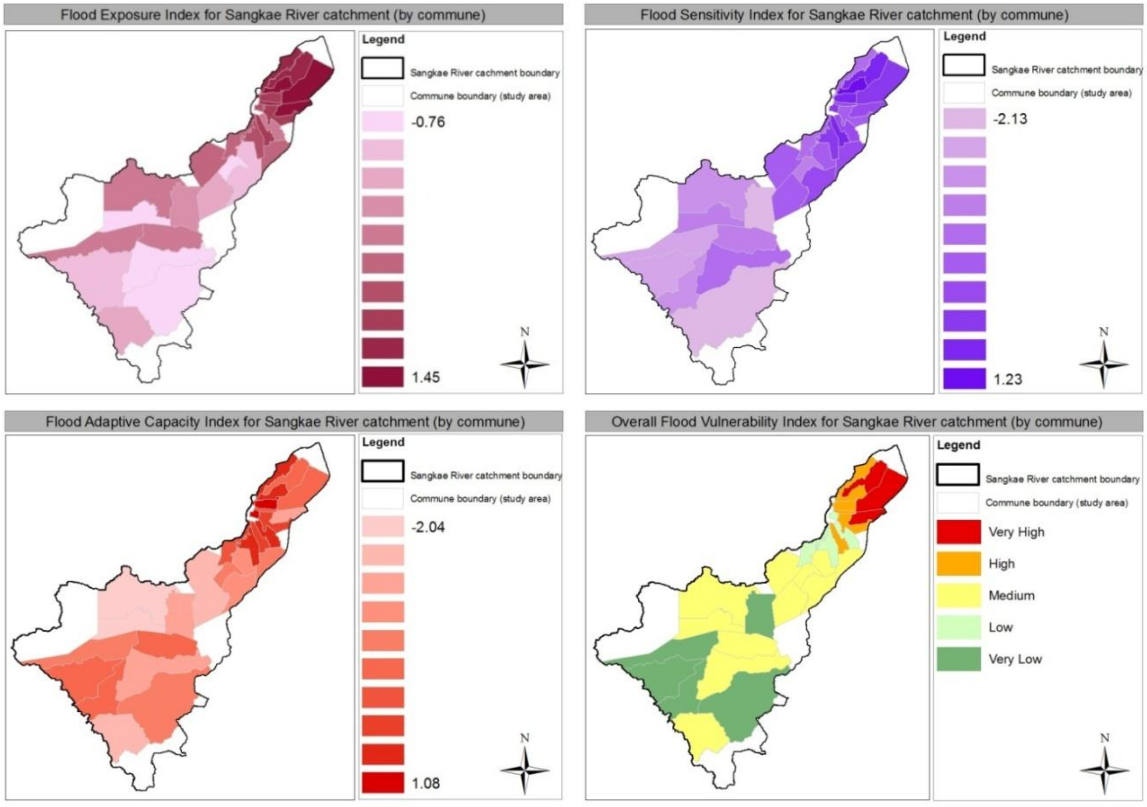

Fig. 4 Flood exposure, sensitivity, adaptive capacity and overall vulnerability indexes by commune in across the Sangkae River catchment area

CONCLUSION

Our study has presented a methodology to analyze and understand the vulnerability of agricultural production to flood. A great deal of information collected through the research process was provided by local stakeholders who are directly affected by flood. The tools and data collection methods are easy to grasp and the approach can be easily replicated in the context of other river basins. The approach is based on the measurement of specific indicators related to three dimensions of vulnerability, namely exposure, sensitivity and adaptive capacity. It further develops composite indexes that integrate a large number of factors in a single value. The use of a geographic information system enables us to comprehend the geography of vulnerability across a river basin area. Additionally, the indicators can be compared over time so that they are indicative values to watershed authorities for making strategic and operational decisions to improve flood management. The framework can be refined further in a number of ways. One is by revising the existing indicators and by identifying new ones. Another could be by incorporating rainfall data so that better links can be made with climate change. The survey has been realized in partnership with a spatial planning team from Battambang and should be considered as a step towards developing a flood management decision-making tool for provincial authorities.

ACKNOWLEDGMENT

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Research article

Comparative Reproductive Behavior of α-Male, β-Male and Subordinate Male Timor Deer (*Cervus timorensis* Blainville) Raised under Captivity

DAUD SAMSUDEWA*
University of Diponegoro, Semarang, Central Java, Indonesia
Email: daudreproduksi@gmail.com

SEVERINO S. CAPITAN
University of The Philippines Los Baños, College, Laguna, Philippines

CESAR C. SEVILLA
University of The Philippines Los Baños, College, Laguna, Philippines

RENATO S. A. VEGA
University of The Philippines Los Baños, College, Laguna, Philippines

PABLO P. OCAMPO
University of The Philippines Los Baños, College, Laguna, Philippines

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Abstract Timor deer were used in an experiment to study the comparative behavior of α-male, β-males and subordinate male raised in captivity. Twelve males (4.25 years old) and 24 females (3 to 4 years old) were randomly assigned into three separate cages following the ratio of 4 males: 8 females. Kruskal-Wallis H test of non-parametric analyses were done for aggressive, libido and mating behaviors. The α-male was the dominant male in terms of aggressive, libido and mating behaviors. Subordinate male showed the highest frequency of wallowing to reduce stress, and running around for expressing libido. Successful mating was mostly exhibited by α-male, Subordinate2 (S2)-male did not show actual mating. The establishment of dominance hierarchy resulted to the manifestation of differences reproductive behaviors.

Keywords reproductive behavior, male Timor deer, captivity

INTRODUCTION

The Timor deer (*Cervus timorensis* Blainville) is a medium-sized cervid with 60 kg mature body weight and 1.00-1.10 m shoulder height (Jacoeb and Wiryosuhanto, 1994). It is currently being reared in farms in many countries including New Zealand, Australia, Indonesia, Mauritius, New Caledonia, China, Korea and Russia (Semiadi and Nugraha, 2004).

The productivity of deer farming in Indonesia is still low. The study of Daningsih (2005) showed that annual population growth of deer was only 0.169 at Kelompok Pemangkuan Hutan (KPH) Bunder, 0.25 at Kulon Progo and 0.17 at KPH Jonggol. The low of the annual population growth suggests that the productivity of deer farming in captivity can be improved if some key aspects of management such as feeding, mating, aggressive male behavior, maternal care and nervousness tendency are addressed. Asher et al., (1996) claimed that intensive deer farming with poor management practices, such as low of the feed quality and high social stress, may lead to poor cervid reproduction health. This is corroborated by Moberg (1991) who stated that behavioral stress has adverse effects on the reproduction system of both males and females. Reproductive success is one of the parameters to monitor stress. Animals that suffer from stress often fail to reproduce successfully.

Timor deer's develop a linear dominance hierarchy consisting of α-males, β-males and subordinate males through aggressive behavior. Social stress including those caused by conflicts related to dominance hierarchy has relatively consistent effects on reproductive behavior. This is manifested by changes in male sexual behavior (Blanchard et al., 2002).

OBJECTIVES

Therefore, in order to develop better management practices to maximize reproductive capacity of deer farms, it is necessary to study reproductive behavior of α-male, β-male and subordinate male Timor deer raised under captivity.

METHODOLOGY

The study was conducted at H. Yusuf Wartono Timor deer captive breeding, Gondosari, Gebog, Kudus, Central Java. The reproductive behavior observation was carried out for 43 days starting August 1, 2011 until September 12, 2011. Twelve (12) males (51 ± 6 months old; 68.29 ± 8.41kg body weight and in same antler stages), and twenty-four (24) females (3-4 years old 40-60 kg body weight with normal estrus) were used. Other materials include 3 communal cages (23.5 x 21.5 m) and ethogram table.

Observation for reproductive behavior was done with behavior sampling (Martin and Bateson, 1993). The observation was done by manual recording using a record book and an ethogram table. Time, frequency, interval, duration and sequence of every behavior were recorded. The data was supported by audiovisual recorder. Data gathering of reproductive behavior was focused on a number of aspects including libido behavior, aggression and mating behavior.

Kruskal-Wallis H test of non-parametric analysis was done for comparing α, β and subordinate male Timor deer in terms of libido, aggressive and mating behavior.

RESULTS AND DISCUSSIONS

Aggressive behavior: Aggressive behavior of male Timor deer was expressed by wallowing, walking with head up, shouting, rubbing antler, expression of threat, pushing, actual fighting, fleeing and climbing. Aggressive behaviors are commonly expressed when more than one male start to approach an estrus female, α-males are the ones commonly displaying these behaviors, especially when β-males or subordinate males are approaching. From the time of actual fighting and incidence of fleeing, dominance hierarchy was established.

Average values of each aggressive behavior of α, β and subordinate male Timor deer's are shown in Table 1. The result of Kruskal-Wallis H test showed significant differences for all aggressive behaviors among the different hierarchy of male Timor deer. The α-male as the dominant male had mostly shown dominancy in all of the behavior parameters except in frequency and interval of wallowing and fleeing. The highest frequency and interval of wallowing were exhibited by S2-male, which could be an attempt of the animal to reduce stress. S2 male had the highest frequency and longer interval of wallowing, but shorter duration because he was disturbed by more dominant males when started. On the other hand, β-male exhibited the highest frequency of fleeing because of he was the opponent of α-male. The β-male also exhibited the longest interval of fleeing because in addition to fighting with α-male, in between also fight with S1 or S2-male and exhibited winning.

Indeed, shouting bouts (shouting in between two periods of shouting) were only done by α-males as a sign of dominance. Wallowing is commonly followed by rubbing antler or expression of threat. In these behavior α-male still shown the most dominant male except for interval of expression threat. In terms of pushing and actual fighting, α-male also shown dominancy in frequency, duration and interval. Actual fighting was longer time between α and β-male compare with other male. Climbing as one sign of dominancy, α-male was shown the most frequent male exhibited this behavior with longest duration and interval. The α-male exhibited climbing everyday

and the males usually disturbing other males when they exhibited this behavior.

Table 1 Average values of each aggressive behavior (43 days observations) of male Timor deer

Behavior	α-male	β-male	S1-male	S2-male	χ^2
Wallowing					
- Duration, seconds	69.56	67.50	63.97	56.26	183.94*
- Frequency, counts	1.18	1,06	1,28	1,93	72.02*
- Interval, minutes	43.15	26.60	30.58	134.72	114.10*
Walking with Head Up					
- Duration, seconds	13.70	11.65	5.61	0.00	374.69*
- Frequency, counts	3.50	1.42	0.63	0.00	404.36*
- Interval, minutes	173.36	127.09	36.81	0.00	241.47*
Shouting Bouts					
- Duration, seconds	33.49	0.00	0.00	0.00	
- Frequency, counts	4.08	0.00	0.00	0.00	
- Interval, minutes	151.69	0.00	0.00	0.00	
Rubbing Antler					
- Duration, seconds	39.06	16.27	4.68	0.17	374.44*
- Frequency, counts	5.26	0.60	0.15	0.01	400.83*
- Interval, minutes	148.56	28.55	1.64	0.00	407.85*
Expression of Threat					
- Duration, seconds	5.76	4.66	2.33	0.29	353.30*
- Frequency, counts	4.22	1.57	0.64	0.07	415.32*
- Interval, minutes	159.31	170.47	35.65	0.00	250.80*
Pushing					
- Duration, seconds	6.14	4.95	2.57	0.47	348.38*
- Frequency, counts	3.92	1.61	0.68	0.11	402.98*
- Interval, minutes	162.15	156.53	40.78	0.37	247.04*
Actual Fighting					
- Duration, seconds	229.72	247.01	204.09	107.36	261.66*
- Frequency, counts	3.55	1.96	1.39	0.68	342.14*
- Interval, minutes	163.64	206.17	88.69	38.41	156.82*
Fleeing					
- Frequency, times	0.00	1.82	1.32	0.69	341.99*
- Interval, minutes	0.00	204.08	71.29	41.14	189.89*
Climbing					
- Duration, seconds	13.61	11.31	6.02	1.50	317.80*
- Frequency, counts	3.00	1.33	0.64	0.13	365.55*
- Interval, minutes	143.27	75.06	26.41	0.00	231.32*

Legend: α-male (The most dominant male); β-male (The second dominant male); S1-male (Subordinate 1 male); S2-male (Subordinate 2 male)

Libido behavior: Libido behavior of male Timor deer was expressed by wallowing, roaring, seeking female, crowning, flehmen, spraying of urine, rutting, climbing and running around. Libido behavior was shown by male as expression of mating desire. In this present study, duration, frequency and interval of each libido behavior was measured. The most behavior exhibited by male Timor deer was seeking female (6.55 counts/day) followed by flehmen, spraying urine rutting and climbing (6.40, 6.32, 4.88 and 4.31 counts/day, respectively). Average values of each libido behavior of α, β and subordinate male Timor deer's are shown in Table 2.

The result of Kruskal-Wallis H test showed significant differences ($P<0.05$) for all libido behavior among the different hierarchy of male Timor deer. The α-male as the dominant male had mostly shown dominancy in all the libido behavior parameters except running around. The highest frequency and longest duration and also interval of running around was exhibited by S2-male, which might be an attempt to express libido.

The α-male has shown dominancy for wallowing and spraying urine (most frequent and also longest duration and interval). Spraying urine and wallowing could be related to release of odors and attract the estrus female, that activity will be repeated when the estrus female shown non-receptive behavior prior to mating. Libido behavior of α-males was found to be related with scent marking (urinary spray and rutting), which was more common compared with other males. Roaring was commonly done by α-males to display their dominancy. Blanchard et al., (2002) reported that dominant male sugar gliders (*Petaurus breviceps*) display frequent scent marking behavior as part of their libido behavior.The α-male also showed dominancy on crowning behavior, which could be

included as a sign of dominance and an act of attracting female. Flehmen is one of the interesting libido behaviors of Timor deer's. It is an important sign signaling the start of a mating behavior. Flehmen is done to facilitate exposure of the vomeronasal gland for a scent or pheromone (Messang-Nallley, 2006). Climbing was also mostly done by α-male. When other males exhibited this behavior, α-male would disturb them. This is the reason for shorter duration and interval of climbing in other males.

Table 2 Average values of each libido behavior (43 days observations) of male Timor Deer

Behavior	α-male	β- male	S1- male	S2- male	χ^2
Wallowing					
- Duration, seconds	252.40	225.78	139.98	37.64	345.92*
- Frequency, counts	3.24	1.40	0.73	0.20	359.41*
- Interval, minutes	146.21	110.65	21.58	0.00	233.78*
Roaring Bouts					
- Duration, seconds	38.87	0.00	0.00	0.00	
- Frequency, counts	4.41	0.00	0.00	0.00	
- Interval, minutes	155.73	0.00	0.00	0.00	
Seeking Female					
- Duration, seconds	228.82	194.01	102.93	17.71	335.81*
- Frequency, counts	4.06	1.59	0.79	0.11	384.72*
- Interval, minutes	151.57	154.56	86.39	3.37	170.91*
Crowning					
- Duration, seconds	61.51	16.76	6.08	0.00	366.77*
- Frequency, counts	2.81	0.43	0.16	0.00	388.85*
- Interval, minutes	170.96	23.82	7.44	0.00	365.40*
Flehmen					
- Duration, seconds	8.06	6.38	3.02	0.21	348.34*
- Frequency, counts	4.13	1.53	0.69	0.05	399.34*
- Interval, minutes	156.66	149.81	72.96	3.37	184.10*
Spraying Urine					
- Duration, seconds	11.98	10.14	5.07	0.96	317.07*
- Frequency, counts	4.04	1.50	0.68	0.10	388.25*
- Interval, minutes	151.21	143.78	64.14	0.00	195.76*
Rutting					
- Duration, seconds	41.13	13.48	2.68	0.00	393.76*
- Frequency, counts	4.19	0.57	0.12	0.00	404.09*
- Interval, minutes	156.90	27.13	2.74	0.00	403.62*
Climbing					
- Duration, seconds	11.86	5.70	2.66	0.51	294.60*
- Frequency, counts	3.33	0.63	0.29	0.06	329.22*
- Interval, minutes	145.53	25.82	12.58	4.10	307.65*
Running Around					
- Duration, seconds	0.00	0.00	45.95	129.90	331.10*
- Frequency, counts	0.00	0.00	0.41	1.58	373.43*
- Interval, minutes	0.00	0.00	24.18	145.31	195.57*

Legend: α-male (The most dominant male); β-male (The second dominant male); S1-male (Subordinate 1 male); S2-male (Subordinate 2 male)

Mating behavior: In the present study, mating behavior of male Timor deer was expressed by following, sniffing, kissing, flehmen, kicking, nudging, mounting, erection, intercourse, ejaculation, refractory and bisexual. The highest frequency of mating behavior of male Timor deer was manifested in following (6.91 counts/day) followed by sniffing and kissing (6.18 and 5.84 counts/day, respectively). Average values of each mating behavior of α, β and subordinate male Timor deer's for duration, frequency and interval are shown in Table 3.

The result of Kruskal-Wallis H test showed significant differences for all mating behaviors among the different hierarchy of male Timor deer. The α-male as the dominant male had mostly shown dominancy in all of the mating behavior parameter except bisexual. Bisexual only observed in the subordinate male. S2-males showed the highest frequency (0.71 counts/day), longest duration (3.16 seconds) and longest interval (37.41 minutes) of bisexual behavior among the male deer's. The Subordinate male Timor deer exhibited bisexual behavior when they cannot mate with female deer's due to intimidation of α-male. Mating behavior was observed to be more frequent in α-males than other males. Subordinate males had the lowest frequency of mating behavior. Indeed, S2 males only exhibited following, sniffing, kissing and bisexual behavior (0.08, 0.03, 0.02 and 0.71 counts/day). Blanchard et al., (2002) also reported that subordinate males of albino mice

(*Rattus norvegicus*), deer mice (*Peromyscus maniculatus*) and lesser mouse lemurs (*Microcebus murinus*) have the least frequent of the mating behavior.

Table 3 Average values of each mating behavior (43 days observations) of male Timor deer

Behavior	α-male	β-male	S1-male	S2-male	χ^2
Following					
- Duration, seconds	229.68	95.72	49.63	4.88	326.96*
- Frequency, counts	5.11	1.22	0.50	0.08	351.55*
- Interval, minutes	111.57	72.80	36.43	3.23	217.04*
Sniffing					
- Duration, seconds	9.96	3.64	1.68	0.13	353.15*
- Frequency, counts	4.87	0.92	0.39	0.03	281.83*
- Interval, minutes	113.75	67.01	26.78	3.23	243.24*
Kissing					
- Duration, seconds	13.55	4.80	2.14	0.10	365.10*
- Frequency, counts	4.65	0.84	0.33	0.02	372.71*
- Interval, minutes	118.15	62.10	20.92	0.00	267.72*
Flehmen					
- Duration, seconds	6.82	2.00	0.90	0.00	383.80*
- Frequency, counts	4.51	0.69	0.27	0.00	327.54*
- Interval, minutes	116.16	39.97	16.83	0.00	298.17*
Kicking					
- Duration, seconds	5.61	1.59	0.70	0.00	379.90*
- Frequency, counts	4.49	0.63	0.24	0.00	281.66*
- Interval, minutes	117.68	33.74	13.40	0.00	313.31*
Nudging					
- Duration, seconds	17.69	4.86	2.11	0.00	382.44*
- Frequency, counts	4.47	0.55	0.21	0.00	386.38*
- Interval, minutes	114.64	21.44	10.41	0.00	355.73*
Mounting					
- Duration Inter, seconds	20.28	5.84	1.64	0.00	331.45*
- Frequency Inter, counts	4.20	0.43	0.09	0.00	403.67*
- Interval Inter, minutes	114.12	7.58	3.11	0.00	416.05*
Erection					
- Duration, seconds	37.99	7.64	2.42	0.00	422.22*
- Frequency, times	4.20	0.24	0.09	0.00	422.33*
- Interval, seconds	112.14	1.27	3.11	0.00	446.74*
Intromisian & Ejaculation					
- Duration, seconds	4.67	0.88	0.28	0.00	393.19*
- Frequency, times	4.20	0.22	0.08	0.00	425.15*
- Interval, seconds	112.28	1.27	0.26	0.00	454.14*
Refractory					
- Duration, seconds	212.50	39.41	13.11	0.00	407.73*
- Frequency, times	4.19	0.22	0.08	0.00	425.16*
- Interval, seconds	112.49	1.27	0.26	0.00	454.14*
Bisexual					
- Duration, seconds	0.00	0.05	1.56	3.16	153.41*
- Frequency, times	0.00	0.01	0.33	0.71	156.46*
- Interval, seconds	0.00	0.00	18.44	37.41	41.09*

Legend: α-male (The most dominant male); β-male (The second dominant male); S1-male (Subordinate 1 male); S2-male (Subordinate 2 male)

Mating behavior of Timor deer was observed to occur mostly between 5 am and 8 pm. Timor deers stopped mating activity when the temperature fell down below 21 ^{0}C, which commonly occurred after 8 pm. These findings were confirmed by Ismail (2008) in Ranca Upas, Indonesia who reported the same observation. Timor deer still continue to mate under rain condition but will look for shelter when temperature dramatically drops. But, in Ranca Upas this condition would happen when temperature dramatically drops until around 16 ^{0}C. It was observed that Timor deer started to rest from 8 pm. Almost all of them would stay and lay in canopy, only a small number would ruminate outside of the canopy. Mating behavior of Timor deer is different compared with Sambar deer (*Rusa unicolor*) in India. Savanth et al., (2011) reported that Sambar deer are nocturnal, therefore during day time mounting and intercourse could not be observed more than once, but other activities related to breeding like chasing females, sniffing and flehmen were observed many times. Territorial behavior, holding the head up high, fighting, spraying urine on its own body and face were also observed a few times.

CONCLUSIONS

The most aggressive males were α-males. The common sequence of aggressive behaviors was expression of threat, followed by pushing, actual fighting and fleeing when one of the males lose the fight. Libido behavior of male Timor deer was expressed by wallowing, roaring, seeking female, crowning, flehmen spraying of urine, rutting, climbing and running around; α-male was the most active in libido behavior. Subordinate male expressed libido through running around. Farm management practices should be given emphasis as an important key for reproductive success. This may include the provision of mud bath in the cage to support expression of normal behavior. Further study on the grouping of the males in relation to the number of males in each cage must be conducted. The possible influence of dominance hierarchy on the subsequent sex ratio of fawns from captive breeding of Timor deer should also be studied.

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Research article

Evaluation of Tide Embankment and Protection Forest Width on Tsunami Disaster Using Tsunami Simulator

YOUKI MAEDA
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan

HIROMU OKAZAWA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: h1okazaw@nodai.ac.jp

YASUSHI TAKEUCHI
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

TOMONORI FUJIKAWA
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

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Abstract The tsunami that occurred after the Tohoku Earthquake of March 11, 2011, devastated the infrastructure in Tohoku, including roads and water channels. This study reports the results of a tsunami simulation experiment using an open channel for evaluation of tide embankments and protection forest in controlling the force of tsunami waves and flow of sand carried by tsunami. Coastal areas in Minami Soma City, Fukushima Prefecture, that were devastated by the Tohoku Earthquake were assumed as the experimental location. A 0.3 m-wide, 12 m-long open channel was used for the tsunami experiment. To simulate a tsunami, a removable barrier was set near the upstream end of the channel to retain water. The barrier was lifted to generate a bore. The scale for the model was 1/100. A model protection forest and a tide embankment made of acrylic were placed at the longitudinal midpoint of the channel. To examine the sand control effect of the tide embankment and protection forest at the time of tsunami, Toyoura silica sand was laid in the channel bottom upstream of the tide embankment and protection forest. The sand left behind after the tsunami simulation was measured for dry weight. The speed of the wave beyond the protection forest tended to decrease with increases in forest width. The amount of sand carried by the tsunami was found to decrease with increases in forest width. The results, however, are from a simplified model channel experiment. It is necessary to perform experiments that more closely reproduce the original sites in terms of topography and vegetation.

Keywords tsunami, protection forest, tide embankment, sand, earthquake

INTRODUCTION

Japan is among the most earthquake-prone countries in the world. The tsunamis that occurred after the Tohoku Earthquake of March 11, 2011, devastated the infrastructure in Tohoku, including roads and water channels. A total area of 443 km^2 was inundated, and 238 km^2 (54 %) of this was almost paddy field (The Geospatial Information Authority of Japan, 2011). Coastal sand carried by the tsunamis deposited in the affected paddy fields in wide areas. Considerable time and labor have been spent in removing the deposited sand.

Restoration and reconstruction of the infrastructure and agricultural lands are underway in the disaster-hit areas. At the same time, the value of establishing tide embankments and tidewater control forests has come under review as a part of efforts to make tsunami-resistant communities. Two tsunami mitigation effects were suggested by Shuto (1985): 1) the forests prevent objects such as boats that drift from sea to land from moving into areas with houses and other buildings, and 2)

the forests reduce the speed of tsunami waves by exerting drag, which limits the flooding. However, the effects of tidewater control forests in mitigating damage have not been fully examined. No studies have addressed the scale of tidewater control forest required to mitigate damage against large-scale tsunamis (wave heights of 10 m or greater) caused by mega-earthquakes (magnitudes around M9.0).

OBJECTIVE

This paper reports the results of tsunami simulation experiments using an open water channel for evaluation of tide embankments and tidewater control forests of several widths in controlling the force of tsunami waves and the amount of sand carried by the tsunamis. The disaster prevention measures of Minami Soma City in Fukushima Prefecture (Fig.1), which was devastated by the Tohoku Earthquake tsunamis, were used as a reference case.

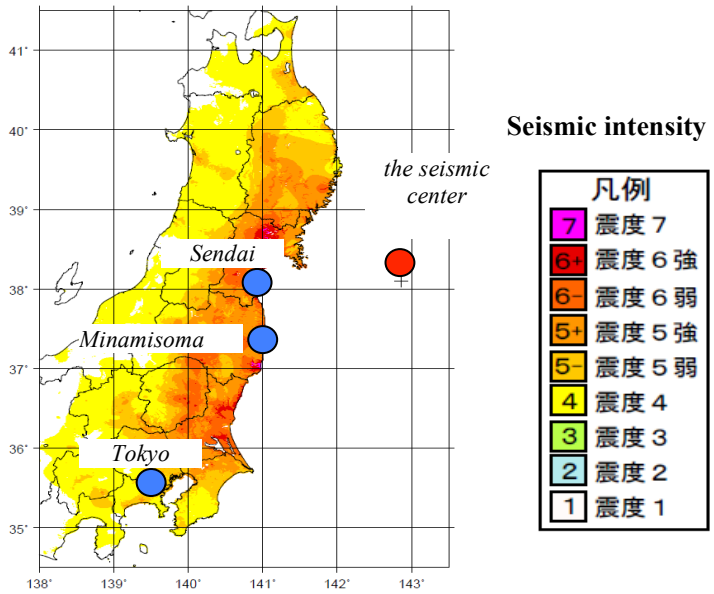

Fig. 1 Seismic intensity's map of the Tohoku Earthquake (March 11, 2011)
Source: Japan Meteorological Agency

METHODOLOGY

A 0.3 m-wide, 12 m-long open channel was used for the tsunami experiment (Fig. 2). To simulate a tsunami, a removable barrier was set near the upstream end of the channel to retain water. The barrier was rapidly lifted to generate a bore. The scale for the model was 1/100. The height of the model waves was set as 12 cm, based on the 12 m height of the actual waves that reached the coastal areas (Takahashi et al., 2011). Tidewater control forest and tide embankment models were placed at the longitudinal midpoint of the channel. The dimensions and alignment of the model trees of the tidewater control forest were determined based on the study by Shuto (1985). Acrylic sticks 2 mm in diameter and 10.5 cm in length were arranged in a staggered pattern. The tide embankment had a trapezoidal cross section, a top width of 12 cm, a bottom width of 16 cm and a height of 45 cm. To examine the sand control effect of the tide embankment and tidewater control forest at the time of tsunami, Toyoura silica sand (Japanese standard sand), which was chosen to reproduce the sea bottom sand at the site, was laid in the channel bottom upstream of the tide embankment and tidewater control forest. The 4.0 kg of sand was laid 30 cm wide, 80 cm long, and 0.9 cm thick. The sand left behind after the tsunami simulation was measured for dry weight.

The experiment conditions are given in Table 1. There were 12 experiment treatments:

without a tide control forest (indicated as 0cm) and with a tide control forest of 20 cm, 30 cm, 40 cm, 50 cm or 60 cm in width, in each case with and without a tide embankment. The tsunami simulation was videotaped, and the speed of the waves after they passed the tidewater control forest was calculated from the video data.

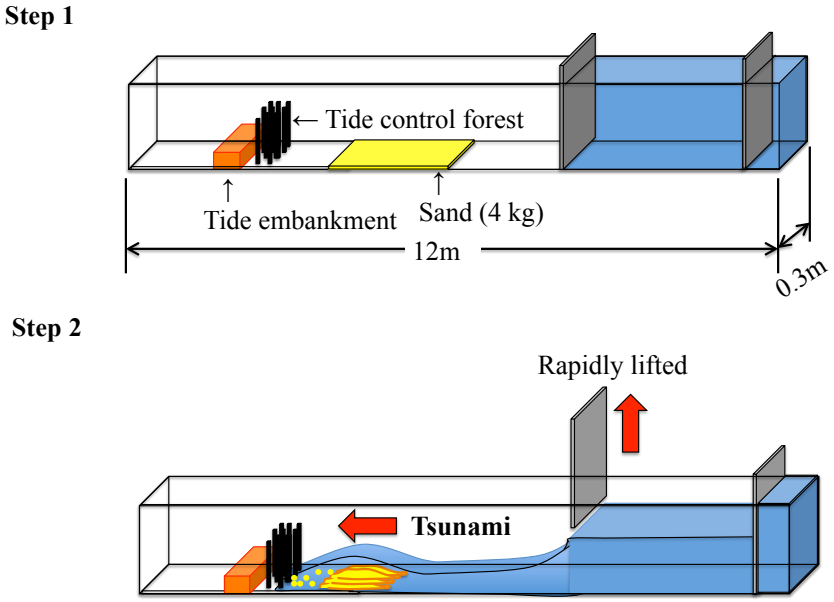

Fig. 2 Outline of the Tsunami Simulator using experimental open channel (0.3 m-wide, 12 m-long)

Table 1 The experiment conditions using Tsunami Simulator

	Width of tide control forest						
With a tide embankment	0 cm	10 cm	20 cm	30 cm	40 cm	50 cm	60 cm
Without a tide embankment	0 cm	10 cm	20 cm	30 cm	40 cm	50 cm	60 cm

As the flow velocity of waves changed in a short time in this experiment, it was impossible to apply the Froude's law of similitude, which is used in normal channel experiments. Referring to Kimura et al. (1968) and based on the condition that the density and gravitational acceleration of water were the same for the original site and for the model, the following two rules of similitude were determined (Eqs. (1)- (3)).

$$\frac{T_2}{T_1} = \left(\frac{L_2}{L_1}\right)^{1/2} = \frac{1}{n^{1/2}} \tag{1}$$

$$\frac{V_2}{V_1} = \frac{L_2 \cdot T_2^{-1}}{L_1 \cdot T_1^{-1}} = \frac{1}{n^{1/2}} = \frac{1}{100^{1/2}} = \frac{1}{10} \tag{2}$$

$$\therefore V_1 = 10\, V_2 \tag{3}$$

where L is length (m), n is reduction scale, V is flow velocity (m/s)and T is time (s). The subscripts 1 and 2 indicate the original and the model, respectively.

After conversion by using Eq.(1) to (3), the speed of tsunami waves measured in the model experiments was found to be 1/10 that of the flow velocity observed at the original site.

RESULTS AND DISCUSSION

Fig. 3 shows the relationship between forest width and flow velocity of tsunami waves. It was clarified that the flow velocities for the case with a 0.2 m-wide forest were reduced to 77% (case without a tide embankment) and to 84% (case with a tide embankment) that of the case without a tide control forest (forest width 0m). However, the differences in flow velocities were small under the condition with forest width of 0.3 cm or wider. Therefore, it can be assumed that flow velocities decreased for the forests with widths of up to 0.2 cm, but did not decrease appreciably at widths greater than that. For cases with a forest of a given width, it was found that, in the case with a tide embankment, the maximum flow velocity decreased to 80% that of the case without a tide embankment.

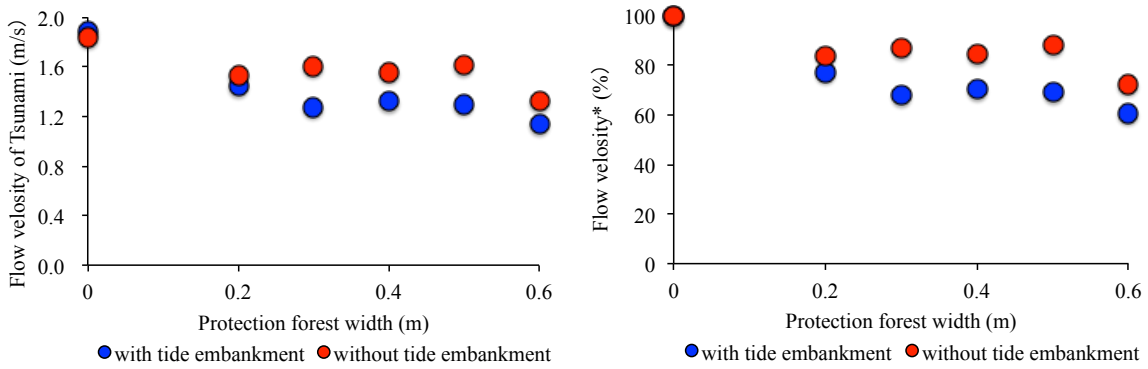

Fig. 3 Relationship between flow velocity of tsunami and protection forest width
**Ratio of flow velocity (m/s) in the case of 20-60 m forest width on that of 0 m forest width*

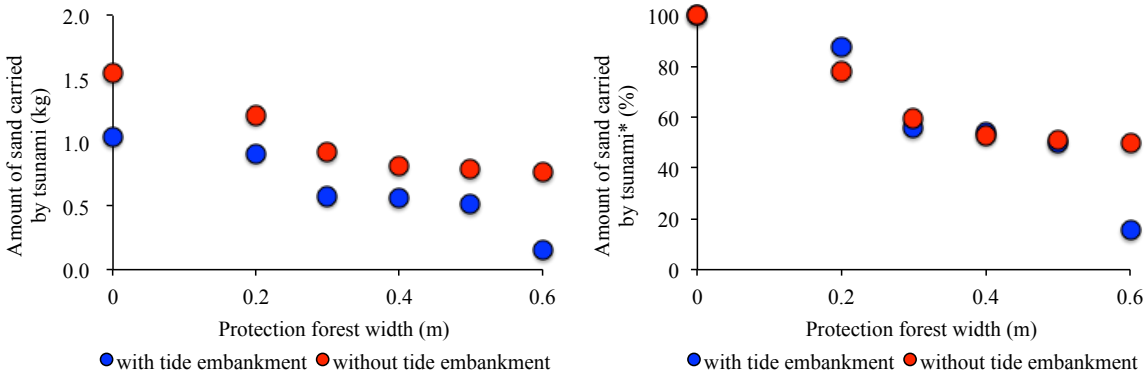

Fig. 4 Relationship between flow velocity of tsunami and amount of sand carried by tsunami
**Ratio of* sand (kg) *in the case of 20-60 m forest width on that of 0 m forest width*

The relationship between forest width and amount of sand carried by tsunami (sediment) is shown in Fig.4. At the forest width of 0m, i.e., without a tidewater control forest, sediment was 1.040 kg in the case with a tide embankment and 1.550 kg in the case without a tide embankment. It was clarified that even without a tide control forest; sediment reduction to 67% was achieved by using a tide embankment. For the cases with a forest of a given width, the sediment for the case with a tide embankment was found to be constantly about 60% that of the case without a tide embankment. Based on the above findings, it is thought installation of tidewater control forests combined with tide embankments can reduce sediment to about 60% that of tidewater control forests alone.

When the relationship between forest width and changes in sediment deposition was examined, it was found that sediment deposition tended to decrease for the forest widths of 0.2 m and 0.3 m, irrespective of the presence of a tide embankment. Sediment in the cases with a forest width of 0.3 m was 56% with the tide embankment and 60% without the tide embankment of those in the cases

without a forest (forest width of 0m). However, the changes in sediment were small in the cases with forests of 0.3 m or greater in width. The above findings clarified that sediment reduction to 60% is possible by installing a forest of 30 m in width (equivalent to the 0.3 m width in the model) and that increases in forest width beyond 30 m would not afford greater reductions in sediment deposition.

CONCLUSION

These experiments examined the effects of a tidewater control forest and a tide embankment on the speed of tsunami waves and the amount of sand carried by a tsunami under the assumption of a tsunami with the scale of those that occurred after the Tohoku Earthquake in Japan on March 11, 2011. Laboratory experiments demonstrated that the minimum width for a tide control forest effectively reduces the speed of tsunami waves and the amount of sand carried by a tsunami is 20 to 30 m. It was also clarified that use of a tide embankment in combination with a tidewater control forest is effective in mitigating the tsunami damage. The results, however, are from a simplified model channel experiment. It is necessary to perform experiments that closely resemble the original sites in terms of detailed topography and vegetation.

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Research article

Awareness of Conversion from Conventional Farming System to Sustainable Farming System in Kampong Cham Province, Cambodia

JUN FUJIHIRA
Extension Center, Institute of Environment Rehabilitation and Conservation, Tokyo, Japan

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan / Institute of Environment Rehabilitation and Conservation, Tokyo, Japan
Email: hq-erecon@nifty.com

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Abstract In Cambodia, 71% of labor force engage in agricultural sector and contribute for creating 36% of Gross Domestic Products on 2010. Besides, Cambodia suits for agriculture because Mekong River and Tonle Sap Lake provide fertile soil. In the research site, Samroung commune in Kampong Cham province, agriculture is the source of income for farmers. Eleven villages are located in this commune and 1,792 families present. Main crop in the commune is rice. Also, some farmers grow vegetables such as cucumber or morning glory in this area. In this country, conventional farming system based on agro-chemicals application becomes a major farming style in recent years. But the ways how to apply the purchased agricultural inputs of farmers, especially chemical pesticides, are not appropriate from a point of view of rural sustainability. It means popular farming systems depending on agro-chemicals are not only deteriorating natural environment and ecosystem but also affecting health of humans. For preventing these impacts, attention has been paid to sustainable farming system. But it also has difficulties for applying. For example, especially in the beginning, it may difficult for farmers to apply its techniques effectively because techniques of sustainable farming system are new techniques. In addition, these techniques needs more care, load and time period for getting the maximum effects compared to applying agro-chemicals. So farmers may be difficult to keep their motivation for adapting sustainable farming system. So, this study dealt with the awareness of conversion from conventional farming system to sustainable farming system, based on the questionnaire and interview survey conducted in Samroung commune of Kampong Cham province, Cambodia. This study concluded that extension approaches which are applied in Samroung commune are effective in order to change farmer's awareness of convert farming system. Addition to this, possibility of reducing the amount of agro-chemicals used was also observed.

Keywords sustainable farming system, conventional farming system, awareness, agro-chemicals, conversion

INTRODUCTION

Agriculture has utmost important role for reducing poverty and improving the capacity for human resource development in rural area. On 2010, 14 million people live in Cambodia and 71% of labor force engages in agricultural sector and it contributes creating 36% of Gross Domestic Products. In this country, mono cropping based on conventional farming system by applying chemical fertilizer and pesticide become a major style, because commercial agriculture has been advanced in recent years. But chemical pesticides effect not only positive but also negatively for the environment and human directly and indirectly. It is also a problem that farmers do not have enough and appropriate knowledge about applying agro-chemicals.

The Royal Government of Cambodia noticed and regarded this abuse of pesticide as a big problem in the country concerning food security, environment and human health. For example, most of the pesticides applied to agricultural lands may affect non-target organisms and contaminate soil and water. In addition, government is concerned that dangerous pesticides such as extremely toxic and banned pesticides are still in use in Cambodia (Royal Government of Cambodia, et. al., 2002).

For producing foods and fiber materials on a sustainable basis harmonizing agricultural production with the natural environment, conversion from conventional farming system to sustainable farming system is considered. In this study, sustainable farming system is defined as a system that can evolve indefinitely towards greater human utility, greater efficiency of resource use and a balance with the environment which is favorable to humans and most other species (Harwood, 1990).

In order to solving the problems, techniques used for sustainable agriculture based on natural resource circulation were extended towards local farmers with distributing materials. So the objective of this study is discussing about effective extension approaches for extending techniques and possibility of reducing using amount of agro-chemicals.

STUDY SITE

Study site consists of 11 villages which are located in Samroung commune, Phrey Chhor district, Kampong Cham province, Cambodia. 11 villages consist of Bonteay Thmey, Takrit, Kondal Koang, Tompang Risey, Svayprey, Samroung, Sodey, Thmey, Veal, Smei and Preykhcheay village. This commune is 83 kilometers from Phnom Penh city (Fig. 1). The commune is consisted of 11 villages and 8,111 people are living in 2011. Main production is rice mainly for both sale and self-consumption. On the other hand, farmers who produce vegetables for sales were much less than that of rice. In Samroung commune, conventional farming system is mainly applied for production in order to increasing yield.

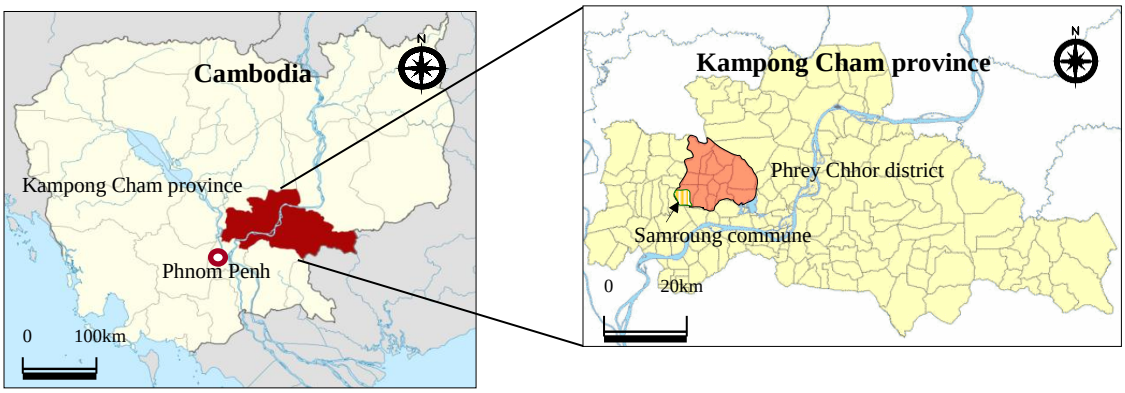

Fig. 1 Location of Samroung commune in Kampong Cham Province

METHODOLOGY

In this study, effectiveness of extension approaches and possibility of reducing amount of agro-chemicals used were studied. Effectiveness of extension approaches was measured by farmer's implementation after technical training. For achieving objectives, the study was advanced with activities included 1) questionnaire surveys, 2) technical trainings, and 3) field investigation. Questionnaire surveys are divided into baseline survey and 2 kinds of questionnaire surveys which conducted after technical training. Between July and October 2011, baseline survey for 443 farmers was conducted in order to understand current fundamental information and thought towards agro-chemicals proper use and sustainable agriculture. It consists of questions about personal

information, economic situation, agricultural practice, perception of using agro-chemical and organic inputs and so on.

Besides, questionnaire survey, about composting and making bio-pesticide were conducted for participants at technical trainings (Fig. 2). From April 2011 to March 2012, a total of 29 technical trainings were held in order to extend about techniques for sustainable agriculture based on natural resource circulation such as composting, making bio-fertilizer and bio-pesticide, preventing insects by using net. The trainings were aim to change farmer's awareness of convert farming system. The techniques were explained with pamphlets and demonstration by local facilitators. At end of the training, questionnaire survey were conducted in order to know the understanding of participants. Totally 928 people participated in trainings and 95% of them answered questionnaire surveys. The main questions of the survey were focused on 1) understanding of trainings, 2) current situation of using agro-chemicals, and 3) perception on sustainable agriculture based on natural resource circulation. Further explanations and monitoring were conducted regularly in the process of extension activities from April 2011 to October 2012.

Fig. 2 Explanation about composting at workshop (left) and demonstration of making bio-pesticide (right)

RESULTS AND DISCUSSION

Extension approaches at Samroung commune

Effective extension approaches for converting sustainable farming system can be studied by comparing references, farmer's technical implementation, result of field investigation and questionnaire surveys.

Neils Roling, et al. (1994) stated that changing to more sustainable practices is more like a paradigm shift, involving a learning path leading to new perspectives on risk avoidance, new professionalism, a greater reliance on one's own expertise and observation.

For promoting paradigm shift of local farmers and so on, extension seems to be an effective way because it is activities related to technology transfer, attitude change and others. The Australasia Pacific Extension Network (1999) stated that extension involves "the use of communication and adult education processes to help people and communities identify potential improvements to their practices, and then provides them with the skills and resources to effect these improvements". According to Neils Roling and Elske van de Fliert (1994), effective extension seems to be based on checks and balances that match intervention power with farmer's countervailing power, and mobilize farmer's creativity and participation in technology development and exchange. They also stated paradigm shift involved seems easier when participatory and group approaches is applied and when learning is experiential and occurs together with other farmers. A. W. Black (2000) explained about 4 extension strategies such as 1) linear top-down transfer of

technology, 2) participatory bottom-up approaches (also termed group empowerment), 3) one-to-one advice or information exchange, and 4) formal or structured education and training.

Although A. W. Black (2000) also mentioned participatory and group-based approaches to agricultural extension have various advantages when they are well implemented, he also mentioned that it should not be regarded as the one and only strategy that can or should be used to facilitate the adoption of sustainable farming system. He also mentions one-to-one exchange of information and advice, where from farmer to farmer or from professional adviser to farmer, will continue to be important. In addition, importance of learning activities that are directly relevant to the farm and that require relatively short blocks of time – from a few hours to a few days (Johnson et al. 1996).

In Samroung commune, techniques for sustainable agriculture based on natural resource, circulation were extended by mixing three extension strategies. There are 1) participatory and group approaches which is included in participatory bottom-up approaches, 2) training, and 3) one-to-one exchange of information and advice. In technical trainings, 10 to 60 farmers participate in and learn new techniques through explanation and demonstration. There are not only farmers and local facilitators but also officer of provincial department of agriculture participate in the training. For demonstration on technical training of composting, participants visit farmers who already start and apply compost. Visited farmer not only show their compost box but also give answers of the questions to participants. For technical training of making bio-pesticide, local facilitator asks a participant to conduct demonstration with their explanation in front of other participants. These demonstrations make participants to understand clearly than just learnt from pamphlet and explanation. From result of questionnaire survey after trainings, many participants answered they could understand the contents well and hope to join in the training again.

In the extension process, there are not only technical trainings but also individual visiting and explanation was implemented. Few months after technical training, local facilitators visit farmer's house individually in order to check technique of implementation. They also provide additional explanation if visited farmers have questions or local facilitators observe visited farmers has any problem on their implementation.

Creativity of some farmers is also mobilized by this extension process. For example, some farmers apply bio-fertilizer into their compost in order to make better quality of compost. For other case, farmers establish compost box near bio-gas facility in order to use waste of bio-gas as material for compost.

However, not only extension approaches but also participation of farmers is important for continuing sustainable farming system. So, it was considered that conversion of farmer's participation level is needed to be studied in order to understand awareness of farmers properly. Besides, sustainability of technical implementation also needed to be studied.

Current situation of Samroung commune

Awareness of conversion from conventional farming system to sustainable farming system can be observed from answers of baseline survey and questionnaire surveys. Local facilitators visit farmers individually for baseline survey but farmers fulfill answers to questionnaire sheet by themselves for 2 kinds of questionnaire surveys about composting and making bio-pesticide.

On 2011, nearly half of the farmers answered that insects and diseases are the main problems on agricultural activities (Table 1). For preventing pest, applying chemical pesticide (72.77%) and pulling up by hand (20.94%) were the major methods.

Table 1 Problems of agriculture

Problems	Answer	Percent (%)
Insects and diseases	187	46.98
High expense for chemical fertilizer and pesticide	73	18.34
Lack of technique and tools	59	14.82
Degradation of soil	52	13.07
Impact to human health and environment	27	6.79

Source: Questionnaire surveys in 2011, ERECON

All of respondents apply fertilizer and almost all of them apply pesticide such as herbicide (40.22%), insecticide (57.22%) and fungicide (1.75%). 84.94% of farmers expend less than 40 USD for pesticide but 60.48% of farmers expend more than 201 USD annually. It seems that farmers apply agro-chemicals for preventing insects and disease.

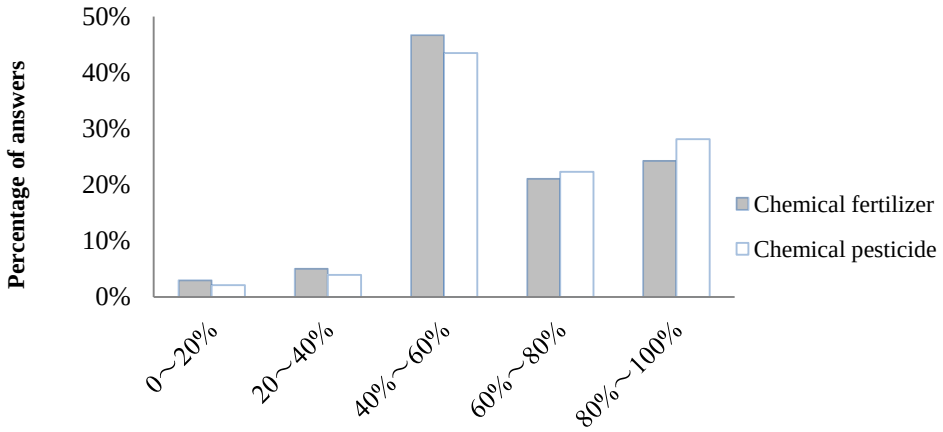

Fig. 3 Desired reduction rate of agro-chemical using amount

However, almost all of farmers hope to reduce using amount of chemical fertilizer and pesticide. In addition, almost all of farmers hope to reduce more than 40% of using amount of chemical fertilizer and pesticide (Fig. 3). For both of fertilizer and pesticide, main reasons for desiring reduction are health and better quality of products.

Farmers' perception for converting farming system to sustainable farming system

Through workshops about composting, 97.59% of the farmers desire to continue composting. As same as conclusion of Tim, et al. (2011), the compost technology was highly accepted by local farmers. Their main objectives are increasing soil fertility and avoiding negative impact for human health. After technical training, local farmers apply compost on rice and vegetables.

Farmers also show a high interest for making bio-pesticide even 88.18% of the farmers does not have experience for making it before participating in the training. It is because the farmers think bio-pesticide has less negative impact to human health and environment (52.70%) (Table 2). Tim, et al. (2011) also stated that local farmers found bio-pesticide is really good for farmer's health, food safety and environment. It is applied for rice and vegetables such as tomato and cabbage after technical training.

From point of view of local farmers, they mentioned compost and bio-pesticide has positive impact on their cultivation. But they also need to share more time for taking care of crops under sustainable farming system.

When the baseline survey was conducted, 76.52% of the farmers did not know what sustainable agriculture was. But 94.58% of them hope to grow and sell products with low chemical input because they think sustainable agriculture lead to positive impacts such as soil fertility, decreasing amount of agro-chemicals.

Table 2 Reasons of interest in bio-pesticide

Reason	Answer	Percent (%)
Less harm to human and environment	156	52.70
Make soil fertile	73	24.66
Decrease expense for pesticide	61	20.61
Other	6	2.03

Source: Questionnaire surveys in 2011, ERECON

CONCLUSION

According to the results and discussions done in this study, it can be concluded that extension approaches which is applied in Samroung commune was effective in order to change farmer's awareness to convert farming system because local farmers in Samroung Commune has a high potential to conduct sustainable farming system and start implementation of techniques. In addition, possibility of reducing the amount of agro-chemicals used was also observed.

Mixing extension strategies seems to work effectively in Samroung commune. As same as references, paradigm shift of farmers seems to happen by extend techniques through group trainings and demonstration. Not only paradigm shift but also creativity of farmer's is also mobilized by the extension process.

In current situation, farmers face problems like pests, diseases and soil degradation. For overcoming these problems, they apply agro-chemicals and lead to negative impacts to human health, soil fertility, finance, etc. Although almost all of the farmer's apply agro-chemicals for their farmland when the baseline survey was conducted, possibility of reducing agro-chemical was observed as a result of the study. It was also exposed that almost all of the farmer's hope to reduce more than 40% of agro-chemicals amount use. They are also eager to grow and sell products with low chemical input at the market. Through technical trainings, farmers became highly interested in applying and continuing techniques for sustainable agriculture based on natural resource circulation such as composting and making bio-pesticide. It is because that they think these techniques have many advantages such as less harm to human health and improving soil fertility.

By this study, it was showed that the farmers at Samroung commune have motivation and potential for converting from conventional farming system to sustainable farming system. However, not only effective extension approaches but also participation of farmers is important for continuing sustainable farming system. So, it was considered that the conversion of farmer's participation level is needed to be studied in order to understand awareness of farmer's properly. Besides, sustainability of technical implementation also needed to be studied.

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Research article

Effects of Adding *Bacillus* sp. on Crop Residue Composting and Enhancing Compost Quality

LIEXIANG LI
Graduate School of Agriculture, Tokyo University of Agriculture, Japan

YUTA ISHIKAWA
Graduate School of Agriculture, Tokyo University of Agriculture, Japan

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan
Email: m-mihara@nodai.ac.jp

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Abstract Local farmers tend to burn crop residues to simplify soil preparation for the following season cultivation. Along with the environmental conservation policies that were implemented by the government, local farmers began to consider the adverse effects of crop residue burning. In this regard, efficient utilization of organic resources through composting of crop residues has been practiced. The objectives of this study were to find out the effects of adding *Bacillus* sp. on composting of crop residues and to observe the effects of *Bacillus* sp. added crop residues on plant growth. The number of *Bacillus* sp. colonies existing in crop residue and soil were determined by agar culture medium. Composting was carried out based on the number of Bacillus Bacterial colonies (cfu): 1.5×10^{14}, 1.5×10^{16} or 1.5×10^{18} cfu. Carbon-to-nitrogen (C/N) ratio and number of *Bacillus Bacteria* were measured once a week. To observe the effects of *Bacillus* sp. added compost on plant growth, pots were prepared as control pots; crop residue pots; *Bacillus* sp. added crop residue pots; and burned crop residue pots. Komatsuna (*Brassica rapa*) were cultivated. Based on the experimental results, it was found that compost with higher number of *Bacillus* sp. have significant decrease of C/N ratio with time. Also, it was found that the mass of the crops in the pots added with *Bacillus* sp. (average 1.4 g) was larger than that control pots (0.5 g). Therefore, adding of *Bacillus* sp. can promote decomposition of crop residues and enhance the quality of compost.

Keywords *Bacillus* sp. growth, C/N ratio, crop residues compost

INTRODUCTION

Burning of crop residues influenced the degradation of soil ecosystem and its quality (Srimuang et al., 2004). Therefore, treating of crop residues such as composting, for bio-fertilizer on crop is strongly recommended (Li et al., 2012). Compost, a kind of organic fertilizer made from crop residues, is an effective material for improving physical and chemical properties of soil. The important factors to enhance decomposition are moisture, air and microorganisms. (Mihara et al., 2009). At rural areas, manure has become the source of microorganisms for compost. But with increment in the rural development, family livestock industry has reduced. Therefore, crop residue compost by manure is difficult to be sustained in the rural areas. Although there were many reports on the effect of adding organic matter on the crop residue composting, few studies have added *Bacillus* sp. on decomposition. Therefore this study has been proposed. The objectives of this study are 1) to find out the effects of adding *Bacillus* sp. on composting of crop residues and 2) to observe the effects of *Bacillus* sp. added crop residues on plant growth.

METHODOLOGY

To extract from corn residue, *Bacillus Bacterial* was cultured for 3 days in the incubator. This is the *Bacillus* sp. in liquid used for the experiment. The number of *Bacillus* sp. colonies existing was determined by agar culture medium. The concentration of *Bacillus* sp. liquid was 6×10^{15} cfu/ml (colony-forming units per milliliter). Dilution of the *Bacillus* sp. liquid was made in different concentrations of 6×10^{11} cfu/ml, 6×10^{13} cfu/ml, 6×10^{15} cfu/ml with crop residue compost (Fig. 1).

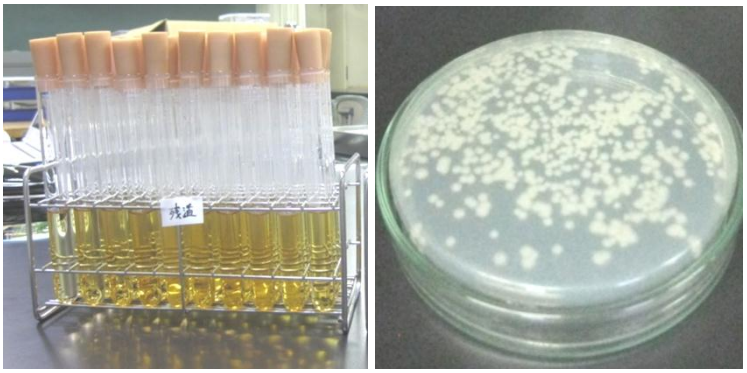


Fig. 1 *Bacillus* sp. liquid made by corn residue

The different concentrations of *Bacillus* sp. at 250 ml was added to the finely cut dry corn residues at 50 g in a tray (L186 mm, W147 mm, and H47 mm). The different concentrations sprinkled were control tray (no cfu added), 1.5×10^{14} cfu added tray (same cfu of 50 g residues), 1.5×10^{16} cfu added tray (100 times more than cfu of 50 g residues) and 1.5×10^{18} cfu added tray (10000 times more than cfu of 50 g residues) at tray (Table 1). Period of composting was from August 3rd to August 31st, temperature of the experiment was about 25 degrees Celsius to 37 degrees Celsius in Tokyo (Japan). 50 ml of water was sprinkled once every 3 days, and samples were stirred after that (Fig. 2). The experiment data was collected once a week. Samples of different concentrations were subjected to carbon-to-nitrogen (C/N) ratio analysis, to understand the effects of adding *Bacillus* sp. on crop residue composting processes. Following that, the number of *Bacillus Bacteria* was measured after water was sprinkled.

Table 1 Number of *Bacillus Bacterial* cfu at corn residues and *Bacillus* sp. liquid

Corn residues	*Bacillus* sp. liquid I	*Bacillus* sp. liquid II	*Bacillus* sp. liquid III
3 $\times10^{12}$ cfu/g	6 $\times10^{11}$ cfu/ml	6 $\times10^{13}$ cfu/ml	6 $\times10^{15}$ cfu/ml
1.5×10^{14} cfu/50g	1.5×10^{14} cfu/250ml	1.5×10^{16} cfu/250ml	1.5×10^{18} cfu/250ml

Fig. 2 Crop residue compost in laboratory of Japan

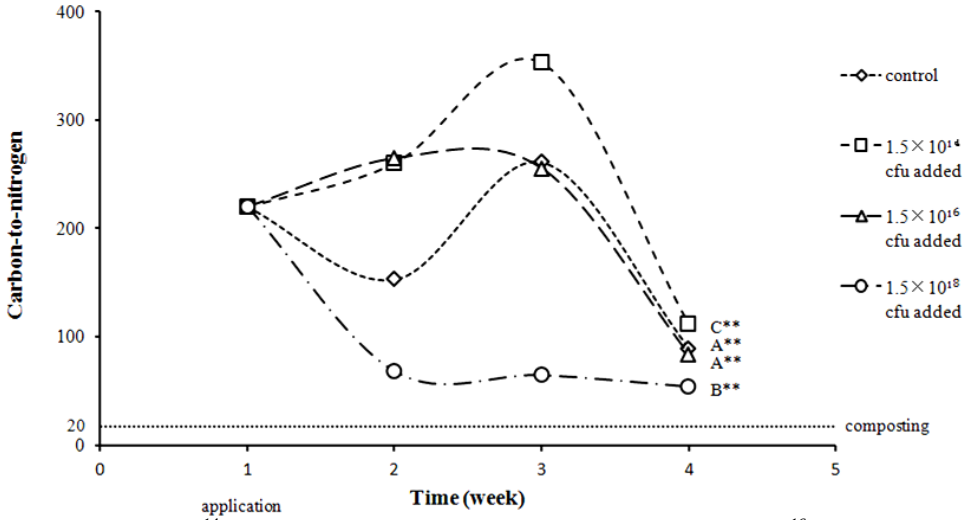
Meanwhile, in the growth experiment; 20 pots were prepared (unit area is 1/10000 a, and a height of 150 mm), and was divided into four experimental pots. In control pots, 900 g of soil was put into 5 pots. In residue added pots, 900 g of soil and 12.2 g dry corn residue was put into 5 pots. In *Bacillus* sp. added pots, 900 g of soil, 12.2 g dry corn residue and 61 ml *Bacillus* sp. liquid (6×10^{15} cfu/ml) was put into 5 pots. In ash of residues added pots, 900 g of soil and ash of 12.2 g dry corn residue was put into 5 pots. Kamatsuna (*Brassica rapa*) were cultivated (Fig. 3). The

growing period was from August 10th 2012 to September 7th 2012, temperature during the experiment was about 25 degrees Celsius to 37 degrees Celsius in Tokyo (Japan); 100 ml of water was sprinkled once every 3 days; and length of growth was obtained after the water was sprinkled. And at the final experiment, weight of growth was measured in laboratory.

Fig. 3 Crop growth in laboratory

RESULTS AND DISCUSSION

In the crop residue composting of sprinkled *Bacillus* sp. experiment with 1.5×10^{18} cfu added tray crop residue, it presented decomposition closer to compost maturity over the others concentrations of *Bacillus* sp. liquid added tray. The carbon-to-nitrogen data showed that 1.5×10^{18} cfu added tray has a tendency to decrease throughout all of the experiment; meanwhile the other tray showed increment at 3 weeks times followed with continuous decrease pattern (Fig. 4). Initially, rise in the carbon-to-nitrogen ratio were observed due to the growth of the added microorganisms and their consumption of nitrogen. After that, in order to decompose organic matter, microorganisms absorb from raw material. Once the decomposition process started the microorganisms populations continually increase to the maximum population level. Having reached maximum population, the C/N ratio decreases to the conversion with the normal composting line where there is no more decomposition (Nishio, 2009) is possible.



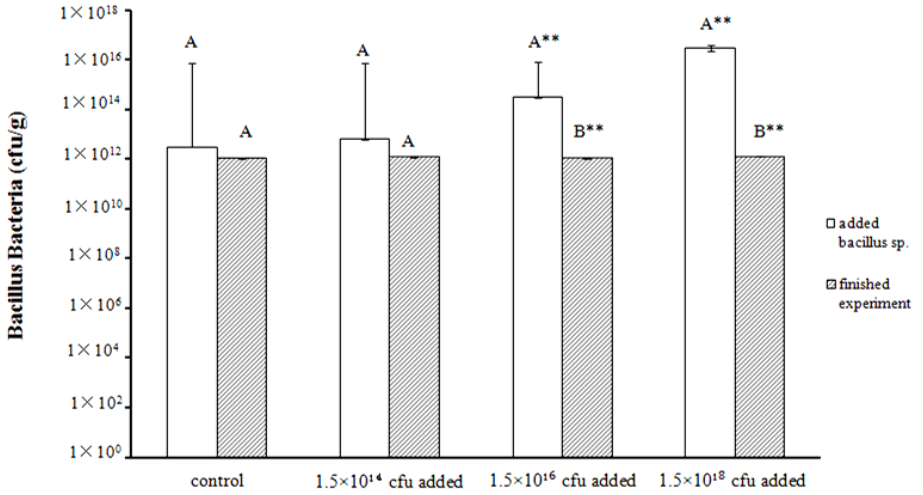
control (no cfu added), 1.5 ×10^{14} cfu added (same cfu of 50 g corn residues added), 1.5 ×10^{16} cfu added (100 times more than cfu of 50 g corn residues added), 1.5 ×10^{18} cfu added (10,000 times more than cfu of 50 g corn residues added)

Fig. 4 Changes in carbon-to-nitrogen with difference concentration of *Bacillus* sp. added

In finished crop residue compost, the number of *Bacillus Bacterial* colonies returned to the same number of that preceding the addition of *Bacillus* sp (Fig. 5). Therefore, the added *Bacillus* sp. was used as a nutrient during the composting experiment.

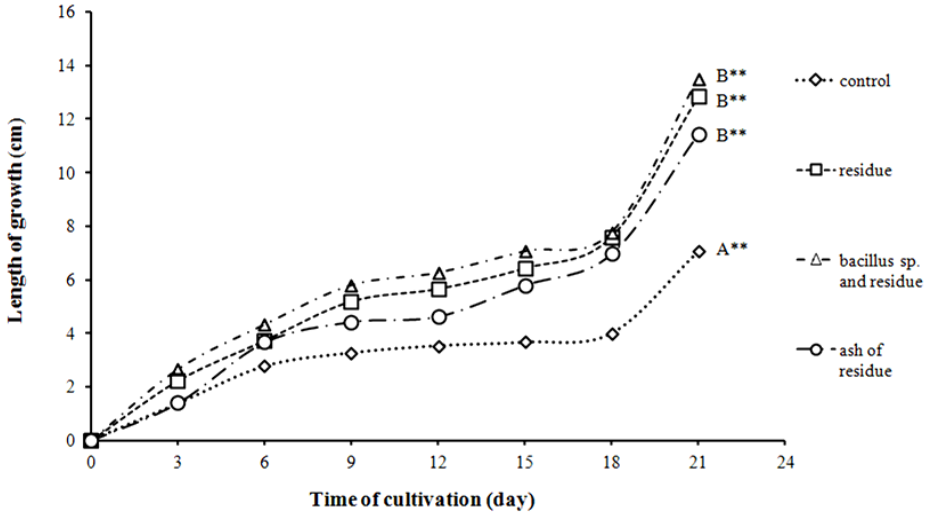
Besides that, in this experiment, the effect of *Bacillus* sp. added into crops can be observed by comparing the height of crop growth. It was found that crops grown in pots added with *Bacillus* sp. have grown 2.8 times higher (1.4 cm) than that of control pots (0.5 cm). A significant difference at

99% was also observed. Although the crop grown in pots added with *Bacillus* sp. is higher than residue pots and ash of residue pots, there is no significant difference observed by the method of dispersion ratio (Fig. 6). The experiment result shows the crop grown with residue grows much better than the crop grows without residues because the residue is rich in nutrients (Zhong et. al 2003).



control (no cfu added), 1.5 ×10[14] cfu added (same cfu of 50 g corn residues added), 1.5 ×10[16] cfu added (100 times more than cfu of 50 g corn residues added), 1.5 ×10[18] cfu added (10,000 times more than cfu of 50 g corn residues added)

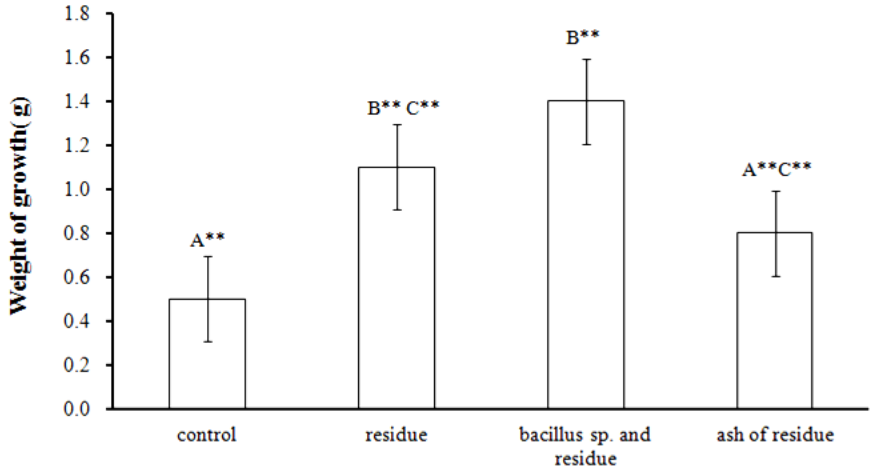
Fig. 5 Change in quantity of *Bacillus* sp. before and after the experiment



control (only put soil in pots), residue (put residues and soil in pots), bacillus sp. and residue (put bacillus sp., residues and soil in pots), ash of residue(put ash and soil in pots)

Fig. 6 Height of crop in growth experiment

The effect of *Bacillus* sp. added compost into crops can be observed by comparing the weight of crop growth. It was found out that crop grown in *Bacillus* sp. added into pots have 2.5 times higher (1.5 g) than control sample (0.6 g). Furthermore, the crop grown in *Bacillus* sp. was 1.9 times heavier than crop grown in ash of residue in Fig.7. A confidence interval at 99% was also observed. Moreover, the order of experiment results which is more environmental friendly way to grow the crop is: adding *Bacillus* sp. > adding residue > adding ash of residue > control. Therefore, based on the result of the experiment, mixing *Bacillus* sp. liquid with mulching crop residues is the best way to improve crop growth compared to burning crop residues in the farmland.



control (only put soil in pots), residue (put residues and soil in pots), bacillus sp. and residue (put bacillus sp., residues and soil in pots), ash of residue(put ash and soil in pots)

Fig. 7 Weight of crop in growth experiment

CONCLUSION

Crop residue composting of sprinkled *Bacillus* sp. experiment found that in the 1.5×10^{18} cfu added tray crop residue decomposition was closer to compost maturity than the others concentration of *Bacillus* sp. liquid added tray. Within the experiment, the added *Bacillus* sp. pots showed better length and weight of crop growth compared to other pots. Therefore, adding *Bacillus* sp. to crop residue compost is recommended. Plus, adding *Bacillus* sp. has positive influence to crop growth.

This experiment was carried out during summer season in Tokyo (Japan). Temperature has a significant impact with crop residue composting. Therefore, location and temperature are two important factors to be taken into consideration in this study.

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Research article

Local Livelihoods and the Tourism Value Chain: A Case Study in Siem Reap-Angkor Region, Cambodia

NARA MAO*
Centre for Tourism and Services Research, Victoria University, Melbourne, Australia
Email: naramao@yahoo.com, nara.mao@live.vu.edu.au

TERRY DELACY
Centre for Tourism and Services Research, Victoria University, Melbourne, Australia

HELENA GRUNFELD
Centre for Strategic Economic Studies, Victoria University, Melbourne, Australia

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Abstract Tourism, which has grown significantly in the Siem Reap-Angkor region, has had significant impacts on the livelihoods of local residents. This paper presents an overview of the Tourism Value Chain (TVC) in the region and examines the involvement of local residents in local TVC components. A qualitative approach, incorporating observations and semi-structured interviews with 25 local residents, was applied in this study. Secondary data were collected from the Siem Reap provincial tourism department and the Cambodian Ministry of Tourism. The results revealed that, although tourism has provided jobs and business opportunities to locals, their earnings have been consistently low. It is difficult for the poor to access tourism jobs and start tourism related businesses because of lack of financial resources, lack of small business knowledge, inability to use foreign languages and low education levels. Lack of knowledge to diversify products, of information about market needs and of capital to purchase production tools, machinery and raw materials are the main constraints facing local artisans to improve their livelihoods. Poor soil fertility, small agricultural landholdings, low agricultural technological know-how, poor extension services, inability to compete with imported products and limited connections between the tourism sector and local peasants also prevent the poor farmers from gaining economic benefits from tourism.

Keywords livelihoods, constraints, tourism value chain, agriculture.

INTRODUCTION

Tourism is considered by many to be an effective tool to accelerate economic growth, to preserve natural resources and local cultures and assist in alleviating poverty in least developed countries. Cambodia has become one of the fastest-growing tourism destinations in South-East Asia, owing to its rich diversity of culture, historical sites, recreational activities and natural attractions. In 2011, 2.88 million international tourists visited Cambodia, an increase of 15.9% compared to 2010 (Cambodian Ministry of Tourism 2012). Tourism has contributed significantly to the goals of promoting national economic growth. The macroeconomic benefits of tourism include employment, GDP growth, foreign exchange earnings and investment. The Royal Government of Cambodia has adopted tourism as a strategy for poverty reduction on the basis that it is one of the Cambodia's main opportunities for rebuilding its economy. The number of tourists has increased dramatically since 1994 and the Cambodian Ministry of Tourism has recently adopted a more conscious policy of promoting sustainable and equitable tourism as a means to national poverty reduction (CMT, 2012). The government expects the number of international tourists to increase, contributing to tourism-related revenues and providing more jobs for the Cambodian people (CMT, 2012).

However, in spite of the potential for tourism to benefit local people, there is much economic leakage in the tourism industry in Cambodia, as found in a study conducted by the United Nations

Development Program (Beresford et al., 2004). It has also been suggested that tourism development in Siem Reap has failed to develop local economic linkages (Beresford et al., 2004). A World Bank study (2006, p.2) acknowledges that "tourism, driven primarily by Angkor, has been a major contributor to economic growth in Cambodia over the last decade." However, this study also notes that "…the impact of tourism on poverty has yet to reach its potential." As a result, the Siem Reap Province, despite being a major tourist destination, is still one of the poorest provinces in the country (Beresford et al., 2004; World Bank, 2006; Cambodian Ministry of Planning, 2010; Siem Reap Provincial Department of Planning, 2012).

Furthermore, tourism has produced both positive and negative effects on local residents. It has resulted in dramatic changes to their livelihoods. As more tourists arrive, increasingly local residents have begun selling off their land and giving up their farms in exchange for off-farm jobs in tourism. Although there are some indications of linkages between tourism and poor people, few in-depth studies have been conducted to examine the complexity of these interrelationships (Gössling, 2004). One reason for this could be that while a livelihood perspective focuses on poor households, tourism research tends to place more emphasis on broader economic and environmental impacts. Drawing on Cattarinich's (2001) suggestion that micro-level analysis of tourism impacts and related interactions with the livelihood of local residents should complement the focus on macro-level impacts, this paper presents an overview of the tourism value chain (TVC) in the Siem Reap-Angkor region and examines the involvement of local people in each TVC component. A TVC is "the full range of activities that are required to bring a tourist to a destination and provide all the necessary services such as accommodation, catering, retail, excursions, etc." (Mitchell, 2009, p.1).

RESEARCH METHOD

The research conducted for this paper forms part of a wider study on the role of tourism for poverty reduction. The main study includes face-to-face interviews and surveys with a range of tourism operators, tourism employees, local residents, other tourism stakeholders and international tourists as well as observations. Data for this paper were derived from interviews with 20 local residents, directly involved the TVC and five other key informants. Non-probability sampling was employed to select research participants. While the key informants were selected by using purposive sampling, those involved in tourism and related tourism businesses were drawn through convenience /accidental sampling. Although this technique is "the least desirable" as it is "neither purposeful nor strategic" (Patton, 2002, p.242), it is often used because "it enables quick collection of data without the expense of a more systematic selection process" (Jennings 2010, p.139). This sampling technique is appropriate for this study because there is no sampling frame (list of local residents involved in the TVC). The study used both primary and secondary data.

RESULTS

Although the TVC starts from booking the tour, this study, which investigates the contribution of tourism to local livelihoods, is concerned with the actual trip to Cambodia only if this is packaged with local services, thereby affecting the ability of small operators to provide services. Therefore, only six employment components of the TVC are explored in this paper: local transportation, accommodation, food and beverages, handicraft and souvenir production, tourism sites and leisure activities.

Transportation

Transportation is a popular means of earning a living for local people. A taxi association, consisting of 94 motorbike taxi members and 231 car and van members (but excluding Tuk Tuks, as these were not in use in Siem Reap when the association was created) has a license to operate transport services from the airport to the city. Car taxi and van drivers earn USD 7-10 for

transporting customers from the airport to hotels and USD 30-35 for a whole day trip to the Angkor complex. In addition to the association membership fee (USD 9/month/car taxi driver and USD 3.75/month/motorbike taxi driver), the members have to contribute to the fee the airport owner charges the association (USD 3,500/month during the tourist high season and USD 3,148/month during the low season). There are also individual independent operators, not members of this association.

Motorbike taxis, which transport only one passenger, operate mainly in the city of Siem Reap and in some rural villages. Operators earn between USD 7-8 per day and most of their clients are locals and domestic tourists. They can earn USD 2 for transporting a tourist from the airport to a hotel and USD10 for a whole day trip to the Angkor complex. Although this type of transport is one of the main income sources of the poor (most operators are low income earners), inadequate foreign language capacity is a key constraint preventing them from accessing foreign visitors.

Tuk Tuks can carry four passengers and are popular among tourists. The number of Tuk Tuks has also increased significantly with the increase in tourism. Mainly operated by locals and immigrants from other provinces, poor families cannot afford to buy them. A brand new Tuk Tuk costs approximately USD 1,700 and a second hand one USD 1,000 - 1,300. A Tuk Tuk driver can earn USD 1 for a short trip in the downtown, USD 3-4 from Siem Reap airport to a hotel/guesthouse and USD10-15 for a whole day trip in the Angkor complex. However, if a trip is managed by a tour operator, a driver gets only USD 8-10 and it takes a few weeks to get paid. In order to get more clients, a driver must have good relationships with guesthouse owners, hotel staff and tour operators and also have a minimum level of foreign language skills to communicate with tourists. Another constraint excluding some poor local people from this livelihood source is that they live too far away from popular tourist places, particularly in the context of the road conditions (unpaved with many potholes). Some drivers have to work without pay, relying on receiving tips. Although most drivers are from poor backgrounds, not many poor local residents living in the periphery of the Angkor complex can access this potential job opportunity.

A former Tuk Tuk operator who became a motorbike taxi driver revealed that he sometimes had to drive the vehicle to the city, waiting unsuccessfully for customers for a whole day, wasting time as well as money for gasoline. For this reason he had to change his job.

A car taxi driver hired by a tour operator earns only USD 18-20 for a daytrip in the Angkor complex. A former car taxi driver who ran this business for more than 10 years revealed that some operators gave up this type of business because what they earned could not cover the price of gasoline, vehicle maintenance, and depreciation.

The bus stations are located four kilometers from downtown. Although motor taxi and Tuk Tuk operators could benefit from these stations, some hotels and bus companies provide free van services, excluding small operators from this opportunity.

Accommodation

In response to the rapid growth of tourism development, the number of hotels, guesthouses and apartments has increased significantly. According to the Siem Reap tourism department, there were 138 hotels (10,407 rooms), 230 guesthouses (3,207 rooms) and 8 apartment buildings (197 units) in 2012. This sector employs approximately 10,000 people, of which 8,372 (2,812 females) work in hotels and apartments and 1,184 (724 females) in guesthouses.

While most hotels are owned by outsiders, most guesthouses are owned by local people who have financial capital to invest. Most guesthouses are operated by owners who need only a few staff, mainly cleaners. Moreover, even though working in hotels is better-paid compared to guesthouses, most jobs require young people who have completed high school or university, that is, with a sufficient educational level and language ability to be able to communicate with customers. The salary of a hotel section manager is about USD 200-300 per month; that of a hotel receptionist USD 100-200; a guard USD 50-80; and gardeners and cleaners USD 40-60. Based on interviews with village chiefs, only a few poor households have members working in hotels.

However, the increased demand for tourist accommodation and other tourist venues has provided employment opportunities in construction and maintenance for poor unskilled local

people, especially poor villagers within the 15-40 age group. Although construction work is very hard labor, an unskilled worker earns on average only USD 7/day (men) and USD 5/day (women).

Food and beverages

This sector has grown significantly in response to the increasing number of tourists. There are two categories in this value chain unit: restaurants and roadside vendors. According to the Siem Reap tourism department, the number of registered licensed restaurants has increased from 17 in 1999 to 155 (2,926 tables and 9,160 seats) in 2012. This sector offered jobs to 2,290 (1,378 females) in 2012. The average monthly wage in this sector is approximately USD 50. The wages of restaurant managers range from USD 200-400. Most large restaurants are operated by foreign investors, and most restaurants in the Old Market are owned and operated by individual foreigners. Only a few locals own and operate restaurants that attract foreign tourists, whereas most locally owned restaurants are frequented by Cambodians.

There are also many self-employed roadside vendors who sell a diverse range of food, including traditional Cambodian foods, from bicycles, carts, stalls or tents. Some of the fruits they sell are imported from neighboring countries. The average daily earnings of vendors are approximately USD 5. Some roadside vendors employ people from poor backgrounds for approximately USD 2 per day.

Although local peasants are able to supply small quantities of products to this sector, most vegetables and meat consumed in hotels are imported. Similar to several other tourism destinations in developing countries, the constraints preventing local peasants from supplying agricultural products into this value chain are: small land holdings, poor soil fertility, low agricultural technological know-how, poor extension services, lack of market information, pests and diseases, lack of financial capital and high costs of inputs mainly fertilizers and pesticides. Inability to compete with imported products, price fluctuations and inadequate connections between the tourism sector and local peasants prevent the poor peasants from gaining economic benefits from tourism.

The Cambodian prime minister recognizes that there is economic leakage in the tourism industry, due to insufficient supply of local agriculture products to hotels and restaurants. Instead large quantities of agricultural goods from neighboring countries are imported to meet the demand from tourists. He claims that USD 400 million of the USD 2 billion Cambodian tourism income in 2012 has flowed out of Cambodia, to pay for agricultural imports (Raksmei Kampuchea Daily Newspaper 12/12/2012).

Handicraft and souvenirs

In Siem Reap, there are many workshops which produce handicraft products for souvenir shops, market stalls, hotels and restaurants. They are operated by NGOs, foreign and locally owned private companies. The monthly salaries of staff in managerial positions range from USD 200-500. The average monthly wage of an experienced sculptor is approximately USD 150, with a less-experienced sculptor earning about USD 60. There are also many handicraft and souvenir outlets (shops or stalls) managed by locals in the downtown, especially in the main markets: the Old Market, Central Market, and a few night markets. Most stalls are managed by family members, while some shops offer jobs for those who are from poor backgrounds, enabling them to earn monthly wages ranging from USD 30-50. According to the Siem Reap tourism department, there are approximately 6,400 people involved in the handicraft and souvenir value chain.

Handicraft and souvenir production has also become one of the main livelihoods and the main income source of some villagers living in proximity of the Angkor complex. Self-employment in this value chain unit has developed quickly in villages where handicraft production is a traditional livelihood. Some villagers have their own workshops at home, producing souvenirs made from various materials, including stone, wood, bamboo, palm leaves and trees, rattan, leather, copper, and silk.

Many villagers, from young to old, poor to better-off, of both genders, are involved in this value chain unit. While men typically make the products, it is the women and children who sell them. There are some roadside shops run by local residents in front of main ancient temples and along the roads to other tourist sites. Small souvenir/handicraft stands have sprung up at temple entrances and inside temple grounds. Several village children are involved in selling these, mainly after school hours. This kind of selling activity annoys many tourists, but souvenir vendors revealed that they have no alternatives.

Although this value chain unit has economic potential for local residents, especially those who are from poor backgrounds, only a small percentage of the handicraft and souvenir goods sold there are made in Siem Reap and in other provinces (Posat, Battambang, Kompong Tom) of Cambodia. About 80 % of goods are imported from other countries, mainly China, Thailand and Vietnam. This economic leakage phenomenon limits the extent to which locals can obtain economic benefits from this sector. As a result, this potential pro poor tourism opportunity is lost. Besides inability to compete with imported products, lack of financial capital, knowledge to diversify products, information about market needs, production tools and machinery, raw materials and transportation vehicles to bring product to market are the main constraints limiting the capacity of local artisans to improve their livelihoods.

Tourism assets

Natural and cultural tourism assets are managed by public institutions such as APSARA (Authorité Pour la Protection du Sites et l'Aménagement de la Région d'Angkor), Ministry of Culture and Fine Arts, Heritage Police and private companies. Private companies receive licenses from the Royal Government of Cambodia to collect entrance fees from visitors to the Angkor complex. Information on the total number of workers and employees working in the tourism asset TVC unit is not available. The monthly wages of temple, environmental and conservation guards range from USD 20-50, indicating that they are from poor backgrounds. They tend to reside in villages around temples. The monthly salaries of those employed in administrative and managerial positions range from USD 100- 200.

The Royal Government of Cambodia has a policy of giving priority to local residents for jobs as guards and cleaners of heritage and temple sites and as park rangers. One temple guard respondent revealed that between five to fifteen local residents from each village in the periphery of the temple complex are given these jobs and that the salary is USD 25-50/month. He explained that, although this is less than other jobs, the working conditions are easier than other types of employment and these workers still have time and energy to help family members with other work, such as handicraft production, souvenir-selling, and farm work.

Leisure activities

In response to tourism growth, the number of leisure activity operators has increased significantly. According to Siem Reap tourism department, the number of travel agencies and tour operators has increased from 12 in 1994 to 149 in 2012. The number of registered licensed tour guides has increased from 95 in 1994 to 3,572 in 2012. The number of registered licensed massage businesses, Karaoke bars and discotheques in Siem Reap Province is 47, 18, and 6 respectively.

This value chain sector employs approximately 3,000 people, excluding self-employed tourist guides, of which 796 (611 females) work in Karaoke bars and discotheques, 494 (432 females) in massage parlors, 577 (231 females) in tour companies and tour agents, 370 in resorts and 450 in golf clubs.

Tour companies and local tour agents pay higher wages than other tourist-related establishments. However, these are accessible only to those few with better education (especially with foreign language skills) and personal connections. Similar to hotel work, these companies employ only young, attractive people, who have good foreign-language communication skills, which is why such jobs are open only to a few. The salary of tour company staff is approximately

USD 250-450/month.

Tourist guide is a popular profession because of high incomes, compared to other tourism related trades and professions. An individual guide can earn from USD 20-40/day, depending on foreign language ability, with a premium for languages other than English. In recent years, Spanish, German and Russian speaking guides have earned more than other guides because only a few can communicate in these languages. The increasing number of Vietnamese, Chinese, and Korean tourists in the last two years has increased the requirement for more guides knowledgeable in these languages. For this reason, being a tour guide is the most popular job. Tour guides can also get extra income, such as tips from generous tourists and commission from restaurants, handicraft and souvenir shops. In addition to foreign language skills, tourist guides also require high school certificate. While inadequate education is a main constraint preventing those from poor backgrounds to access these jobs, another constraint, according to some respondents, is the requirement to pay an "unofficial" fee for a tourist guide license.

However, similar to other units in the local tourism value chain, the monthly average wages of employees who work in Karaoke bars, massage parlors, discotheques, and golf clubs are about USD 50. While some are from the villages in this area, the majority of them are from other provinces, from poor family backgrounds.

CONCLUSION

Tourism influences livelihoods in the Siem Reap area in several ways and there are complex interconnections between the poor residents of this region and actors in the various tourism sub-sectors. Consistent with prior studies in other areas, the poor residents in this area face considerable barriers to exploit opportunities presented by tourism. Although the number of tourists has increased significantly recently, the positive impact of tourism on local livelihoods has not been as significant. Poor families have received only a small portion of the revenue generated by tourism and more measures should be taken to integrate them into the TVC in ways that can improve their livelihoods.

By pointing out the constraints limiting the extent to which poor residents of Siem Reap can benefit from tourism, this finding can serve to help identify a set of possibilities that could remove or at least reduce those barriers, thereby contributing to reshaping tourism research towards paying more attention to improving livelihoods at the micro-level.

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Research article

The Biochemical Substances in Plants on Salt Affected Area in Northeast Thailand, Bamnet Narong District, Chaiyaphum Province, Thailand

NARARAT POODEETIP
Faculty of Science, Khon Kaen University, Khon Kaen, Thailand

KANLAYA KONG-NGERN*
Faculty of Science, Khon Kaen University, Khon Kaen, Thailand
Email: kkanla@kku.ac.th

SAMANG HOMCHUEN
Faculty of Science, Khon Kaen University, Khon Kaen, Thailand

BUPHA TOPARKNGAM
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

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Abstract This study was aimed to examine biochemical substances and their relationships in plants growing on salt affected area. The study took place in a very high salinity in Bamnetnarong District, Chaiyaphum Province between the rainy season (August 2011) and the dry season (April 2012). Two groups of plants were analyzed; halophytes and salt tolerant species. The halophytes consisted of *Azima sarmentosa*, *Maytenus mekongensis*, and *Pluchea indica* whereas the salt tolerance plant is *Combretum quadrangulare*. The results of the biochemical substances analyzes and showed that in the dry season all the plants produced more the contents of proline, hydrogen peroxide, peroxidase activity and malondiadehyde, and the percentage of electrolyte leakage than in the rainy season. Additionally, in both two seasons, the plants in the halophyte group produced substances less than in the salt tolerance plant. The best self-adjustment mechanism was discovered in *A. sarmentosa*, which produced a small and stable quantity of substances even though the electrical conductivity rose up.

Keywords important substances, halophytes, salt-tolerant species, salt affected area

INTRODUCTION

Salt stress leads to a series of morphological, physiological, biochemical and molecule changes that adversely affect plant growth and productivity. In glycophytes, plant growth and development are generally limited by salinity. The most of the word's crop species are glycophytes, and they do not grow under high soil salinity (Abbaspour, 2012). Salt tolerance is complex genetically and physiologically. Tolerance often shows the characteristics of a multigenic trait, with quantitative trait loci (QTLs) associated with tolerance identified in barley, citrus, rice, and tomato and with ion trans-port under saline conditions in barley, citrus and rice (Flowers, 2004).

When plants are subjected to salt stresses, active oxygen species (AOS) are generated in response to stress condition. AOS include superoxide (O_2^-), hydroxyl radicals (OH^-), hydrogen peroxide (H_2O_2) and singlet oxygen ($^1O_2$) are metabolic by products of plant cell (Abbaspour, 2012). It is already known that these cytotoxic active oxygen species, which are also generated during metabolic processes in the mitochondria and peroxisomes (Khan and Panda, 2008).

Under stresses, plants possess several antioxidant enzyme systems to protect their cell form the negative effects of AOS, such as peroxidase (POX), catalase (CAT), superoxide dismutase (SOD), glutathione reductase (GR), and ascorbate peroxidase (Sevengor et al., 2011). Peroxidases

catalyze the subsequent breakdown of H_2O_2 water and oxygen Catalase is involved in scavenging H_2O_2 generated during the photorespiration and β-oxidative of fatty acids. Super oxide dismutase can convert O_2^- to H_2O_2 and then H_2O_2 is removed by ascorbate peroxidase and glutathione reductase in the ascorbate-glutathione cycle. (Lu et al., 2006). Moreover, plants accumulate compatible osmolytes such as proline, glycine betaine and sugar alcohols, when they are exposed to drought or salinity stress (Yoshiba et al., 1997). Verdoy et al. (2006) considered in higher plant, proline is synthesized form both glutamic acid and ornithine. Nanjo et al. (1999) reported to many organisms, including higher plants, accumulate free proline in response to osmotic stress.

Salt tolerance is a complex phenomenon, but the specific mechanisms of salt tolerance in each plants species, can grow in high soil salinity in Northeast Thailand is poorly defined. The detrimental effects of high saline soil salinity on biochemical substances such as the contents of proline, hydrogen peroxide, peroxidase activity and malondiadehyde, and the percentage of electrolyte leakage in both season (rainy and dry season) and their relationship in each plant grown were determined.

METHODOLOGY

Study Area

The study took place in Bamnetnarong District, Chaiyaphum Province between the rainy season (August 2011) and the dry season (April 2012).

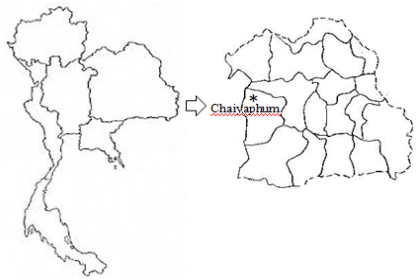

Fig. 1 The study area in Bamnetnarong District, Chaiyaphum Province between the rainy season (August 2011) and the dry season (April 2012)

Plant and soil samples

Plants and soil samples were collected by stratified sampling method between the dry season (April 2012) and the rainy season (August 2011). Two groups of dominate plants in the site study such as the 4 halophytic plants (namely, *Azima sarmentosa*, *Maytenus mekongensis*, *Pluchea indica*) and the salt tolerance plant (*namely, Combretum quadrangulare*) were selected.

Soil was sampled form root zone of each plant at width of 20 cm and at the depth of 15 cm Electrical conductivity (EC) and soil pH were determined in 1:5 (soil to water solution) by using a conductivity meter and a pH meter, respectively.

Electrolyte leakage (EL) was determined according to the method of Dionisio-Sese and Tobita (1998). The 0.1 g of fresh leaf samples was cut into 5 mm length and placed in test tubes containing 10 ml of redistilled water. The tubes were incubated in a water bath at 32 °C for 2 h and the initial electrical conductivity of the medium (EC_1). The samples were autoclaved at 121 °C for 20 min to release all the electrolytes and the final electrical conductivity (EC_2) measured. The percentage of EL was calculated by using the formula: EL (%) = (EC_1/EC_2) x100

Malondialdehyde (MDA) content was measured according to the method of Stewart and Bewley (1980). The 0.1 g of fresh leaf samples was homogenized under ice-cold (liquid nitrogen) was extracted with 50 mM phosphate buffer (pH 7.0) and centrifuged at 12,000 rpm at 4 °C for 30 min. As much as 1 ml of supernatant was then vortexed with 1 ml of 0.5% (w/v) thiobarbituric acid

solution containing 20% (w/v) trichloroacetic acid. The mixture was heated at 95°C for 25 min. The sample was cooled on ice for 10 min and centrifugated at 10,000 x g for 10 min. After subtracting the non-specific absorbance at 532 and 600 nm, the MDA content was determined by its extinction coefficient of 155 $mM^{-1}cm^{-1}$ and the concentration was express as mM g^{-1} FW.

Proline content was determined according to the procedures of Bates et al. (1973). Leaf sample 0.1 g was homogenized in 5 ml of 3% (w/v) sulfosalicylic acid and the homogrnate was filtrated through Whatman No.2. One ml of the filtrate was pipette laced in a 10 ml test tube and reacted with 1 ml of acid ninhydrin mixture and placed in a water bath at 100 °C for 1 h. The reaction was stopped on ice bath. The mixture was extracted with 2 ml. of toluene and stirred for 15 sec. The toluene phase containing the chromophores was aspired, warmed to room temperature, and the absorbance was read at 520 nm. The proline content was determined using from a standard curve and expressed as ug g^{-1}FW.

Hydrogen peroxide content in the leaves was determined according to the methods of Sergiev et al. (1997). Leaf tissues (0.5 g) were homogenized with 5 ml of 0.1% (w/v) trichloroacetic acid (TCA) on an ice bath. The homogenate was centrifuged at 12,000 x g for 15 min and 0.5 ml of the supernatant was transferred to a 15 ml test tube. The supernatant was added with 0.5 ml of 10 mM potassium phosphate buffer (pH 7.0), 1 ml of 1 M KI. The absorbance of supernatant was measured at 390 nm. The content of H_2O_2 was determined using a standard curve and the concentration was expressed as μmole g^{-1} FW.

Peroxidase enzyme activity was determined using the guaiacol oxidation method (Chance and Maehly, 1955) in a 3 ml reaction mixture containing 10 mM phosphate buffer (pH 6.4), 8 mM guaiacol, 100-200 μl crude extract and 2.75 mM H_2O_2. The increase in absorbance was recorded at 470 nm within 30s (linear phase) after H_2O_2 was added. One unit of peroxidase activity was expressed as $\Delta A470\ min^{-1}$ mg $protein^{-1}$

The protein was extracted by the method of Bradford (1976) using the Bio-Rad assay kit (Bio-Rad Laboratories, USA) with bovine serum albumin (BSA) as standard.

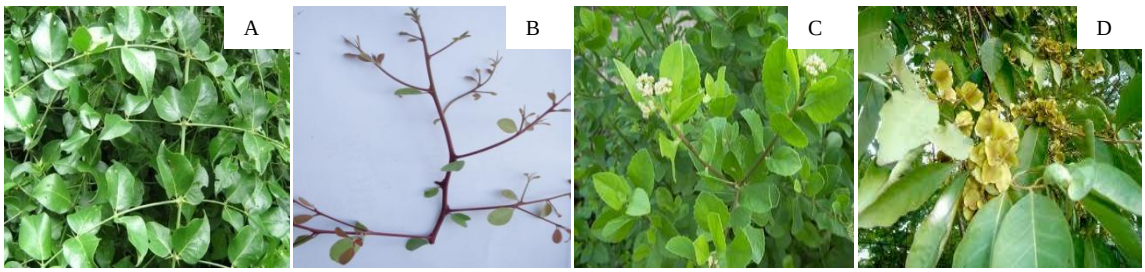

Fig. 2 Leaf of dominant plants in Bamnetnarong District, Chaiyaphum Province
Azima sarmentosa (A) *Maytenus mekongensis* (B), *Pluchea indica* (C), *Combretum quadrangulare* (D)

RESULTS AND DISCUSSION

Electrical conductivity and pH of soil

The EC in the rainy season and the dry season in the halophytes were ranged from 1-22 and 36-147 dS/m respectively, while in salt tolerance plant was ranged from 0.4-3.0 and 28-76 dS/m (Fig.1 A-C). During the rainy season the electrical conductivity was lower than in the dry season. In the rainy season, the rain will wash off salt of the surface. Soil pH in the rainy season and the dry season in the halophytes were ranged from 5.35-8.38 and 4.56-8.11, respectively, while in salt tolerance plant was ranged from 6.00-7.61 and 5.96-6.82 (data not shown).

Effect of soil salinity on electrolyte leakage

The effect of soil salinity on membrane integrity was monitor means of EL test in fresh samples. The amount of EL out of the cells was assessed indirect by conductometric measurements. EL of

the halophytes in the rainy season and in the dry season was in the range of 11-36% and 24-55%, respectively, whereas EL of salt tolerance plant (*C. quadrangulare*) was in the range of 15-24% and 21-45%, respectively (Fig. 3A-C). In both season, EL increased with increasing soil salinity level. Similar changes in the level of lipid peroxidation and electrolyte leakage in response to NaCl stress have been reported by several authors. Dhindsa et al. (1981) reported that there are similar changes in the level of lipid peroxidation and in electrolyte leakage in tobacco leaves. Lutts et al. (1996) also found a significant positive correlation between MDA and EL.

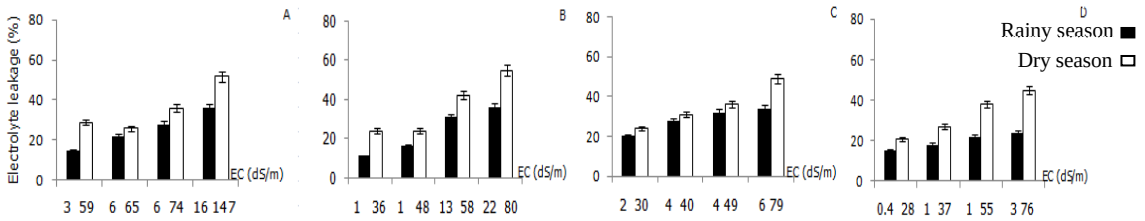

Fig. 3 The effect of soil salinity on electrolyte leakage in leaves of 4 plants
Azima sarmentosa (A), *Maytenus mekongensis* (B), *Pluchea indica* (C), *Combretum quadrangulare* (D), *Vertical bars represent mean + S.E. (n = 5)*

Effect of soil salinity on lipid peroxidation

A product of lipid peroxidation in the leaves of 4 plants was assessed as the content of MDA. In the rainy season, the content of MDA in the halophytes ranging from 0.3-4 mM/gFWx10^{-3} and in the salt tolerance group produced MDA ranging from 1-5 mM/gFWx10^{-3} is more than in the halophyte group. The dry season in the salt tolerance group produced MDA more than in the halophyte group. In the dry season salt tolerance group produced MDA more than the rainy season. Due to the higher electrical conductivity of the soil affect the oxidation increases as shown in Fig. 4.

These result is support by previous reports such as by Khan and Panda (2006) studied the effect of NaCl stress (50, 100 and 150 mmol l^{-1}). They found that the salt-tolerant Lunishree showed higher MDA than the salt-sensitive Begunbitchi. Indicating a higher rate of MDA in Begunbitchi due to salt stress MDA with the increase in salt stress.

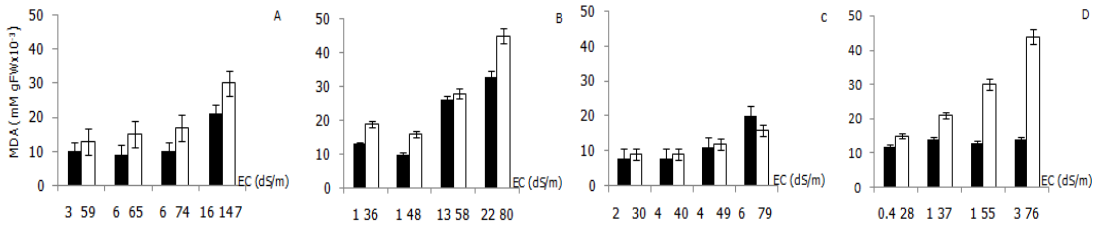

Fig. 4 The effect of soil salinity on malondialdehyde content (mM gFWx10^{-3}) in leaves of 4 plants
Azima sarmentosa (A), *Maytenus mekongensis* (B), *Pluchea indica* (C), *Combretum quadrangulare* (D), *Vertical bars represent mean + S.E. (n = 5)*

Effect of soil salinity on proline

Proline is an osmoprotectant that has been show to accumulate in plants in response to salt stress. Earlier studies form this showed that there is accumulation of proline in 4 plant species. In concurrence with this (Fig. 5), our results show that in the rainy season, proline content in the halophyte group and in the salt tolerance group were similar ranging from 1-15 µg g^{-1} FW. Whereas, in the dry season, the salt tolerance plant accumulate proline more than in the halophyte group. The results are in accordance to other findings such as by Lin and Kao (1996) studied the effect of NaCl stress (0, 50 and 150 mM) on root rice accumulation of proline when the concentration of the solution increases.

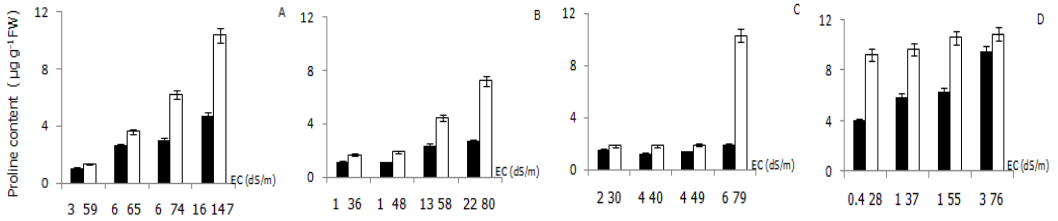

Fig. 5 The effect of soil salinity on proline content (µg/gFW) in leaves of 4 plants
Azima sarmentosa (A), *Maytenus mekongensis* (B), *Pluchea indica* (C), *Combretum quadrangulare* (D), *Vertical bars represent mean + S.E. (n = 5)*

Effect of soil salinity on peroxidase enzyme activity

The present results on increase in the peroxidase enzyme activity are shown in Fig. 6. Peroxidase enzyme activity in the rainy season plants in the halophyte group with peroxidase enzyme activity ranged from 0.1-1Δ470 min mg g^{-1} protein. Plants in the salt tolerance group ranged from 0.1-4 Δ470 min mg g^{-1} protein. In dry season plants in the halophyte group with peroxidase enzyme activity ranged from 0.1-4 Δ470 min mg g^{-1} protein and salt tolerance plants ranged from 0.1-4 Δ470 min mg g^{-1} protein. When plants are under stress to reduce stress by creating antioxidants, antioxidant enzymes to prevent damage from ROS to the plant cell such as catalase, glutathione reductase, superoxide dismutase and ascorbate peroxidase when compared with the controlled plant.

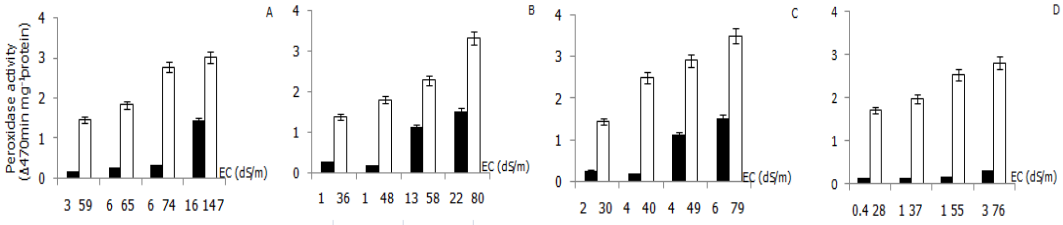

Fig. 6 The effect of soil salinity on peroxidase enzyme activity (Δ470min mg^{-1}protein) in leaves of 4 plants
Azima sarmentosa (A), *Maytenus mekongensis* (B), *Pluchea indica* (C), *Combretum quadrangulare* (D), *Vertical bars represent mean + S.E. (n = 5)*

Effect of soil salinity on hydrogen peroxide

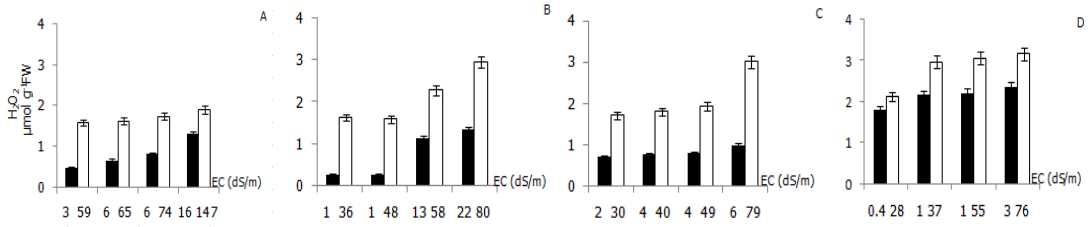

Fig. 7 The effect of soil salinity on hydrogen peroxide content (µmol g^{-1}FW) in leaves of 4 plants
Azima sarmentosa (A), *Maytenus mekongensis* (B), *Pluchea indica* (C), *Combretum quadrangulare* (D), *Vertical bars represent mean + S.E. (n = 5)*

Many authors has been reported that reactive oxygen species, including superoxide and hydrogen peroxide, are elevated with increased salinity, due to the imbalance in the production and destruction of reactive oxygen species (Uchida et al., 2002; Vaidyanathan et al., 2003) Fig. 7 show that the hydrogen peroxide level was increased with increasing salinity in this similar in 4 plant species. This result of hydrogen peroxide in the dry season than in the rainy season and halophytes

group increased hydrogen peroxide than the salt tolerant species of soil salinity was increased. This result supported the previous report of Vaidyanathan et al. (2003), who studied the effect of NaCl stress (100-300 mM) on two rice cultivars differing in salt tolerance. They found that the salt-tolerant Pokkali showed higher activity of catalase and lower levels of H_2O_2 than the salt-sensitive Pusa Basmati 1.

CONCLUSION

In summary, with increasing soil salinity, all plants showed a remarkable increase in the percentage of EL, the contents of proline, MDA, hydrogen peroxide, and peroxidase enzyme activity. The ability of salt tolerance in each plant depend on it's ability to produce biochemical substances, helps that it can be grow and survive in different soil salinity level. The results showed that *A. sarmentosa* is the best one that can be grown on high soil salinity upto 147 dS/m, while the other plants can grow in soil salinity not over than 102 dS/m. One of the characteristics of thick and glossy leaves of *A. sarmentosa* can be reduce water loss and maintain water status. In the future *A. sarmentosa* may be used to improve saline soil structure and used as a renewable energy such as wood for firewood.

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Research article

Effects of Chitosan and Lotus Extracts as Growth Promoter in *Dendrobium* Orchid

PIYAVADEE CHAROENWATTANA*
Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand
Email:piyavadeec@yahoo.com

UMNOUI PETPRAPAI
MahidolUniversity, Bangkok, Thailand

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Abstract The objective of this research was to investigate the effects of chitosan and lotus extracts to stimulate growth of orchid plantlets in greenhouse conditions. Chitosan was extracted from prawn shells (*Penaeus monodon*) with 90% deacetylation (DD) and 85-89% purity. The lotus extracts from the leaves of *Nelumbo nucifera* 'Roseum Plenum' were used as the sources of antimicrobial agents. The *Dendrobium* orchid 'Sureepeach' plantlets were treated with 10,30,50 and 100 mg L^{-1} chitosan and 1,3 and 5 g L^{-1} lotus extracts at 7 day intervals. The combination of 100 mg L^{-1}chitosan and 5 g L^{-1} lotus extracts gave the maximum number of leaves and shoots of the plantlets after 10 weeks of transplanting.

Keywords chitosan, lotus extracts, orchid, growth promoter

INTRODUCTION

Thailand is the world premier producer and exporter of orchids. The Thai orchid industry is well-known for both cut orchid flowers and the supplier of *in vitro* plantlets and pre-blooming plants. Most micro-propagated *Dendrobium* hybrids are the majority of Thai cut flowers. Key export markets are in Asia (China, Korea, and Japan), Europe (Italy and the Netherlands), the US and Australia. In 2011, the quantity of orchid exports was 23,392 tons or equivalent to Baht 2,111 million (Office of Economic Agriculture, 2012). The government's orchid strategy (2011-2016) envisages that Thailand will become the world's leading orchid exporter, with a target export value reaching 10,000 million Baht by 2016 (Than Sethakit. 2012). Increased demand for orchids could lead to an expansion of cultivated areas, especially for large scale production of orchid plantlets. To triple orchid production, the strategy aims to improve the quality of orchids and diversify their varieties. The orchid industry will benefit from the development of more efficient micro-propagation techniques, especially *Dendrobium* orchids.

Chitosan is wildly used in agriculture due to its positive effects on plants growth and development. Chitosan (poly [b-(1→4)-2-amino-2-deoxy-D-glucopyranose]), a biopolymer derivative of chitin, is mostly found in the exoskeleton of arthropods and crustaceans (Palpandi, *et al*., 2009). In Thailand, chitin can be extracted from the abundant prawn and crab shells that are sustainable and readily available as a natural waste product from the seafood industry. For the cut flower hybrid orchid, *Dendrobium* 'Earsakul', chitosan of 45 kDa molecular weight and a >90% degree of deacetylation (DD) applied at a concentration of 1–100 mg/L significantly increases both quantitatively and qualitatively inflorescence yields (Limpanavech et al., 2008). However, the impacts of chitosan on *in vitro* orchids and orchid propagation have been limited. Nge et al. (2006) found that the size and the origin of the chitosan as well as its concentration affected the number of *Dendrobium* and *Phalaenopsis* plantlets regenerated from a protocorm-like body (PLB). Additionally, the research also found that spraying with chitosan significantly reduced the severity of leaf spot diseases in orchids, promoted plant growth of some orchids, and increased the size and length of the *Dendrobium* florets and inflorescences, respectively (Uthairatanakij et al., 2007).

Moideen et al. (2011) found that the medicinal plant of *Nelumbo nucifera* (lotus) has a wide range of medicinal properties. Various techniques using different chemical solutions such as ethanol, methanol and water were applied to the leaves of *Nelumbo nucifera* to obtain some extracts for testing using preliminary phytochemical analysis. The antimicrobial susceptibility studies were conducted against gram (-) bacteria such as *E. coli, P. aeruginosa, K. pneumonia* and gram (+) bacteria such as *Staphylococcus aureus*. The results show that ethanol extract is anti-microbial.

Li and Xu (2008) tested the anti-microbial of the lotus leaf extracts against five microorganisms. The most active antimicrobial extract was subjected to spectroscopic analysis. The result shows that the minimum inhibitory concentrations of the most active extract were 0.625, 1.25, 1.25, 0.625 and 2.5 mg/mL for *Actinobacillus actinomycetemcomitans* Y4, *Actinomyces viscosus* 19246, *Porphyromonas gingivalis* 33277, *Fusobacterium nucleatum* 25586, and *Actinomyces naeslundii* wvl45. Quercetin from lotus leaves was found to have the greatest antimicrobial activity; this suggests it could be a potential antibacterial agent for periodontitis.

The use of chitosan and lotus leave extracts to stimulate growth and increase disease resistance is expected to increase orchid production and thus further develop the orchid export industry. They will replace chemical fertilizer and pesticide and are environmental friendly.

OBJECTIVE

This research aims to demonstrate that chitosan and lotus extracts can stimulate the growth of *Dendrobium* orchid plantlets.

METHODOLOGY

Extraction of chitin and chitosan

Chitin and chitosan were produced from prawn shells through demineralization, deproteinization and deacetylation (Burrows *et al*., 2007). Shells of prawns (*Penaeus monodon*) were washed, dried and then ground into small pieces. Approximately 25 g of prawn shells were demineralized with 100 ml of 1% (v/v) hydrochloric acid (HCl) for 24 h to remove the minerals (mainly calcium carbonate). To obtain the chitin, the washed and cleaned shells were transferred to 50 ml of 2% (w/v) sodium hydroxide (NaOH) and soaked for 1 hour in order to dissolve proteins and sugars. Subsequently, the chitin was cleaned and oven dried, resulting in a chitin product that was subsequently de-acetylated in 100 ml 50% (w/v) sodium hydroxide (NaOH) and boiled at 100°C for 2 h on a hot plate to obtain chitosan. The 1% (w/v) chitosan solution was obtained from dissolving 5 g of chitosan in 500 ml of 0.1M acetic acid and stirred continuously at 55°C for 12 h. The filtrated chitosan solution had the pH of 3.99, 90% deacetylation (DD), and 85-89% purity. Concentrated chitosan of 10, 30, 50 and 100 mg $L^{-1}$was obtained from diluted chitosan in 1% acetic acid.

Lotus extracts

The leaves of *Nelumbo nucifera* 'Roseum Plenum' were air dried for 2-3 days before cutting into small pieces (2-3 cm.) and ground up. The leaves were coldly extracted using ethanol at room temperature. 200-gram leaves were filled in a cloth bag and soaked in 3 L of ethanol three times during one week until no extracts came out. Subsequently, the ethanol was discarded using a rotary evaporator to get the brown and concentrated crude extracts that were kept in a cold dry place. Crude extracts were fractioned using the Column Chromatography technique to derive hexane crude extracts, which were then diluted into 1, 3 and 5 g L^{-1} concentrations.

Plantlets preparation

The study also used *Dendrobium* 'Sureepeach' plantlets from Mana orchid farm, Nakornpathom province. 2 to 4 leave plantlets with well-developed roots were removed from medium culture and washed thoroughly under running tap water to remove traces of agar. Plantlets were acclimatized in pots for 4 weeks, then transferred to a greenhouse and watered daily with 400 g L^{-1} of 21-21- 21 fertilizer every week for 10 weeks. The *Dendrobium* orchid 'Sureepeach' plantlets were treated with 10, 30, 50 and 100 mg L^{-1} chitosan and 1, 3 and 5 g L^{-1} lotus extracts at 7 day intervals.

Data analysis

All experiments were carried out in a completely randomized design with three replications under daily visual observations to record the number of leaves and shoots over the course of 10 weeks. Subsequently, an analysis of variance (ANOVA) and means were calculated and compared using Duncan's new multiple rang test (DMRT).

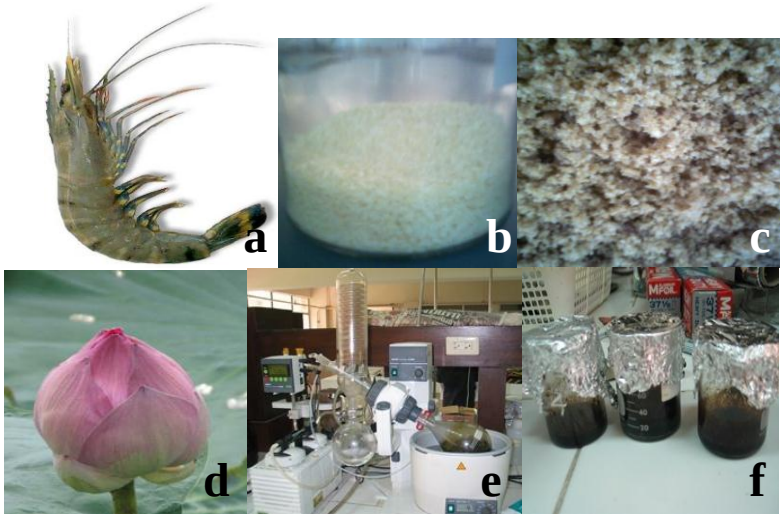

Fig. 1 Chitin (b) and chitosan (c) are produced from prawn shells (a) through demineralization, deproteinization and deacetylation, ethanol extracts come from lotus leaves (d), the crude extracts were fractioned by rotary evaporator (e) to obtain brown crude extracts (f)

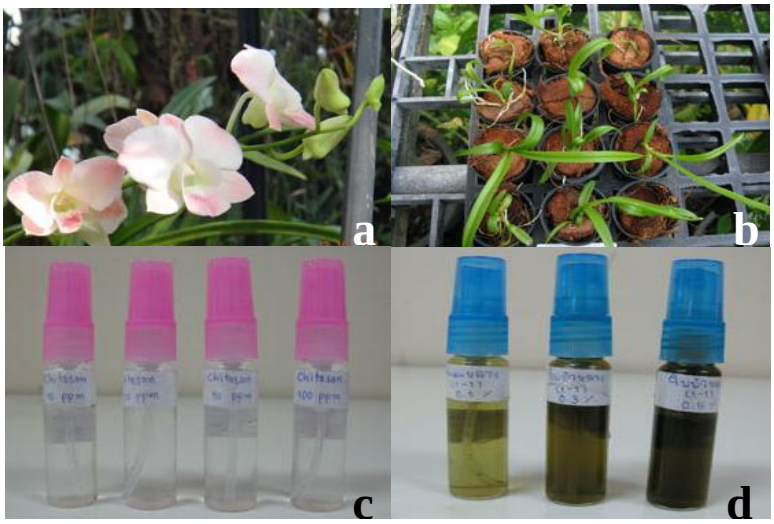

Fig. 2 Flowers of *Dendrobium* 'Sureepeach' (a), plantlets were transplanted to pots filled with small pieces of coconut husk (b), chitosan and lotus leave extracts (c, d)

RESULTS AND DISCUSSION

The study found that the number of leaves after 2 weeks of transplanting was not statistically different. However, the number of leaves after 4, 8 and 10 weeks of transplanting was significantly different. The orchid plantlets treated with 100 mg L^{-1} chitosan in combination with 5g L^{-1} lotus extracts gave the maximum number of 8.5 leaves. The control plantlets without the treatment of chitosan and lotus extracts gave an average number of 5.1 leaves. The new shoots and leaves that emerged after 8 weeks were strong compared to those without the chitosan and lotus extract treatment after 10 weeks. The application of 100 mg L^{-1} chitosan combined with 5g L^{-1}lotus extracts resulted in the maximum number of leaves on average. The concentrated chitosan used in this study was higher than in *Dendrobium* orchid 'Earsakul' that was applied to 1-100 mg L^{-1} chitosan.

Table 1 The effects of chitosan and lotus extracts on the number of *Dendrobium* 'Sureepeach' leaves within 10 weeks after transplanting in the greenhouse

Treatment		Number of leaves per pot				
Chitosan (mg L^{-1})	Lotus extracts (g L^{-1})	Week 2	4	6	8	10
0	0	3.0	3.1 a-e	3.2 a	3.9 a-d	5.1 b-f
	1	3.6	3.3 a-d	2.2 b-d	2.8 de	3.7 ef
	3	3.3	4.0 a	2.8 ab	4.9 ab	6.4 a-d
	5	3.8	2.7 c-e	2.7 ab	2.8 de	2.8 f
10	0	3.4	3.6 a-c	2.8 ab	3.4 c-e	4.9 b-f
	1	3.4	3.7 ab	2.8 ab	4.4 a-c	6.3 a-d
	3	3.0	3.0 b-e	2.7 ab	2.5 e	3.7 ef
	5	3.2	2.8 b-e	2.2 b-d	4.1 a-d	5.6 b-e
30	0	2.8	2.8 b-e	2.2 b-d	4.1 a-d	4.2 c-f
	1	3.2	2.7 c-e	2.1 b-d	3.3 c-e	4.5 c-f
	3	3.4	3.4 a-d	2.3 a-c	4.4 a-c	6.6 a-c
	5	3.3	4.0 a	2.9 ab	3.5 b-e	4.2 c-f
50	0	3.1	2.9 b-e	2.8 ab	4.5 a-c	5.7 b-e
	1	2.7	2.2 e	2.3 a-c	3.6 b-e	4.9 b-f
	3	3.4	3.2 a-d	2.6 a-c	3.6 b-e	4.7 c-f
	5	2.7	2.6 de	1.4 d	3.7 a-e	5.6 b-e
100	0	3.2	2.8 b-e	1.7 cd	3.4 c-e	4.0 d-f
	1	2.7	2.8 b-e	2.6 a-c	4.4 a-c	6.1 a-e
	3	3.4	2.7 c-e	2.6 a-c	3.8 a-e	7.4 ab
	5	3.3	3.1 a-e	2.5 a-c	5.0 a	8.5 a
F-test		Ns	**	*	**	**
CV (%)		15.7	15.9	18.9	18.6	4.2

Means followed by the same letter in the same column had no significant difference by DMRT
**, ** indicatessignificance at 5% and 1% levels of probability, respectively.ns = not significant*

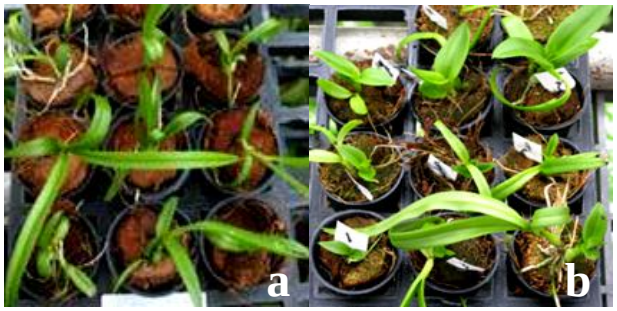

Fig. 3 Comparison of the effects of chitosan and lotus extracts on plantlet growth
controlled plantlets (a) and plantlets treated with chitosan and lotus extracts after10 weeks (b), Photograph is representative of three such independent replications.

It increased both the yield and quality of the inflorescence (Limpanavech *et al*., 2008). The plant responded differently to various type of chitosan molecule. The lower molecular weight of chitosan was more effective in inducing and disease resisting than the higher molecular weight of chitosan (Lin *et al*., 2005).

CONCLUSION

The appropriate concentrations of chitosan and lotus extracts were investigated for their effects on the growth of *Dendrobium* orchid plantlets in greenhouse conditions. According to the result obtained, prawn chitosan has the ability to enhance the survival rate and the growth of the plantlets. Chitosan of 100 mg L^{-1} are the most effective. The results indicates that plantlets treated with 100 mg L^{-1} chitosan and 5 g L^{-1} lotus extracts yielded the maximum number of leaves and shoots after 10 weeks of transplanting. However, further work is required to evaluate the effects of chitosan and lotus extracts interaction or alone for various stages of plant growth.

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Research article

Water Footprint of Energy Crops under the Rain-Fed and Irrigated Cultivation in Eastern Thailand

SANIDDA TIEWTOY*
Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand
Email: saniddatiewtoy@hotmail.com

THANUTYOT SOMJAI
King Mongkut's University of Technology North Bangkok, Prachinburi, Thailand

CHALITA SUWAN
King Mongkut's University of Technology North Bangkok, Prachinburi, Thailand

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Abstract Under the current 15-year Renewable Energy Development Plan (REDP) of 2008-2022, Thailand's Ministry of Energy promotes the production and use of ethanol to substitute fossil oil. Two major crops used to produce ethanol in Thailand are sugarcane and cassava. This research assesses the water footprint (WF) of sugarcane and cassava under the rain-fed and irrigated agriculture in the eastern provinces of the Kingdom. The data on crop evapotranspiration, use of fertilizer, and yield are required for the estimation of the water footprint in crop production, the approach of which is based on *The Water Footprint Assessment Manual* of Hoekstra et al. The results of this study show that the average WF's of sugarcane in rain-fed and irrigated cultivation are respectively 171 m^3/ton (89% green, 11% grey) and 162 m^3/ton (83% green, 7% blue, 10% grey). For cassava, the average WF's in rain-fed and irrigated agriculture are 387 m^3/ton (85% green, 15% grey) and 413 m^3/ton (81% green, 5% blue, 14% grey), respectively. Rainfall is still a key factor in the cultivation of sugarcane and cassava taking into consideration the proportion of water use. The sugarcane yield in the rain-fed fields is lower than that in the irrigated fields, while the yield of cassava in both environments is similar. The findings not merely would be of use to stakeholders and policymakers for better water management but also could be used as basis data of sub-national water footprint for crop production.

Keywords water footprint, sugarcane, cassava, energy crops, Thailand

INTRODUCTION

Ministry of Energy of Thailand , has since 2008 implemented the current 15-year Renewable Energy Development Plan (REDP 2008-2022) with the goal to increase renewable energy use to 20% of the total energy consumption by 2022. In addition, the present government, to expedite the realization of the REDP, has tasked the Energy Ministry with the drawing up of the Renewable and Alternative Energy Development Plan (AEDP 2012-2021) to identify the framework and direction of Thailand's renewable energy development. Encouraging collaboration among the community people in greater production and use of renewable energy is one of six strategies to promote AEDP. The target of ethanol production output is 9 Ml/day by 2021 through improvement of average yields of sugarcane and cassava to not less than 15 and 5 t/rai/yr (6.25 rai=1 ha). Moreover, other alternative energy crops such as sweet sorghum are promoted.

Based on the aforementioned policies, the data on the amount of water consumption is important for policymakers in the promotion of ethanol production and use. In this regard, the aim of this research is to assess the water footprint (WF) of sugarcane and cassava under the rain-fed and irrigated agriculture in the eastern part of Thailand.

METHODOLOGY

Study area: The eastern region is an important cultivation area of fruits, maize, sugarcane and cassava. Provinces of Chachoengsao, Chonburi, Prachinburi and Sakaeo (i.e., 4 out of 7) were selected as the study area (Figure 1).

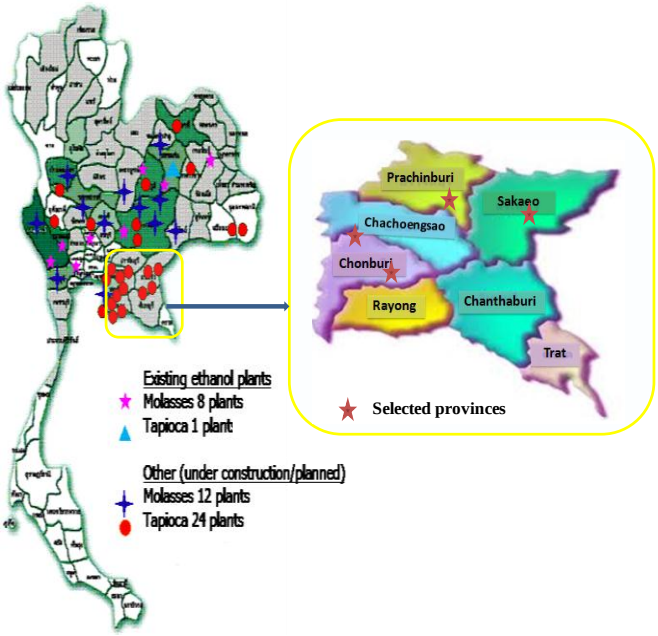

Fig.1 Ethanol plants in Thailand and study area
Source: (DEDE, 2008)

Research methodology: Calculation of water footprint of sugarcane and cassava under the rain-fed and irrigated conditions in this research follows the Water Footprint Assessment Manual of Hoekstra et al. (2011). The data on crop evapotranspiration, use of fertilizer, and yield are requisites for the estimation of the water footprint in crop production.

The water footprint concept: Water footprint (WF) is an indicator of freshwater use that takes into account both direct and indirect water use of a consumer or producer. It consists of three components: green, blue, and grey water footprints. The green water footprint is the volume of rainwater consumed during the production process, the blue water footprint refers to consumption of natural water resources (surface and groundwater) along the supply chain of a product, and the grey water footprint is defined as the volume of freshwater required to assimilate the load of pollutants to meet the water quality standards (Hoekstra et al., 2011).

Calculation of green and blue water footprint: Green and blue water evapotranspiration during crop growth can be estimated with CROPWAT 8.0 model based on the Food and Agriculture Organization (FAO, 2009). According to Hoekstra et al. (2011), this research selects the irrigation schedule option to determine the crop evapotranspiration. The calculated evapotranspiration is called ET_a, which is calculated as the crop evapotranspiration under optimal conditions (ET_c) times a water stress coefficient (Ks) as shown below:

$$ET_a = K_s \times ET_c = K_s \times K_c \times ET_o \quad (1)$$

Where ET_a is the actual crop evapotranspiration, ET_C the crop evapotranspiration, ET_o the reference evapotranspiration, K_c the crop coefficient, and K_s a water stress coefficient with a value between 0 and 1.

The green and blue components of crop water use (CWU) are calculated by accumulation of daily evapotranspiration over the complete growing period. The total ET_{green} and ET_{blue} in mm are converted to crop water use in m^3/ha by a factor 10.

Calculation of the green, blue and grey water footprint for crop production: Calculations of the water footprint (WF) of crop growing process are shown in Eq. (2) and (3). The total water footprint of the crop growing process is the sum of the green, blue, and grey components as shown in Eq.(5).

$$WF_{proc,green} = \frac{CWU_{green}}{Y} \quad (2)$$

$$WF_{proc,blue} = \frac{CWU_{blue}}{Y} \quad (3)$$

$$WF_{proc,grey} = \frac{(\alpha \times AR)/(c_{max} - c_{nat})}{Y} \quad (4)$$

$$WF_{proc} = WF_{proc,green} + WF_{proc,blue} + WF_{proc,grey} \quad (5)$$

Where CWU is crop water use (m^3/ha), Y crop yield (ton/ha), α leaching-run-off fraction (%), AR chemical application rate (kg/ha), C_{max} the maximum acceptable concentration (kg/m^3), and C_{nat} the natural concentration for the pollutant considered (kg/m^3).

Data collection: Primary and secondary data were obtained from various sources. Primary data were collected using interviews and questionnaires while secondary data, such as land use map, climatic data, soil type etc., were taken from reports and publications. Additional details about the methods used in this study are indicated below:

Climate data: The climate data for a 30-year period (1981-2010) were taken from the Thai Meteorological Department.

Soil types: Based on the Land Development, Department classification, soil types are mostly sandy loam suitable for cassava and sugarcane production.

Crop parameter: Farmers from the four selected provinces were interviewed with the questions from the questionnaire. Data on household size, age structure, water source for crop production, cropping pattern, crop yield, and fertilizer application were part of the questionnaire.

Ambient water quality standard: Based on the Notification of the National Environment Board No. 8, the maximum acceptable concentration for nitrate in surface water quality standards is 5 mg/l.

Crop coefficient (kc): Crop coefficients of sugarcane and cassava were taken from the Royal Irrigation Department (RID, 2010).

RESULTS AND DISCUSSIONS

Calculation of green and blue WF under the rain-fed and irrigated conditions in this research employed irrigation scheduling based on actual water use from field survey. In the case of irrigated condition, irrigation schedule option of without irrigation was used to determine the water use by crop. The sugarcane yield in the rain-fed fields is lower than that in the irrigated fields, while the yield of cassava in both conditions is similar. The outputs of sugarcane and cassava for rain-fed and irrigated conditions are respectively shown in Tables 1 and 2.

The grey WF is estimated based on the application of nitrogen fertilizer to crops. The average nitrogen fertilizers applied to sugarcane and cassava are 66.21 and 68.23 kg/ha, respectively. The leaching run off fraction is assumed at 10% of the application rate (Chapagain et al., 2006). Due to surface quality standards (DEQP, 1994), the maximum allowable concentration is 5 mg/l. The natural concentration in the receiving water body is assumed to be zero. The grey WF is calculated based on Eq.(4). The outputs of the grey WF of sugarcane and cassava for rain-fed and irrigated conditions are respectively shown in Tables 3 and 4.

Table 1 Components of green and blue water footprint for sugarcane production

Province	ET_{green} (mm)	ET_{blue} (mm)	ETa (mm)	CWU_{green} (m^3/h)	CWU_{blue} (m^3/h)	CWU_{total} (m^3/ha)	Y (ton/ha)	$WF_{proc,green}$ (m^3/ton)	$WF_{proc,blue}$ (m^3/ton)
Rain-fed									
Chonburi	944.4	0.0	944.4	9444	0.0	9444	70.0	134.9	0.0
Prachinburi	1105.7	0.0	1105.7	11057	0.0	11057	65.9	167.7	0.0
Sakaeo	1111.2	0.0	1111.2	11112	0.0	11112	70.6	157.3	0.0
Irrigated									
Chonburi	944.4	280.5	1224.9	9444	2805	12249	96.9	97.5	29.0
Prachinburi	1105.7	46.0	1115.3	11057	460	11153	70.3	157.4	1.4
Sakaeo	1111.2	2.2	1113.4	11112	22	11134	72.3	153.4	0.3

Table 2 Components of green and blue water footprint for cassava production

Province	ET_{green} (mm)	ET_{blue} (mm)	ETa (mm)	CWU_{green} (m^3/ha)	CWU_{blue} (m^3/ha)	CWU_{total} (m^3/ha)	Y (ton/ha)	$WF_{proc,green}$ (m^3/ton)	$WF_{proc,blue}$ (m^3/ton)
Rain-fed									
Chonburi	832.5	0.0	832.5	8325	0.0	8325	25.0	333.0	0.0
Prachinburi	709.2	0.0	709.2	7092	0.0	7092	23.3	305.0	0.0
Sakaeo	773.3	0.0	773.3	7733	0.0	7733	25.0	309.3	0.0
Chachoengsao	742.8	0.0	742.8	7428	0.0	7428	20.3	396.0	0.0
Irrigated									
Chonburi	832.5	33.6	866.1	8325	336	8661	24.9	333.8	13.5
Prachinburi	709.2	129.1	838.3	7092	1291	8383	23.7	299.4	54.5
Sakaeo	773.3	35.5	808.8	7733	355	8088	25.1	308.5	14.2
Chachoengsao	742.8	24.9	767.7	7428	249	7677	19.5	394.0	13.0

Table 3 Water footprint of sugarcane production in Eastern Thailand

Province	Rain-fed (m^3/ton)				Irrigated (m^3/ton)			
	WF_{green}	WF_{blue}	WF_{grey}	WF_{total}	WF_{green}	WF_{blue}	WF_{grey}	WF_{total}
Chonburi	134.9	0.0	18.0	152.9	97.5	29.0	13.0	139.4
Prachinburi	167.7	0.0	22.3	190.0	157.4	1.4	20.9	179.7
Sakaeo	157.3	0.0	14.2	171.5	153.7	0.3	13.8	167.8
Average	153.31	0.0	18.17	171.48	136.18	10.21	15.90	162.29

Table 4 Water footprint of cassava production in Eastern Thailand

Province	Rain-fed (m^3/ton)				Irrigated (m^3/ton)			
	WF_{green}	WF_{blue}	WF_{grey}	WF_{proc}	WF_{green}	WF_{blue}	WF_{grey}	WF_{proc}
Chonburi	333.0	0.0	61.6	394.6	333.8	13.5	61.8	409.1
Prachinburi	305.0	0.0	58.3	363.4	299.4	54.5	57.3	411.2
Sakaeo	309.3	0.0	53.9	363.2	308.5	14.2	53.8	376.5
Chachoengsao	396.0	0.0	60.1	426.0	394.0	13.0	62.6	456.0
Average	335.8	0.0	58.5	386.8	393.9	23.8	58.9	413.2

Table 5 Comparison of this study result, Mekonnen and Hoekstra's (2011) and global average water footprint

Area/Farming system	Sugarcane (m^3/ton)				Cassava (m^3/ton)			
	WF_{green}	WF_{blue}	WF_{grey}	WF_{proc}	WF_{green}	WF_{blue}	WF_{grey}	WF_{proc}
Eastern Thailand								
Rain-fed	153	0	18	171	336	0	56	387
Irrigated	136	10	16	162	334	24	59	413
Mekonnen and Hoekstra (2011)								
Rain-fed	164	0	13	176	-	-	-	-
Irrigated	120	104	14	238	-	-	-	-
Global Average	139	57	13	210	550	0	13	564

The estimated total water footprint of crop production process (WF_{proc}) is the summation of the green, blue, and grey water footprint as Eq.(5). The water footprints of sugarcane and cassava production in eastern Thailand under rain-fed and irrigated agriculture are illustrated in Tables 3-4.

The results show that the average WF's of sugarcane in rain-fed and irrigated cultivation are 171.48 m^3/ton and 162.29 m^3/ton, respectively. For cassava, the average WF's in rain-fed and irrigated agriculture are 386.8 m^3/ton and 413.2 m^3/ton, respectively.

As shown in Table 5, water footprint of sugarcane of eastern Thailand of the irrigated condition (162) is lower than that of rain-fed (171), those of rain-fed (176) and irrigated cultivation (238) of Mekonnen and Hoekstra, and that of global average (210). In the same table, water footprints of cassava of eastern Thailand (387 and 413 for rain-fed and irrigated respectively) are lower than that of global average (564).

CONCLUSION

This paper deals with the assessment of water footprint (WF) of sugarcane and cassava under the rain-fed and irrigated agriculture in the eastern part of Thailand. The results show that the average WF's of sugarcane in rain-fed and irrigated cultivation are 171 m^3/ton (89% green, 11% grey) and 162 m^3/ton (83% green, 7% blue, 10% grey), respectively. For cassava, the average WF's in rain-fed and irrigated agriculture are 387 m^3/ton (85% green, 15% grey) and 413 m^3/ton (81% green, 5% blue, 14% grey), respectively. The average WF of sugarcane in rain-fed is higher than that in irrigated agriculture because the rain-fed yield is lower than the irrigated yield. The yields of cassava in both conditions are very similar, but crop water use of irrigated cassava is higher than rain-fed cassava, thereby leading to the lower average WF of cassava in rain-fed than in irrigated agriculture. With the proportion of water use taken into account, rainfall remains a key factor in the cultivation of sugarcane and cassava. The WF reduction in the eastern region is achievable through adoption of part or all of the following suggestions in combination: 1) increase yield through improved agricultural practice; 2) improve the irrigation schedule by optimizing timing and volumes of application; 3) support investments in irrigation systems and techniques that conserve water; and 4) reduce the use of chemical fertilizers, pesticides and insecticides. The findings of this study not only would be of great use to both stakeholders and policymakers for better water management but also could be further used as basis data of sub-national water footprint for crop production.

ACKNOWLEDGMENTS

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Research article

Analysis of Requisite Quality of Cassava and Temperature for Baking Cookies

SARIN NEANG*
Royal University of Agriculture, Phnom Penh, Cambodia
Email: neangsarin@gmail.com

VITOU ORNG
Royal University of Agriculture, Phnom Penh, Cambodia

VOUCHSIM KONG
Royal University of Agriculture, Phnom Penh, Cambodia

SAROM MEN
Royal University of Agriculture, Phnom Penh, Cambodia

LINDA FORRESTER
Education Advisor, Australia

BORARIN BUNTONG
Royal University of Agriculture, Phnom Penh, Cambodia

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Abstract Cookies are a kind of food product made from flour and other ingredients such as butter, egg, sugar, milk, and baking soda. This research was conducted to find the optimum temperature and the optimum proportion of cassava flour required in cookie production. The experiment was divided into nine treatments with three replications, different temperatures included 160 °C, 170 °C ; 180 °C and proportions of cassava flour trialed were 50 %, 75 %; 100 %. The processing and sensory testing were conducted in the food processing laboratory of the Faculty of Agro-Industry, Royal University of Agriculture (RUA) while the analysis of chemicals was done in the Industrial Laboratory Centre of Cambodia (ILCC). The results show that using 50%, 70% and 100% 5 % and 100 % of cassava flour at the temperature of 160 °C, 170 °C and 180 °C affected the chemical properties of cookie products such as ash, moisture, protein, fat, sugar, carbohydrate, and energy. Also, they affected the color, texture, odor, as well as flavor and crispness, factors which all related to consumers identifying cookies as their favorites. Among nine treatments, the second treatment which used 50% of cassava flour at the temperature of 170 °C was the best treatment; whereas, the ninth treatment which used 100% of cassava flour at the temperature of 180 °C had the lowest quality. Therefore, results show that 50 % of cassava flour baked at the temperature of 170 °C for 8 minutes is the optimum configuration to use in cookie production.

Keywords processing, temperature, sensory test, cassava, cookies

INTRODUCTION

Cassava is a kind of plant that mostly grows in tropical area in South America. The root of Cassava has poisonous substances, but the rest of the plant is edible and provides a lot of essential nutrients. Cassava is rich in Carbohydrate and low lipids that play a role in providing energy to the human body. Energy from Cassava is related to the density of calories, where 100 gram provides 160 calories (Willett, 2005). Cassava is known and grown by Cambodian farmers since 19th century. It was grown for starch production for commercial purpose, livestock feed and used for human.

Before 1970, this crop was planted in small areas, especially on black soil, along the river, and upland areas and red soil in some areas of the country.

Between 1975 and 1979, this crop becomes a staple, and people eat cassava instead of rice. This is a very popular crop among farmers in southeastern and eastern areas of the country, especially for people living in upland areas. However, some farmers living in lowland areas also grow this crop on the space around their house, and they consume it as their food (MAFF, 2003).

The cassava yield increased from 535,600 tons in 2005 to 2 million tons in 2007. This is the result of increasing lands for growing cassava crops. Cassava was planted on 30,000 hectares in 2005 and 1,000,000 hectares in 2007 and the yield rose from 17.9 tons/ha to 20.5 tons/ha (CIAT, 2008). Cassava has an important role in the development of rural areas because it is the raw material in industrial productions such as animal feed, starch, ethanol, bioethanol and other food processes in bakery production, such as ice cream, cakes, and biscuits (Willett, 2005).

OBJECTIVE

This research was aimed at finding the optimum temperature and the amount of cassava flour required in cookie production.

METHODOLOGY

Study site

This research included processing cookies, analyzing chemical contents and sensory testing and was conducted at the laboratory of the faculty of Agro-Industry, Royal University of Agriculture (RUA). The analysis of chemical contents in processed cookies was done at the Industrial Laboratory Centre of Cambodia (ILCC), Phnom Penh, while the sensory test was done at RUA. The research study was conducted between May and August, 2012.

Experimental design and treatments

The factorial Complete Randomized Design (CRD) was used in this experimental method; there are three factors including temperature (160ºC, 170 ºC and 180 ºC), cassava flour (50%, 75% and 100%), and wheat flour (50% and 25%) as shown in table 1.

Table 1 Divisions of experimental treatments

Treatments	Temperature (ºC)	Cassava flour (%)	Wheat flour (%)
T_1	160		
T_2	170	50	50
T_3	180		
T_4	160		
T_5	170	75	25
T_6	180		
T_7	160		
T_8	170	100	00
T_9	180		

Raw materials of the cookies were cassava flour, wheat flour, sugar, egg, butter, baking soda, blue berries and milk. 11% of egg white was mixed by a hand mixer and then 31. 25% of butter was added in the egg port. 31. 25% of sugar, 6.25% of milk, 16% of blue berries and 1% of baking soda were subsequently mixed in the egg and butter port. The cassava flour and wheat flour were added and compressed into cookie dough 1 cm thick before baking in the oven for eight minutes in each temperature that had already been set. Noticeably, before using the oven, it needed to be

heated 250 ºC for 20 minutes. Taken out from the oven, the cookies were placed on the tray in ambient temperature for 10 minutes before packing in a plastic bag.

Chemical analysis

After getting the processed cookies, all were taken to test chemical contents such as ash, energy and sensory test (color, texture, odor, flavor and crisp). Recorded data was organized for analysis using Microsoft Excel to specifically determine comparative, quantitative and qualitative analysis.
A. Ash: Dry the cup of ash in an oven with temperature of 150 ºC for 1 hour and then take the cup to further dry in desiccators for 30 minutes before weighting. Then, put a sample of about 2 g in the cup. Weigh and record the weight. Take the sample to dry in the oven with the temperature 600 ºC for 3 hours. Lastly, take it to put in desiccators and weight it again (AOAC, 2005).
B. Energy: Energy consists of carbohydrate, fat and protein (Willett, 2005).

$$Total\ energy =)Protein \times 4\ cal/g) + (fat \times 9\ cal/g) + (carbohydrate \times 4\ cal/g)$$

Where, protein 100 g, energy 100 g, fat %, carbohydrate 100 g
C. Sensory test: The questionnaires designed to test, color, texture, odor, flavor, and crispness. Preference was recorded from 30 participants. The score ranged from 1 to 5 (1: dislike, 2: somewhat dislike, 3: like, 4: somewhat like and 5: like very much).

RESULTS AND DISCUSSION

Ash

Figure 1 showed that the fourth treatment used cassava flour 75% and wheat flour 52% in temperature of 160 °C had the highest ash of 0.978% and the third, sixth, seventh, eighth and ninth had similar percentage of ash. On the other hands, the second treatment used cassava flour 50% and wheat flour 50% in 160 °C had the lowest ash of 0.95 %. In general, food products that made of flour had ash between 0.3 to 1.4 %.

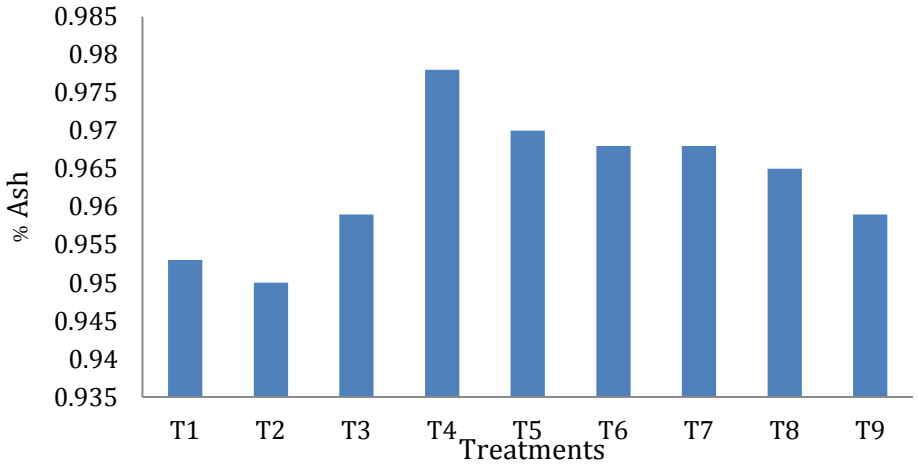

Fig. 1 Ash analysis in each treatment

Energy

Figure 2 showed that the fourth treatment using cassava flour 50% and wheat flour 50% at the temperature of 160 °C has energy of 454 kilocalories, which was the highest energy of all treatments. Conversely, the ninth treatment using 100% of cassava flour in temperature of 180 °C to 160 °C had energy 445.544 kilocalories, which was the lowest energy of all treatments.

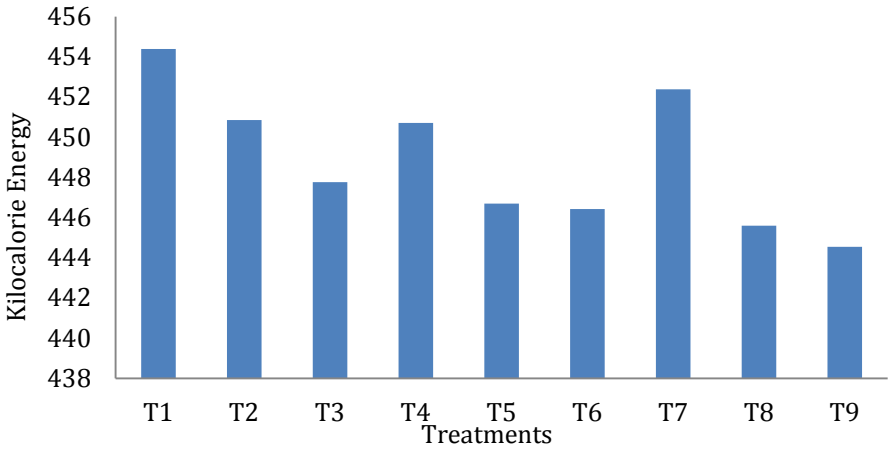

Fig. 2 Energy analysis of each treatment

Color

The second treatment using cassava flour 50% and wheat flour 50% in the temperature of 170 °C scored 4 out of 5, which was the highest mark. Conversely, the ninth treatment using cassava flour 100% without using wheat flour in the temperature of 180 °C scored 3.37 out of 5, which was the lowest mark. The changing score was because the cookie's color changed. Baking cookies in a temperature of 160 °C gave a pale color, in a temperature of 180 °C the cookies had a dark color, and in a temperature of 170 °C the outcome was a pleasing golden color, which was the favorite cookie for participants. The cookie's color changed because of the changing temperature.

Texture

Figure 3 shows that the second treatment using cassava flour 50% and wheat flour 50% at a temperature of 170 °C was the highest mark of 4 out of 5, and the ninth treatment using cassava flour 100% without using wheat flour at a temperature of 180 °C was the lowest mark of 3 out of 5. The changes in marking were because the temperature of 160 °C and 180 °C made the cookies crack. Baking cookies in a temperature of 170 °C resulted that a cookie was red and shinier than both of the others. The changes of food texture were caused by the changes of temperature; in addition to, the changes of texture also made cassava flour changes in color and brightness.

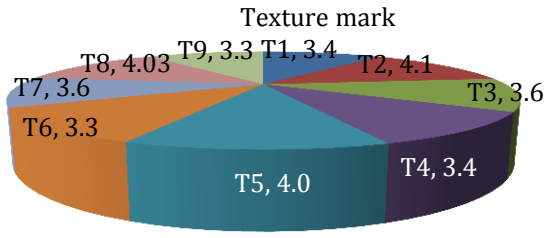

Fig. 3 Evaluation on texture of cookie in each treatment

The results above showed that the second treatment that used cassava flour 50% at temperature of 170 ^{o}C was the best treatment out of the nine treatments because in this treatment pH value, moisture, ash, protein, fat, and energy were in appropriate level when compared to the standard of Hard biscuit or Hard Cookie that contains pH 7.6, humid 2.6%, ash 2%, protein 7.6%, lipid 10% and carbohydrate 77.8%. Moreover, in outcomes of sensory testing of color, texture, odor, sweet flavor, hardness, and crispness, the second treatment was the favorite one for participants, followed by first and third treatments. However, treatment nine, which used 100%

cassava flour at a temperature of 180 ^{o}C was the least appropriate treatment of all because this treatment contained the lowest protein and energy, and it was also the least favorite treatment from the participants' point of view.

CONCLUSION

Using more than 50% of cassava flour in cookie production produced less quality cookies. In cookie processing, the temperature range from 160 to 180 ^{o}C could affect chemical properties such as humidity, proteins and lipids and also lower the calories. This problem showed that the higher the temperature we used the lower quality of chemical properties the cookie had. 50 % of cassava flour baked at a temperature of 170 °C for 8 minutes should be recommended and used in cookie production.

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Research article

Assessment of the Shelf-life of Cucumber under Three Low Cost Storage Methods

SONGHAK PHAL*
Royal University of Agriculture, Phnom Penh, Cambodia
Email: songhakphal@rocketmail.com

THIDA KEM
Royal University of Agriculture, Phnom Penh, Cambodia

VOUCHSIM KONG
Royal University of Agriculture, Phnom Penh, Cambodia

BORARIN BUNTONG
Royal University of Agriculture, Phnom Penh, Cambodia

THONG KONG
Royal University of Agriculture, Phnom Penh, Cambodia.

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Abstract Cucumbers, harvested from Saang district, Kandal province, Cambodia were wrapped with low density polyethylene (LDPE) or high density polyethylene (HDPE) or in the open before they were stored in two types of storage conditions (evaporative cooling system (ECS)(80 USD), designed in the faculty of Agro-Industry, Royal University of Agriculture and in ice foam box (2.375 USD) filled with an amount of ice for cooling the cucumbers or in ambient condition (1.5 USD) in order to seek for appropriate and low cost methods to maintain the quality and enhance shelf-life of cucumbers. The shelf-life of cucumbers were determined based on weight losses, fruit shriveling, changes in color, titratable acidity (TA) and total soluble solids (TSS). Of the storage treatments, keeping fruit in both type of polyethylene film in ice foam box filled with husk-covered ice was the most effective way in reducing weight loss, maintained higher TA, TSS and the color changes as well as retarding fruit shriveling than that of the other treatments. Fruit stored in the open at ambient condition had the highest weight losses and shortest shelf-life due to rapid yellowing and shriveling. Regarding the cost of storage, ice foam box was significantly reasonable accepted in term of gaining better quality (benefit) comparing to the higher weight losses and unmarketable quality of other treatments.

Keywords cucumber, shelf-life, quality, evaporating cooling system, ice foam box

INTRODUCTION

Cucumbers (*Cucumis sativus*) of Cucumbitaceae family are one of the famous vegetable consumed freshly and as processed food in Cambodia. The fruits were harvested in immature stage based on the fruit size and skin color. They are used as salad, fresh slicing vegetable and pickling for daily diet (New Guyana Marketing Corporation, 2004). These fruits normally suffer high moisture losses, rotting, and change color quickly from green to yellow during storage. They are also bruised or injured under mechanical forces in case of improper handling which cause of short shelf-life and unmarketable quality after harvesting. Improper storage condition of cucumbers both at low temperature (below 10°C) and at ambient temperature rapidly results in water loss, decay, and yellowish color in several days that lead to unacceptable quality in the market (Mikal, 2010).

So far, to improve the storage condition of many vegetables to recast in Cambodia, evaporating cooling system (ECS) has been set up and introduced to the vegetable grower for

preserving the vegetables quality. The system has shown the effectiveness in many aspects since its temperature is decreased lower than the ambient at least 3 to 5°C while its RH is higher than ambient from 20 to 40%. It is very effective to extend the color changes and decay during storage time of vegetable such as chili, eggplant and leafy vegetables (Buntong, 2010). However, the combination treatment with film wrapping or other modified packaging materials were not fully tested for such kind of cucumber vegetable. It is known whether vegetables stored in low or high density polyethylene can maintain the shelf-life and quality of vegetable better than those stored in ambient temperature because of polyethylene films that can acts as moisture and oxygen barrier and delay the respiration of the vegetables (ITDG, 2010). As a result, cucumbers can be stored longer than those in the ambient condition for a few days (Buntong, 2010).

In this study, in order to seek for appropriate and low cost methods to maintain the quality and enhance shelf-life of cucumbers, cucumbers harvested from Saang district were wrapped with either low density polyethylene (LDPE) or high density polyethylene (HDPE) or left in the open before they were stored in two types of storage conditions (evaporative cooling system (ECS), designed in the faculty of Agro-Industry, Royal University of Agriculture and in ice foam box filled with an amount of ice for cooling the cucumbers) or in ambient condition.

OBJECTIVE

The objective of this study was to find out the appropriate and low cost methods that effectively maintain the quality and prolong self-life of cucumbers.

METHODOLOGY

Fruit sampling

Cucumber (*Cucumis sativus)*, for the age about 45 days after planting, were harvested from Saang district and immediately brought to the postharvest laboratory located in the faculty of Agro-Industry, Royal University of Agriculture, Phnom Penh, Cambodia.

Storage materials and conditions

Initially, they were washed with the 100 ppm concentration of chlorine for eliminating microbial contaminations and preventing fungal infections; then sorted only for uniform size, maturation, color and non-injured cucumbers (FAPRT, 2011). Before storing the fruits in different containers (evaporating cooling system, ice foam box and the ambient condition), they were wrapped with low density polyethylene (LDPE) or high density polyethylene (HDPE) or in the open.

Evaporating cooling system (ECS), made from zinc and iron film and covered by wet tissues along with dropping-water system, to conduct heat that kept the temperature between 24-28 ^{o}C with relative humidity between 76-94%.

Ice foam box designed in faculty Agro-Industry is the low cost materials that can be used as storage equipment for maintaining cucumber quality. The ice foam box was filled with 21kg of ice and covered with rice husk to reduce ice melting with the temperature between 17-21 ^{o}C and relative humidity 60-70%. Husk rice is traditionally used for keeping ice from melting and easily find in local area. It is a good material to reduce the interaction between heat and cool air of ice in box that decrease melting and stabilize temperature cold (17 to 21 °C) and RH (60 to 70%). The husk rice have low water and moisture permeability, low value of equilibrium moisture content, low value of the coefficient of temperature conductivity (below 0.036 $W.m^{-1}.k^{-1}$), high resistance to damage of fungi (Valche et al, 2009). Ice foam box is the well-organized and effective equipment used for reducing moisture loss, color changes and decay as polyethylene was used in ECS condition for this study. In addition to storing cucumbers in ECS and ice foam box, fruits were also stored in ambient condition at (temperature at 28-29^{o}C and relative humidity at 80-86%).

Experimental design and treatments

Split plot design was applied in this research. The fruits were packed in Open, LDPE and HDPE and stored in different containers including ambient, ECS and ice foam box. The summary of treatments is as in table 1.

Table 1 Treatments of experimental cucumbers

Treatments	Packaging materials	Storage conditions	Replications
T_1	Open	Ambient	3
T_2		ECS	
T_3		Ice foam box	
T_4	LDPE	Ambient	
T_5		ECS	
T_6		Ice foam box	
T_7	HDPE	Ambient	
T_8		ECS	
T_9		Ice foam box	

Fruit analysis

Throughout the storage, all treatments were tested and recorded every two days with four parameters-weight losses (WL); color changes (a* and L value) done by using color reader CR-10; Titratable Acidity (TA) tested by titrating NaOH concentration with phenophtelenine and Total Soluble Solids (TSS) were tested by using refractometer. Recorded data were analyzed by using Microsoft Excel 2010.

Weight losses: Weight losses was determined by weighting and recording every 2 days for all treatments, calculated as a percent of the initial weight following equation 1.

$$WL\ (\%) = (W_o - W_i) / W_o \times 100 \quad (1)$$

Where W_o is the weight on the first day of storage and W_i is the weight in the tested day (Moalemiyan & Ramaswamy, 2012).

Color changes: Color reader CR-10 was used to assess external color of cucumbers. External color readings were taken on screen of color reader CR-10 before storing in equipment on the following day of observation. Individual fruit was measured at three point along the axis of the furit for three fruit in a replication.

Total acidity (TA): TA contents was determined by titrating NaOH concentration 0.1N along with phenophtelenine as indicator and calculated by following euquation 2.

$$C_{Total\ acidity}\ (g/L) = (V_{NaOH\ titration} \times F \times C_{NaOH} \times M) / V_{sample} \quad (2)$$

Where $C_{\text{total acidity}}$ is the concentration of acid in cucumber (g/L); V_{NaOH} is volume of sodium hydroxide; C_{NaOH} is concentration of sodium hydroxide of titration (N), and M is molecular weight of ascobic acid ($C_6H_8O_6$) (g/mole).

Total soluble solids (TSS): Total soluble solid was determined by using refractometer. The cucumber was extracted and its juicy part was put on the refractometer prism and read for its value of total soluble solid in Brix degree.

RESULTS AND DISCUSSION

Weight losses

An evaluation of the postharvest quality of cucumbers was conducted after the fruit had been stored in different conditions. Figures 1, 2 and 3 had shown that moisture losses of opened cucumbers in

the three conditions decreased orderly from 0 day to 10 days. Ambient lost 21% more than ice foam lost 17.75%, while ECS had RH higher than ambient (20-40%) and lost only 3.09% during 8 days with fewer changes for wrapped HDPE cucumbers. RH of ambient was lower than ECS, but higher than RH of ice foam box which caused possible higher weight loss (5.7%) for HDPE cucumber in ice foam box as ambient lost 0.95% in 10 days. However, water loss of wrapped LDPE cucumber of ambient condition dramatically rose (6%) as water loss of wrapped LDPE cucumber of ECS and ice foam box slightly changed when the temperature and RH of them was probable in the remaining of moisture contained in cucumber.

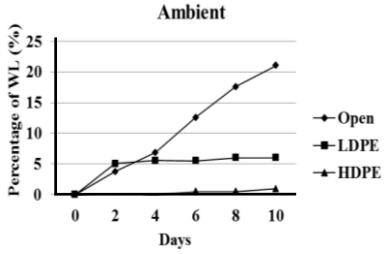

Fig. 1 Percentage of weight in Ambient

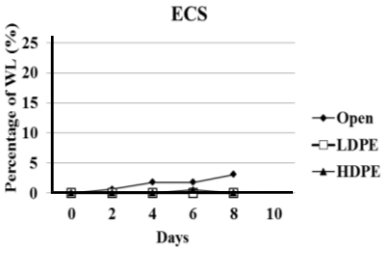

Fig. 2 Percentage of weight loss in ECS

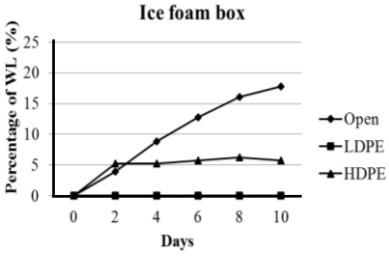

Fig. 3 Percentage of weight loss in Ice foam box

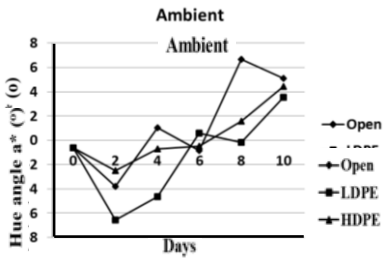

Fig. 4 a* value of cucumber stored in Ambient

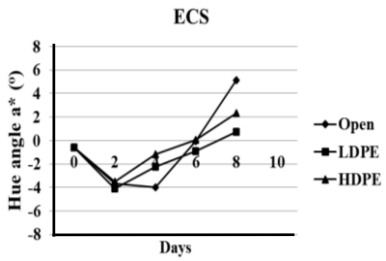

Fig. 5 a* value of cucumber stored in ECS

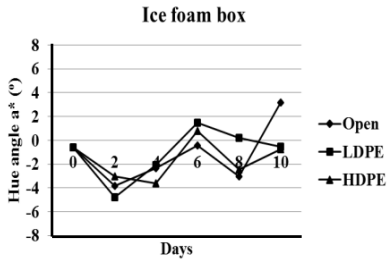

Fig. 6 a* value of cucumber stored in Ice foam box

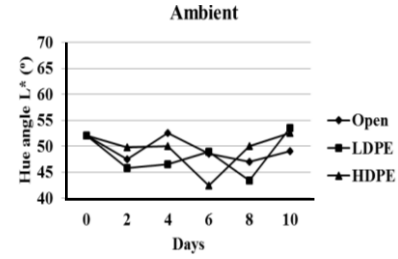

Fig 7. L value of cucumber stored in Ambient

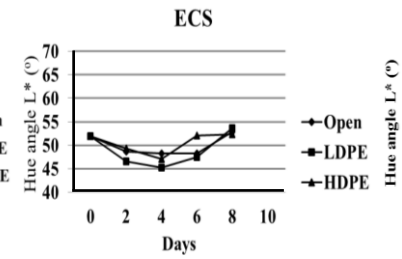

Fig 8. L value of cucumber stored in ECS

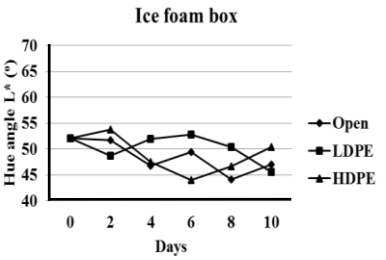

Fig 9. L value of cucumber stored in Ice foam box

Color changes

Peel color of cucumber originally remained dark green at ambient and in ECS after 6 days of storage. Although the previous stages retained original color, its color kept changes very quickly becoming yellow as shown in the fig. 4 and 5. For ice foam box, cucumber peel color was relatively dark green from the initial day to the end of storage period, with a bit changes a*=1.46, 0.81 for LDPE and HDPE respectively on the 6th day of storage. The open cucumber stored in ice foam box was in yellow (color a*=3.17) on the 10th day while others remained green color.

The L value of color's of cucumber at Ambient and Ice foam box get result of insignificant change in color L comparing to original brightness color L= 52, accept for ECS condition. It is more changed in the L value that reached to L= 48.27, 45.29, 47.12 for Open, LDPE, HDPE respectively at 4th day storage.

Total acidity (TA) and total soluble solids (TSS)

Changeable decline of TA value (1.26-0.88 g/L) of opened cucumbers in each condition had no significant differences (0-6 days). ECS had higher RH (20-40%) and lower temperature (1-2 °C) than ambient that leaded to senescence very quickly and its TA declined in 1.31 g/L at 8 days. HDPE cucumbers in ambient condition and ice foam box had similar TA value (1.26-0.80 g/L) in 4 days, then TA of ambient values 1.05 g/L, when TA of ice foam box values 0.73 g/L developed to senescence in 10 days. TA of HDPE cucumbers in ECS were slightly different in TA value (1.26-0.83 g/L) in 6 days then it would reach to aging when its TA was 1.18 g/L in 8 days. Low density polyethylene, which was a good moisture barrier and had high gas permeability resistance, wrapped cucumbers up. They were remarkably varied in the three conditions. In 6 days, TA of ECS dropped sharply in 0.94 g/L which was higher than TA of ice foam box (0.66 g/L), when the lowest TA of ambient values was 0.71 g/L in 4 days.

Total soluble solids interactively changed and slowly increased in all fruit treatments stored in three equipments (shown in fig. 13, 14 and 15), but fruit stored in ice foam box had the highest TSS value. TSS value increased higher in ambient-stored fruit as in open and as followed by HEPD. LEPD showed the minimal increase in TSS value of stored-fruit with ECS and ice foam box.

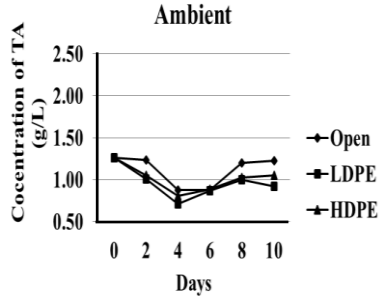

Fig. 10 Concentration of TA of stored-cucumber in Ambient

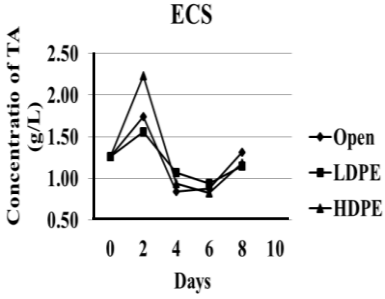

Fig. 11 Concentration of TA of stored-cucumber in ECS

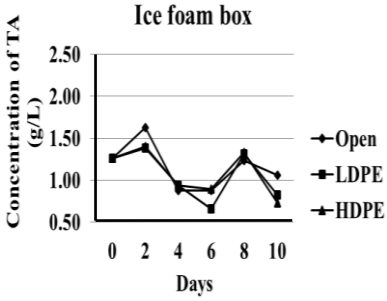

Fig. 12 Concentration of TA of stored-cucumber Ice foam box

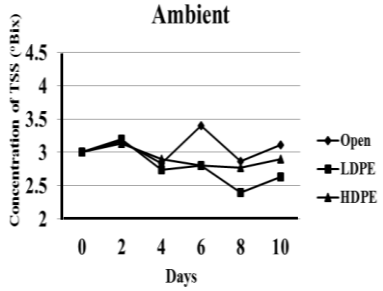

Fig. 13 Concentration of TSS of stored-cucumber in Ambient

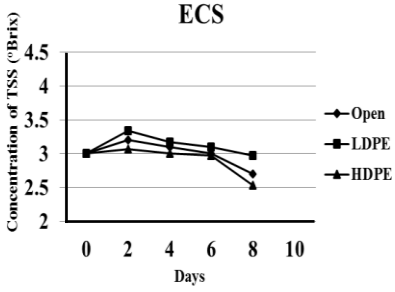

Fig. 14 Concentration of TSS of stored-cucumber in ECS

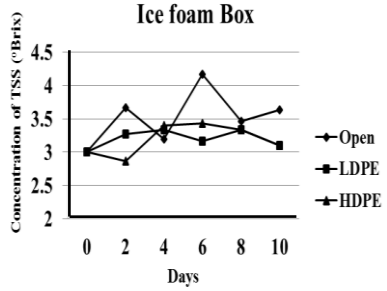

Fig. 15 Concentration of TSS of stored-cucumber in Ice foam box

CONCLUSION

Wrapped-cucumber with LDPE was effective when used with ice foam box and ECS for reducing water losses. However, ambient was ineffective in storing fruit which made both moisture losses and color changes remove high. ECS and ambient could maintain water losses from wrapped-cucumber with LDPE, but it could not maintain color changes, TSS increase or TA decrease that developed to senescence very fast. Water losses, color changes, TA, and TSS of wrapped-cucumber of LDPE stored for 10 days in ice foam box was better than the ECS and ambient condition. According to the result and discussion, ice foam box used in this storage method was

effectively available to buy, convenient for storing fruit, and cost-saving (only 2.375 USD per set).

ACKNOWLEDGEMENTS

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Research article

Passive Sampling Approach to Identify Contaminants in a Tropical Freshwater River System

TATIANA KOMAROVA*
Queensland Health Forensic and Scientific Services (QHFSS), Brisbane, Australia
Email: Tatiana_Komarova@health.qld.gov.au

CHULEEMAS BOONTHAI IWAI
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

ATCHARAPORN SOMPARN
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

NATSIMA TOKHUN
Faculty of Agriculture, Khon Kaen University, Khon Kaen,Thailand

BARRY NOLLER
Centre for Mined Land Rehabilitation (CMLR), Sustainable Minerals Institute, The University of Queensland, Brisbane, Australia

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Abstract This study aimed to understand labile metal distribution and water quality associated with agro-industry and farming activities along the Namphong River, a sub catchment of the Mekong River located in NE Thailand. An integrated sampling program was designed to identify the range of potential contaminants in the Namphong River by incorporating active or grab sampling along with passive sampling using the diffuse gradients in thin films technique (DGTs) for the bio available heavy metal forms, field measurement of pH, electrical conductivity, temperature and dissolved oxygen and laboratory-based measurement of total solids, total alkalinity, hardness, nutrients and dissolved organic carbon concentration together with heavy metals (total and filtered (< 0.45 µm) fractions). The DGTs were deployed at 10 different sites along approximately 50 km of the Namphong River for 4 days to enable sufficient integrative sampling of heavy metals. One liter of water samples were collected from the sites before and after deployment of the DGTs. Although total and filtered (<0.45 µm) concentrations of cadmium, chromium, copper, lead and zinc in the Namphong River from active sampling significantly exceeded the trigger values of water quality guidelines for protection of freshwater aquatic species, the concentration of metals estimated from DGT data indicated more accurately that the bio available metal levels were below the trigger values and that there were no predicted effects on aquatic species. The agro-industrial area (pulp and sugar mills) was a major potential source of contamination of the Namphong River associated with increased levels of heavy metals (aluminium, chromium, cobalt, iron and manganese) but diluted to insignificant levels in the Namphong River. The release of copper, nickel and lead to the downstream Namphong River occurred in the area of rice and mixed vegetable cultivation and was most likely related to extensive pesticide use. The outcome of this study will help to develop more focused monitoring of specific toxic heavy metals at particular locations on the Namphong River.

Keywords active and passive sampling, aquatic ecosystem, DGT, heavy metals, bioavailability

INTRODUCTION

The NE part of Thailand is the location of extensive wet-dry agricultural activities with major use

of irrigation from dam storage and some supplementation of water supply from groundwater sources. The rivers systems of NE Thailand are also part of the sub-catchment of the Mekong River (Fig. 1). One of the sub-catchments of the Chi River is that of the Namphong River. Below the Ubolratana Dam there are extensive agro-industry and farming activities along the Namphong River which flows to the Chi River and via the Mun River to the Mekong River. A key question was the extent and the effects on aquatic species of heavy metal additions to the river system that result from the collective of agricultural activities. River water may also be used for human consumption and recreational activities.

The Diffusive Gradients in Thin-films (DGT) technique uses passive sampling to give an integrated concentration measurement (Davison and Zhang 1994). The DGT technique was previously described for measurement of labile metal forms in water and predicting their toxicity to aquatic biota (Komarova et al. 2012). In contrast, active sampling collects a grab sample at a fixed time. This paper uses passive sampling techniques to measure dissolved inorganic compounds in waters at sub-nanogram per liter levels. "Passive" samplers are defined as human-made devices where sample collection is completely passive. The DGT technique is designed to accumulate labile metal species in environmental systems including from water (Davison and Zhang, 1994; Davison et al. 2000; Zhang and Davison, 1995; Zhang and Davison, 2000).

OBJECTIVE

This study aimed to understand the labile metal distribution associated with agro-industry and farming activities along the Namphong River a sub catchment of the Mekong River located in NE Thailand. The study addressed the following questions: (i) to compare passive DGT and active sampling techniques for heavy metals and associated water quality in the Namphong River water body for different locations; (ii) to compare labile heavy metal concentration data from the DGT technique with water quality guidelines that can be incorporated into the trace metal monitoring programs in water together with traditional methods and replace them in the future; and (iii) to use DGT analysis for labile metals to assess bioavailability to aquatic freshwater species.

METHODOLOGY

The DGT technique employed an ion exchange resin (Chelex-100) that was immobilized in a polyacrylamide gel (the binding or resin gel), to exchange analytic species from solution (Davison and Zhang 1994). Chelex-based resins can be used for simultaneous collection of many metals in water including aluminium (Al), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni) and zinc (Zn) (Komarova et al. 2012). The binding gel was separated from the bulk solution by a permeable polyacrylamide gel (the diffusive gel) and a solution diffusive boundary layer.

An integrated sampling program was designed to identify the range of potential contaminants in the Namphong River by using diffuse gradients in thin films technique (DGTs) for the passive (integrated) sampling of labile heavy metal forms, field measurements of pH, electrical conductivity (EC), temperature and dissolved oxygen (DO) concentration and active sampling for total solids (TS), total alkalinity (mg/L $CaCO_3$), hardness (mg/L $CaCO_3$), nutrients, dissolved organic carbon (DOC) and heavy metal concentrations for the total and filtered (< 0.45 µm) fractions. DGTs were deployed for 4 days from 19-23 January 2012 to accumulate labile heavy metals at 10 different sites along approximately 50 km of the Namphong River (Fig. 1).

One liter of grabbed water samples were collected before and after DGT deployment; the mean concentrations of metals were calculated from the measured parameters. All measurements on the active water samples were undertaken in the field or at the Division of Land Resources and Environment, Department of Plant Sciences and Agricultural Resources, Faculty of Agriculture Khon Kaen University. Following deployment, DGTs were sent by air courier to the Queensland Health Forensic and Scientific Services (QHFSS), Inorganic Chemistry Division laboratory at Coopers Plains, Australia to separate the gels and elute the accumulated analyte from the binding

gel using dilute nitric acid. The concentrations of metals in the eluant were then determined by inductively-coupled plasma mass spectrometry (ICPMS). The time-averaged concentration of dissolved metal species in the bulk solution, C, is then calculated using Eq. (1), which is derived from Fick's first law of diffusion (Zhang and Davison, 1995): M is the accumulated mass of a metal on the binding gel; Δg is the thickness of the diffusive gel, D is the diffusion coefficient of a specific metal in the diffusive gel, t is the deployment time, and A is the surface area of the diffusive gel exposed to the bulk solution.

$$C = M \Delta g / D t A \quad (1)$$

The assessment of water quality for the protection of the aquatic ecosystem made use of a combination of analytical methods based on following the Australian ANZECC/ARMCANZ (2000) decision tree process for assessing metal toxicity in water. An initial step was to calculate site-specific trigger values for metals by using a correction for hardness, calculated from the calcium plus magnesium concentrations expressed as mg/L $CaCO_3$, to the default ANZECC/ARMCANZ (2000) guideline value. This more accurately predicts aquatic metal toxicity which decreases with increasing water hardness as soluble metal is precipitated. The next step in the decision tree process used the measurements of metals in labile or bioavailable forms and metals in particulate and insoluble colloidal fractions that could be measured through filtration (<0.45 µm membrane) to predict the bioavailable fractions of metals in waters. Thus DGT samplers offered an alternative to conventional water sampling techniques for measuring labile trace metals.

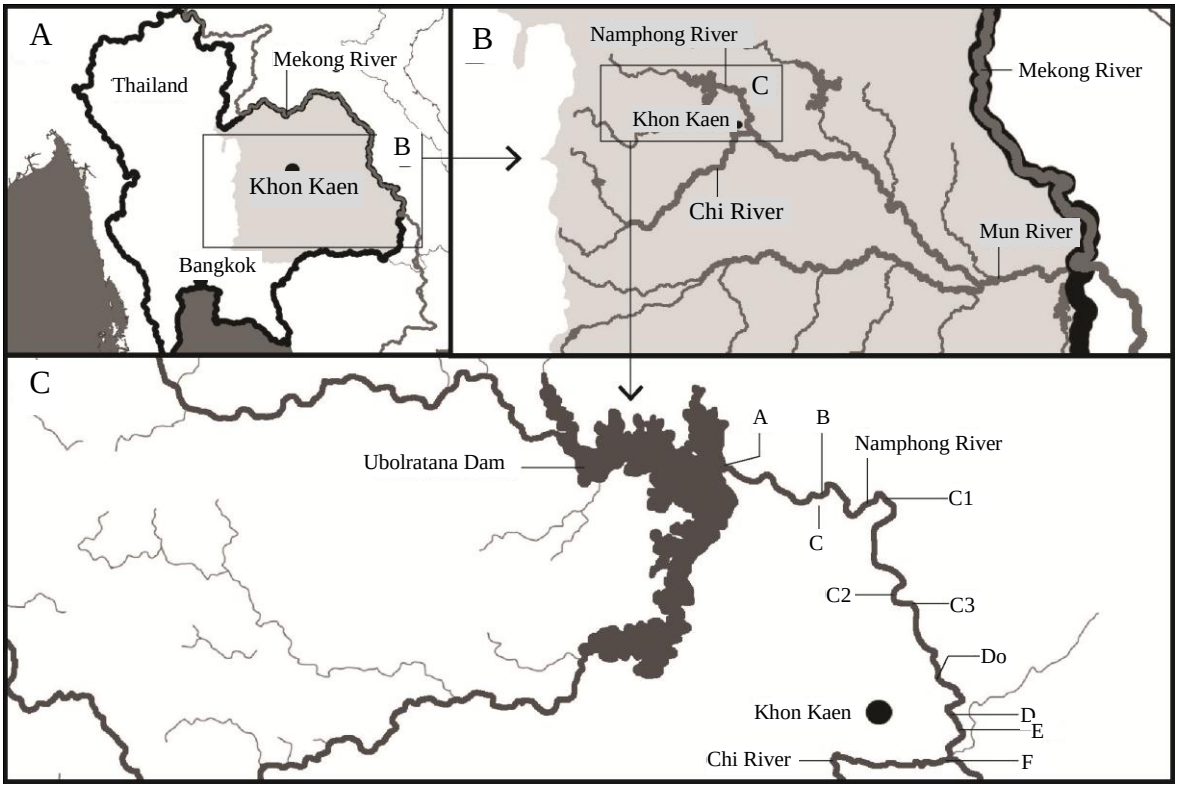

Fig. 1 Location of study site in the Mekong River basin NE Thailand (Maps A and B) and sampling sites along the Namphong River (Map C)

Sites A – Ubolratana Dam; B – fish cage (in-river cage aquaculture for Tilapia production); C – pulp/paper industrial plant (discharge via tributary to main river); sugar industrial plant; C2 cucumber culture; C3 corn culture; Do vegetables culture; D vegetable culture and paddy fields; E vegetables culture; and F – vegetables culture, residential discharge to Chi River just upstream from confluence with Namphong River

RESULTS AND DISCUSSION

Tables 1 and 2 give the water quality data (mean (±sd) of before and after DGT sampling) for the 10 sampling sites along the Namphong River below the Ubolratana dam (Fig.1).

Table 1 Field water quality data (mean of before and after DGT sampling)

Sampling site	pH	EC (µS/cm)	Temp (^{0}C)	DO (mg/L)	Sat (%)
A. Ubolratana	7.0	94	23.0	6.28	76.4
B. River cage Aquaculture	7.0	86	23.0	5.45	62.8
C. Pulp mill	7.7	1250	25.0	5.88	75.1
C1. Sugar mill	7.3	97	25.0	5.29	70.3
C2. Cucumber culture	7.4	80	23.0	7.65	91.4
C3. Corn culture	7.4	99	23.0	7.31	90.1
Do. Vegetable culture	7.3	102	25.0	5.46	69.6
D. Vegetable culture and paddy field	7.3	106	25.0	5.75	70.5
E. Vegetable culture	7.2	109	25.0	5.54	69.6
F. Vegetable culture	7.3	110	25.0	5.47	69.7

Table 2 Water quality data (mean±sd of before and after DGT sampling)

Sampling site	TS (mg/L)	TDS (mg/L)	Alkalinity (mg/L $CaCO_3$)	Hardness (mg/L $CaCO_3$)	DOC (mg/L)	Total N (mg/L)	NO_3^- (mg/L)
A. Ubolratana	53± 2	46±3	18±1	64± 4	2.3	23±4	1.8±0.2
B. River cage aquaculture	80± 4	47±1	31±1	66± 4	1.9	26±4	2.8±0.3
C. Pulp mill	1790±80	672±7	131±1	227± 5	2.3	28±7	2.5±0.5
C1. Sugar mill	360±20	52±0	24±0	70± 7	3.4	19±8	3.1±0.2
C2. Cucumber culture	107±10	47±4	29±7	69± 4	1.9	23±8	2.9±0.3
C3. Corn culture	80± 0	51±3	12±0	67± 5	1.8	12±2	2.0±0.1
Do. Vegetable culture	133±19	55±0	18±1	65± 7	1.3	13±2	1.9±0.6
D. Vegetable culture and paddy field	120± 0	55±0	23±3	69± 3	3.6	12±4	3 ±1
E. Vegetable culture	150±19	57±0	30±2	61±13	2.9	12±4	2.2±0.7
F. Vegetable culture	150±19	57±0	30±0	66± 7	3.1	7 ±0	2.4±0.1

Generally good water quality was found. The Namphong River water pH (range 7.0-7.4) and hardness (range 64-70 mg/L as $CaCO_3$) were consistent and electrical conductivity showed slight increase in proceeding downstream, apart from Site C (pulp mill) which was a tributary receiving discharge to the main river and indicated that groundwater may be used in the processing. Sites C and C1 also showed that increased total solids in water were associated with these agro-industries. Nitrate was consistent travelling downstream while dissolved organic carbon (DOC) tended to increase downstream and total-nitrogen decreased downstream (Table 2). Total and filterable phosphorus (ranges 0.33 - 0.39 mg/L and 0.03 - 0.05 mg/L respectively, excluding Site C) showed no change from upstream to downstream Namphong River.

The total and filtered (<0.45 µm) concentrations of cadmium, chromium, copper, lead and zinc in the Namphong River were measured from before and after sampling and significantly exceeded the ANZECC/ARMCANZ (2000) the hardness-adjusted trigger values of water quality guidelines (Table 3). However, the concentration of metals estimated from the DGT data were below the hardness-adjusted trigger values (Table 3) and indicated (more accurately) that the labile (bioavailable) metal concentrations in the Namphong River were not significant to freshwater

aquatic biota. The industrial area (Site C - pulp and sugar mills) was a major potential source of contamination of the Namphong River associated with increased levels of heavy metals (aluminium chromium, cobalt, iron and manganese). Confirmation that groundwater was being used in the pulp mill (Site C) was indicated by the increased total alkalinity, hardness, electrical conductivity (Tables 1 and 2) and the presence of iron and manganese from the total, <0.45 µm filtered and DGT concentration data (Table 3 and Fig. 2). Comparison of the DGT and active sampling (<0.45 µm filtered) data for manganese (Fig. 2) at Site C suggested that there was a high short term release of manganese into the tributary of the Namphong river during DGT deployment. Active sampling technique data (Fig. 2) showed only a slight elevation in manganese concentration as sampling was undertaken before and after the release.

Table 3 Mean concentrations of heavy metals in Namphong River and trigger values for 95% level of aquatic species protection (ANZECC/ARMCANZ 2000)

Metal	Cmax (µg/L) DGT conc.	Cmin (µg/L) Total conc.	Cmin (µg/L) Filtered (0.45 µm) conc.	Trigger value (µg/L) 95% of aquatic species protection (adjusted for hardness)
Cd	0.03	57.9	11.5	0.5
Co	0.2	0.3	0.1	ID
Cr	0.2	58.7	48.0	2.5
Cu	1.5	42.2	19.2	3.5
Fe	34.3	470.0	77.0	ID
Pb	0.5	64.0	28.0	13.6
Zn	3.8	223.0	32.2	20.0

ID; insufficient data to derive reliable trigger value

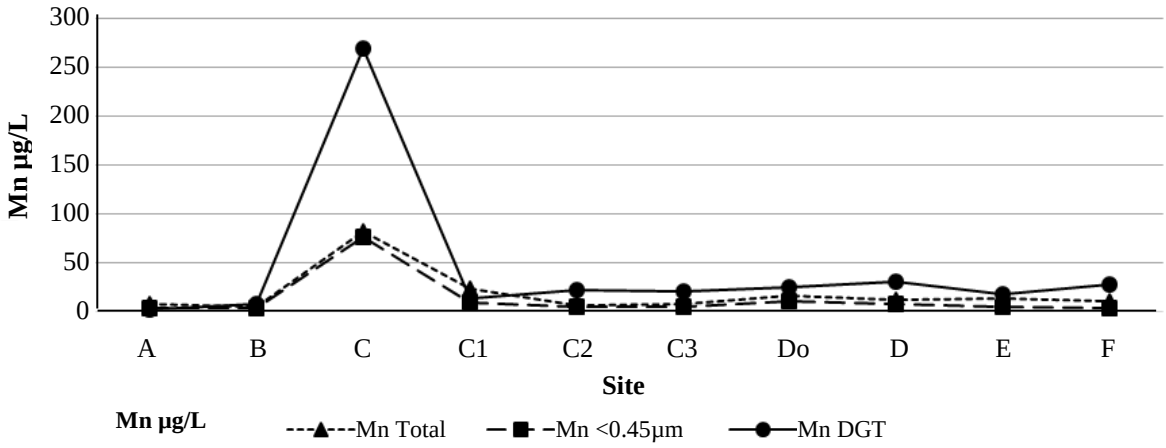

Fig. 2 Manganese (µg/L) in total, 0.45 µm filtered water fraction by active sampling and passive DGT technique from the Namphong River

The release of copper, nickel and lead in the Namphong River occurred in the area of rice and mixed vegetable cultivation (Sites Do − F) and was most likely related to extensive pesticide uses (metals in the pesticides used such as carbamates).

The overall finding is that there is little effect on the water quality of the Namphong River from upstream to downstream and taking into account of dilution removing observed additions of suspended solids and metals from the major agro-industrial activities located upstream. In addition the Namphong River water is considered safe for human consumption and recreational activities based on comparison with relevant guidelines.

CONCLUSION

Active and passive sampling methods produce similar trends with results when used simultaneously at the same sites. DGTs were shown to be effective for measuring ultra-trace levels of the labile fraction of heavy metals in water. DGTs offer an extra cost effective and sensitive method for the independent evaluation of environmental sites. DGTs help to estimate the actual levels of toxicities of metals under the specific environmental conditions and measure time integrated average water concentrations of metals over the deployment time where active sampling represents single points in time. Concentrations of Cd, Cr, Cu, Pb, and Zn in the Namphong River by active sampling significantly exceeded the hardness-adjusted ANZECC/ARMCANZ (2000) trigger value for 95% protection of aquatic species. Concentration of metals estimated from DGT data were far below the trigger values and indicated more accurately that there were no predicted toxicity effects on aquatic biota in the Namphong River from dissolved metals. Although the industrial area (pulp and sugar industries) is a major source of contamination of the Namphong River with heavy toxic metals (aluminium, cobalt, chromium, iron and manganese), there is sufficient dilution from the Namphong River to give safe levels downstream for protection of aquatic species. The outcome of this study will help to develop more focused monitoring of specific toxic heavy metals at particular locations on the Namphong River.

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Research article

Changes in Soil Nitrous Oxide and Carbon Dioxide Dynamics after the Application of Digested Liquid Cattle Manure

TOMONORI FUJIKAWA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: t3fujika@nodai.ac.jp

MASATO NAKAMURA
National Institute for Rural Engineering, National Agriculture and Food Research Organization (NARO), Tsukuba, Japan

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Abstract The aim of this study was to clarify the changes in N_2O and CO_2 emission from the soil surface, their concentrations in soil gases, and gas diffusion fluxes after application of digested liquid manure (DL) produced by anaerobic digestion of cattle manure slurry. N_2O emission increased more and faster after application of DL compared to after the application of conventional inorganic fertilizer. The N_2O emission rate from the DL was 0.25% of the applied nitrogen. CO_2 emission after the DL application also increased, and the CO_2 emission ratio from the DL was 33% of the applied C. Soil N_2O concentration increased after DL application. The highest soil N_2O concentration occurred earlier than the largest N_2O emission. The increase in CO_2 concentrations near the surface was small. The largest N_2O diffusion flux was observed near the surface, and a negative flux was observed in deeper layers 14 days after DL application. The difference in the CO_2 flux between deeper and surface layers flux was smaller than that in the N_2O flux, which suggests that the contribution of CO_2 generation in deeper layers is larger than that of N_2O.

Keywords Methane fermentation, soil gas concentrations, gas diffusion, greenhouse gases

INTRODUCTION

Anaerobic digestion of livestock slurry can potentially reduce greenhouse gas (GHG) emission and sustainably generate electrical and heating energy (Rico et al., 2011). However, digested liquid manure, which is a by-product of anaerobic digestion, contains a large quantity of organic matters. Treatment of wastewater containing the digested liquid manure is expensive in terms of energy and chemicals (Massé et al., 2007). The digested liquid manure contains high levels of carbon and nitrogen compounds and other nutrients that can promote plant growth. Application of this liquid to agricultural fields as liquid fertilizer would therefore be an efficient use of the digested liquid manure, but the environmental effects of this application, and especially the emission of GHGs need to be better understood.

In a farmland soil, GHGs such as N_2O and CO_2 are generated by the decomposition of the applied nitrogen or carbon compounds by soil microorganisms, and the generated gases diffuse through the soil profile following concentration gradients until the gas is emitted from the soil surface into the atmosphere. This scenario indicates that the emission of the gases from the soil surface depends on not only the total amount of generated gases in the soil but also the location (i.e. depth) of the generation and gas diffusion fluxes.

The aim of this study were to clarify the changes in N_2O and CO_2 emission from the soil surface, the corresponding changes in their concentrations and gas diffusion fluxes in the soil after the application of digested liquid manure produced by digestion of cattle manure slurry.

METHODOLOGY

Site description and experimental setup

Samples of digested liquid manure produced by anaerobic digestion mixture of dairy cattle manure slurry and vegetable scraps at the Yamada Biomass Plant in Katori City, Chiba Prefecture, Japan (Nakamura et al., 2007) was obtained. The digested liquid manure used in the present study was collected in September 2007. Approximately half of the nitrogen in the digested liquid manure is organic nitrogen, and the remainder is NH_4-N, with a very small NO_3-N content. In this study, the digested liquid manure without any dehydration or filtration was used. The field experiments were conducted in an experimental field at the National Institute for Rural Engineering in Tsukuba City, Ibaraki Prefecture. This field was classified as Andosol soil, and the surface soil was light clay (LiC). This field had not been cultivated for more than 3 years prior this experiment.

A total of 4 plots (1 m × 2 m) in the field were established. Based on previous standard fertilizer application rate that has been used around this site, we applied 24 g N m^{-2} (7800 cm^3 m^{-2}) of the digested liquid manure to the surface soil in the first plot (hereafter, the DL treatment). In the second plot, $(NH_4)_2SO_4$, which included the same total amount of nitrogen as in the DL treatment, was applied (hereafter, the conventional fertilizer [CF] treatment). In the third plot, we added the same amount of $(NH_4)_2SO_4$ used in the CF treatment, but added water equal to the amount included in the digested liquid manure; hereafter, we refer to this as the conventional fertilizer plus water (CW) treatment. We also included a non-fertilized plot (hereafter, the NF treatment) as the control. All three treatments were applied in October 2007. In the DL, CF, and CW treatments, $Mg_3(PO_4)_2$ and KCl were also applied to prevent P or K deficiency from affecting the results. Japanese mustard spinach (Komatsuna: *Brassica rapa* var. *perviridis*) was sown 7 days after the fertilizer application. The komatsuna plants were harvested after 57 days. The field was not irrigated, and rainfall during the growth period totaled 169 mm which is normal for the study area; thus, the soils were neither excessively dry nor flooded. The yield of komatsuna was highest in the DL treatment, at 1900 g m^{-2} (9.1 g N m^{-2}). The plants absorbed 37% of the applied nitrogen in this treatment. The yield in the CF treatment (890 g m^{-2}) was smaller than that in the CW treatment (1800 g m^{-2}). These differences appear to have resulted from a water shortage during the early growth stages suggested by Fujikawa and Nakamura (2010).

Measurements

Emissions of N_2O and CO_2 from the soil were measured surface using the closed-chamber method (Rolston and Moldrup, 2002). Daily measurements were completed between 09:00 to 11:00 h. Three collars were installed in each plot. N_2O and CO_2 concentrations in the sampled gas were analyzed using a GC-8A gas chromatograph (Shimadzu, Kyoto, Japan) with an electron capture detector and a GC-14A gas chromatograph (Shimadzu) with a thermal conductivity detector, respectively. Hutchinson and Livingstone (2002) estimated the gas emission flux (q; g N m^{-2} h^{-1} for N_2O; g C m^{-2} h^{-1} for CO_2) using the slope of the change in gas concentration in the chamber (a; m^3 m^{-3} h^{-1}), the height of the gas chamber (h; 0.20 m), the ratio of nitrogen mass to N_2O mass or carbon mass to CO_2 mass (s; 28/44 for N_2O; 12/44 for CO_2), the density of each gas at 273.15 K (ρ; g m^{-3}), and the temperature (T; K):

$$q = \left(\rho \cdot \frac{273.15}{T} \right) \cdot a \cdot h \cdot s \qquad (1).$$

Cumulative gas emission (Q; g N m^{-2} for N_2O; g C m^{-2} for CO_2) in the DL, CF, and NF treatments were calculated based on the assumption of linear changes between consecutive measurements:

$$Q = \sum_{i=1}^{n} \left(\frac{1}{2} \times \Delta t_i \times \left(q_{i-1} + q_i \right) \right) \qquad (2).$$

where q_i is the ith measurement flux, Δt_i is the time interval between measurements i and i - 1, and n is the total sampling time. The increase in emission of each gas as a result of fertilizer application (Q') was calculated by subtracting Q in the NF treatment from Q in the DL and CF treatments, and the nitrogen and carbon emission rates were estimated by dividing Q' by the amount of nitrogen or carbon (respectively) in the applied fertilizer.

Soil gas was collected using the stainless-steel gas sampling pipes described by Fujikawa et al. (2000). Soil gas samples (10 cm^3) from around the gas inlets were removed from the pipes using a syringe. The N_2O and CO_2 concentrations in the soil gases were quantified using the gas chromatographs, as described above.

Undisturbed 100 cm^3 soil cores were collected to determine the gas diffusion coefficient of each soil layer. The soil gas diffusion coefficient for O_2 was quantified using the non-steady-state method suggested by Osozawa and Hasegawa (1995). Relative gas diffusivity (D/D_0) was calculated by dividing the O_2 gas diffusion coefficient of the soil (D) by that in the atmosphere (D_0). The gas diffusion coefficient of each gas (D_a) was estimated by multiplying the relative gas diffusivity by the diffusion coefficient in the atmosphere for each gas (N_2O = 0.0514 m^2 h^{-1}, CO_2 = 0.0756 m^2 h^{-1}) as suggested by Rolston and Moldrup (2002).

The gas diffusion flux (q_d) in the soil was calculated by multiplying the gas diffusion coefficient (D_a; m^2 h^{-1}) by the gas concentration gradient, which was obtained by dividing the difference in gas concentrations by the distance between two measurements at adjoining depths:

$$q_d = -\left(\rho \cdot \frac{273.15}{T}\right) \cdot s \cdot \frac{C_u - C_d}{z_u - z_d} \cdot D_a \qquad (3).$$

where C_u and C_d are the gas concentrations at depths of z_u and z_d, respectively, where u and d refer to the upper and deeper soil layers, respectively. The datasets for the calculation of q_d are shown in Table 1. The values of D_a of the samples obtained 3 days after the fertilizer application were used for q_d after 7, 14 and 21 days and those of the samples obtained 36 days after the application were used for q_d after 36 days.

Table 1 Datasets of z_u, z_d and Da for the calculation of the gas diffusion flux (q_d) in the soil

Depth of q_d (cm)	z_u (cm)	z_d (cm)	Depth of D_a* (cm)
- 2.5	- 5**	0**	(atomosphere***)
2.5	0**	5	0 to 5
7.5	5	10	5 to 10
12.5	10	15	10 to 15
22.5	20	25	20 to 25
32.5	30	50	30 to 35
42.5	30	50	40 to 45

**: Depth of the undisturbed samples using for the measurement of D_a*
***:The atmosphere above the soil surface was also sampled using a syringe.*
****: D_a at -2.5 cm is gas diffusion coefficient in the atmosphere (D_0)*

RESULTS AND DISCUSSION

Emissions of N_2O and CO_2

One week after fertilizer application, a strong increase in N_2O emission was observed in DL. The increase of N_2O emission were also observed in CF and CW but it took about 7 days longer to reach its peak in CF and CW than in DL. The difference in N_2O emission between the CF and CW treatments was negatively small, even though plant growth was much lower in the CF plot. Changes in cumulative N_2O emissions in the DL, CF, CW and NF treatments over time are shown in Fig. 1(a). The cumulative N_2O emission in DL was higher than that in CF or CW for about 30days after the fertilizer application. The difference in N_2O emission rates could have resulted

from activation of microorganisms by the organic compounds in the digested liquid manure. The cumulative N_2O emission in DL was 63 mg N m^{-2} (reached after 57 days) and the N_2O emission rate was 0.25%. This emission rate was similar to that (0.17%) reported by Wulf et al. (2002).

In the DL treatment, the peak CO_2 emission was observed just after the fertilizer application. The CO_2 emission decreased with time after 2 days from the application and remained relatively constant or increased slightly until about 57 days after fertilizer application. No significant difference between that in CF and CW and that in NF during the first 20 days after the fertilizer application. This suggests that the effect of the application of inorganic nitrogen and water on the CO_2 emission rate was small and that the increase in CO_2 emission after application of the digested liquid manure was caused by 1) the decomposition of the organic matter in the digested liquid manure and/or by 2) the activation of soil microorganisms by the organic nitrogen. By 30 days after the fertilizer application, CO_2 emission in CF and CW became larger than that in NF. The reason for this increased CO_2 emission was probably that promotion of plant growth by the fertilizer increased root respiration. The cumulative CO_2 emission by the application of digested liquid manure during the first 28 days, during that time the effect of plant root respiration would be small, was 41 g CO_2-C m^{-2} (Fig. 1(b)). The CO_2 emission rate was 33% in the DL plot. Part of the carbon applied to the soil was emitted as a gas and the remainder moved downward into the groundwater after dissolving in the soil water or accumulated in the soil.

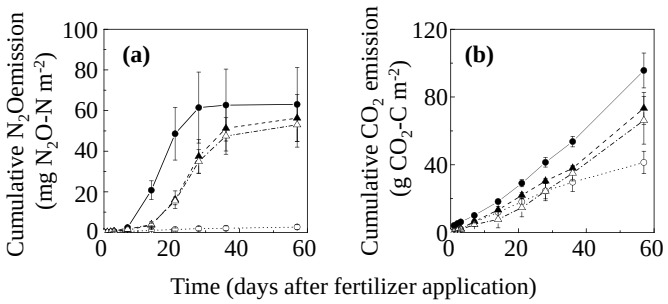

Fig. 1 Changes in cumulative (a) N_2O and (b) CO_2 emission in DL and CF, and NF plot.

Concentrations of N_2O and CO_2 in the soil

The soil N_2O concentration increased after the fertilizer application in both the DL and CF treatments (Fig. 2). Soil N_2O concentrations remain unchanged throughout the study period in the NF treatment. Throughout the first 7 days of the study, the N_2O concentration increased with increasing depth in the DL and CF treatments; in contrast, at 14 days, the N_2O concentration in both treatments increased to a depth of 5 cm, then decreased thereafter with increasing depth. The decrease in the N_2O concentration in DL was faster than that in CF, which agrees with the changes in N_2O emission. The highest N_2O concentration occurred between 7 and 14 days (DL) and between 14 and 21 days (CF), which were earlier than the largest N_2O emissions observed in these plots. This suggests that the increase in N_2O emission is delayed compared with the increase in the N_2O concentration in the surface soil layers.

The soil CO_2 concentration tended to increase with increasing depth in all plots (Fig. 3). In the DL treatment, there was a small and possible non-significant increase in CO_2 concentration between days 7 and 14 in the surface layers (0 to 20 cm). However, the amount of the increase in DL was smaller than that in CF and NF, which indicates that changes in CO_2 concentration in the surface soil after the application of the digested liquid manure were smaller than those caused by the changes in the temperature, aeration, and water content of the soil. Changes in CO_2 concentrations in deeper layers (> 30 cm) were larger than those in surface layers in each plot. This agrees with the results of Fujikawa et al. (2000) stated that diurnal fluctuations in soil CO_2 concentrations were larger in deeper layers in a field with a hard pan. The large diffusion flux of CO_2 negated the effect of changes in generation of CO_2 by soil microorganisms, although the

respiration rates of roots and microorganisms would be larger in this layer because of the abundant substrate and oxygen availability.

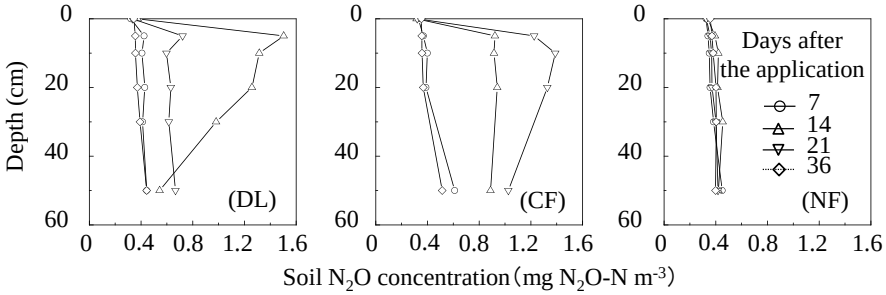

Fig. 2 Distribution of the concentration of N_2O as a function of time

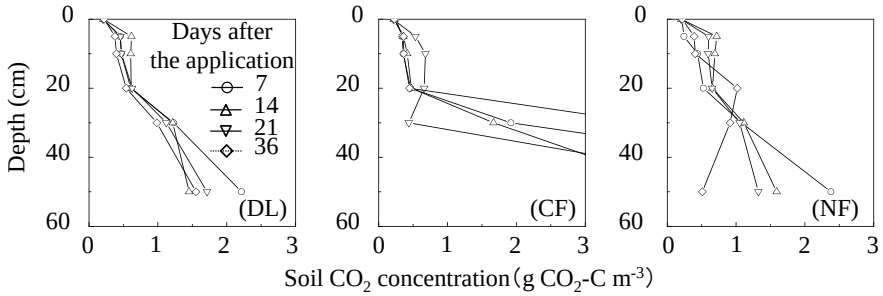

Fig. 3 Distribution of the concentration of CO_2 as a function of time

Soil gas diffusivity and diffusion flux

In DL, agglutination of the soil particles was observed, and the bulk density of the soil was reduced by these large pores. However in the top layer of the soil (0 to 5 cm) the differences in air-filled porosity and the relative gas diffusivity between treatments were small, whereas in deeper layers, the differences were large because of the large differences in bulk density in these deeper layers.

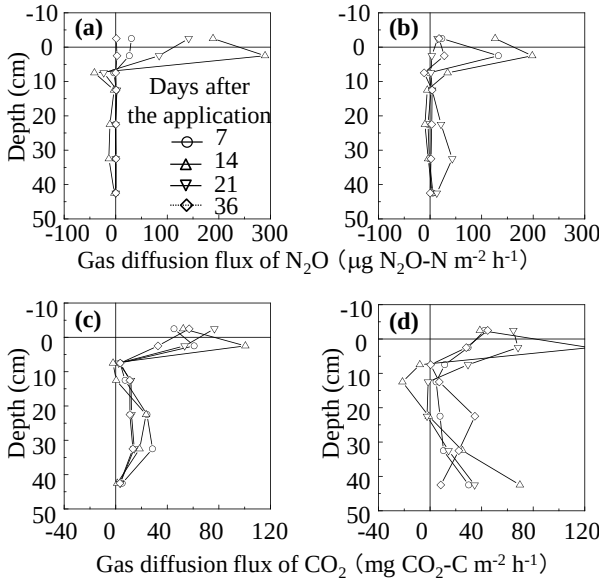

Fig. 4 Distributions of the gas diffusion flux of N_2O in the (a) DL and (b) CF treatments and of the gas diffusion flux of CO_2 in the (c) DL and (d) CF treatments

The maximum N_2O gas diffusion flux in the top layers of the soil (Fig. 4(a), (b)) was larger in DL than in CF. A negative flux was observed in DL at 5 to 50 cm in depth 14 days after the fertilizer application. This indicated that downward N_2O diffusion occurred as a result of the application of digested liquid manure. It must be verified whether the larger downward flux of N_2O by digested liquid manure than inorganic fertilizer originated from the properties of the digested liquid manure. The CO_2 gas diffusion flux decreased with increasing depth in the DL and CF treatments (Fig. 4(c), (d)). Compared with the N_2O diffusion flux, the difference in the CO_2 flux between deeper and surface layers was smaller. This supports previous reports that the contribution of the generation of CO_2 in deeper layers is larger than that of N_2O. The distribution of the CO_2 gas flux in CF varied with time; for this scenario, further research need to be conducted.

CONCLUSION

We cultivated komatsuna in the field under three fertilization treatments, inclusive of digested liquid manure and an unfertilized control, to clarify the changes in N_2O and CO_2 dynamics in the soil and at the soil surface. N_2O emission increased more rapidly and substantially after the application of the digested liquid manure compared to inorganic fertilizer. Based on the cumulative N_2O emission, the N_2O emission rate was 0.25% for the digested liquid manure. CO_2 emission increased drastically after the application of the digested liquid manure, and then decreased with time from 2 days after the fertilizer application, but remained higher than the initial value. The CO_2 emission ratio for the digested liquid manure was 33%. The soil N_2O concentration increased after the application of digested liquid manure and inorganic fertilizer. The increase in N_2O emission is delayed compared with that in the N_2O concentration in the surface soil. The changes in the CO_2 concentration in the surface soil caused by the application of digested liquid manure were smaller than those caused by changes in the temperature, aeration, and water content of the soil. The largest N_2O gas diffusion flux was observed in the surface layer and negative flux was observed in deeper layers 14 days after the application of digested liquid manure. The difference in the CO_2 flux between deeper and surface layers was smaller than that for N_2O. This suggests that the contribution of CO_2 generation in deeper layers is larger than that of N_2O after the application of digested liquid manure.

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Research article

An Evaluation of Evaluation Systems for Rural Water Supply and Sanitation Systems

TUNG NGUYEN NHU*
Vietnam National University, Ho Chi Minh City, Vietnam
Email: nntung@hcmiu.edu.vn

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Abstract An evaluation of evaluation systems applied to water supply and sanitation systems in rural areas would contribute to improving the validity and quality of the evaluation results. An evaluation system is supposed to be based on latest indicators in the field, theory-based evaluation principles, in consideration of threats to the validity of the evaluation. A case study of the Mekong Delta Rural Water Supply and Sanitation Project (AUSAID Project) is used for a review of its evaluation system. This project was implemented in five provinces in Vietnam for the period from 2000 to 2007. Information on this evaluation is collected from regular project monitoring and evaluation reports and the Activity Completion Report. The author's work as an evaluation officer for the project improves the understanding of the project's evaluation approaches. The project evaluation reports serve the purpose of measuring the effectiveness and sustainability of the project's activities. Several potential threats to the validity of the evaluation include some missing assumptions and intermediate outcome for the project's impacts. Notwithstanding the above threats, this evaluation system of rural water and sanitation was the first in this field in Vietnam, and its indicators satisfy the evaluation standards. This evaluation of evaluation, based on theory-based evaluation principles, for a specific case of rural water supply project in Mekong Delta has never been conducted before.

Keywords threats to validity, effectiveness, evaluation systems, water supply, sustainability, participatory

INTRODUCTION

Because of its importance, an evaluation report must be a useful document for learning. However, Busby (1999) has stated that evaluation reports are not used effectively because their contents are too shallow: they fail to explicitly identify the true causes of problems, lack of objective outcome of data and misinterpret data. The validity of an evaluation report depends on the quality of its evaluation system design and implementation. Therefore, it is necessary to determine whether an evaluation system is free of technical errors, misinterpretation, and bias. This type of auditing helps to improve an ongoing evaluation process. A review of post-project evaluation also audits the completeness and soundness of final evaluation reports to provide information to future project managers. Because of this importance, international donors conduct reviews of evaluations. For example, AUSAID audited 162 evaluation reports of its funded activities from July 2006 to June 2010 and found that approximately one-quarter of these evaluation reports were of "insufficient quality to be published", and that only 11% of them were of excellent quality (Bazeley, 2011).

An evaluation of an evaluation is defined as a way "to aggregate findings from a series of evaluations. It is also used to denote the evaluation of an evaluation to judge its quality and/or assess the performance of the evaluators" (glossary for M&E terms, OECD-DAC 2002). Other names for an evaluation of an evaluation are a secondary evaluation, a meta-evaluation and an evaluation audit. This evaluation category includes professional critiques of evaluation reports, reanalysis of data and external evaluations of internal audits. In this paper, the term "meta-evaluation" is used to refer to the evaluation of evaluations.

OBJECTIVE

The purpose of this study is to compile meta-evaluation criteria for a Rural Water Supply and Sanitation (RWSS) evaluation based on an intensive literature review and to assess the evaluation system used by an AUSAID-funded project, the Mekong (Cuu Long) Delta Rural Water Supply and Sanitation (CLDRWSS) Project. Specifically, the research questions are as follows: 1) What should be reviewed in an evaluation of a RWSS evaluation system? 2) What are the evaluation methodologies used by the CLRWSS Project? 3) What are some threats to the validity of the evaluation results in the CLRWSS Project?

This research will contribute by providing a proposed framework of meta-evaluation to which future evaluation efforts in the relevant sector may refer. Evaluators will be able to determine which aspects of their evaluation content will be checked to allow their auditing to be more complete, accurate, accountable, and usable.

The limitation of this paper is that it ignores considerations of some meta-evaluation indicators, including cost-benefit or cost-effectiveness issues (e.g., was the evaluation conducted at a reasonable cost?) and the extent of learning from evaluation results (what did people learn and how well did people learn from these lessons?). It is important that future meta-evaluations include these contents.

METHODOLOGY

For the first research question, literature review is used to compile a set of relevant meta-evaluation indicators to answer the first question. Substantial research has been conducted to include relevant meta-evaluation indicators in the rural water and sanitation sector. The sources of this information are mainly evaluation books, journal articles and websites. I also refer to the guidelines published by the World Bank, OECD, AUSAID and UNICEF for evaluation standards.

To answer the second and third research questions, desk research is used to retrieve the CLDRWSS Project's Monitoring and Evaluation (M&E) reports and the M&E Summary Report for the Activity Completion Report to provide evidence of the evaluation system. The above evaluation reports are scrutinised through the lens of theory-based evaluation model to understand how and why the project activities would lead to outcomes (Weiss, 1995; Fitz Gibbon et al., 1996; Rogers et al., 2000). Theory-based evaluation is more and more popularly used in designing evaluation of community-based interventions and the CLDRSS project evaluation system is not an exception. The theory-based evaluation normally uses a form of logic framework (Logframe) to guide the collection and analysis of data for evaluation reports.

RESULTS AND DISCUSSION

What should be reviewed in an evaluation of a RWSS evaluation system?

Stufflebeam (1974) proposed eleven specific criteria to determine the quality of an evaluation (Table 1). Weiss (1995) and Rogers (2007) suggested that theory-based evaluation should include a logical framework, or Logframe, which has increasingly been applied in health community-based interventions such as water and sanitation projects. According to these authors, the outcomes of an intervention are based on theories of how and why this intervention will work or through a pathway in a particular context. Therefore, a theory-based evaluation must be designed based on a logical framework or Logframe, and its focus should be on collecting and analysing data as required by the framework. Chelimsky (1995) regarded the political dynamics or environment as one of the constraints to the quality of an evaluation, which may lead to "the total restriction or classification of information". Furthermore, according to the World Bank, three major criteria for evaluating rural water supply and sanitation systems are sustainability, effective use, and replicability. Capacity building is central to the progress of these dimensions. Narayan (1993) has emphasised the importance of a participatory approach to the evaluation of Rural Water Supply and Sanitation

community-based (RWSS) interventions for the purpose of sustainability (Table 1).

Table 1 Summary of Meta-Evaluation Considerations/Indicators

Authors/ Organisations	Meta-Evaluation Considerations/Indicators
Stufflebeam (1974)	1) Internal validity, 2) External validity, 3) Reliability, 3) Objectivity, 4) Relevance, 5) Importance, 6) Scope, 7) Credibility, 8) Timeliness, 9) Pervasiveness, 10) Cost/ effectiveness
Weiss (1995) and Rogers (2007)	Theory-based evaluation (logical framework, input-outcome model, assumptions, context)
Narayan (1993)	Rural Water Supply and Sanitation (RWSS) indicators (participatory evaluation, effectiveness, sustainability, capacity building, replicability)
OECD Development Assistance Committee Evaluation Criteria	Effectiveness (e.g., Independent Completion Report effectiveness, gender, M&E system, lessons learned); relevance (theory of change/intervention logics, context); sustainability (use of government systems, transactional vs. transformational); efficiency (e.g., size and scale, expenditure)
AUSAID criteria	Gender equality, monitoring and evaluation, analysis and learning, overall quality
Chelimsky (1999)	Political dynamics as a constraint

Source: Compilation from literature

What are the evaluation methodologies used by the CLRWSS project?

Evaluation Indicators: A set of indicators, with checklists, were established to review the major components (Table 2).

Table 2 Major Components of CLDRSS Evaluation Indicators

Component	Project Indicators	Relevance to literature indicators
A. WATER SUPPLY AND SANITATION SYSTEMS	1. System Quality (4 sub-indicators) 2. Coverage and Access (2 sub-indicators) 3. Costs and Affordability (3 sub-indicators) 4. Operation – Maintenance – Management (3 sub-indicators)	Sustainability Effective Use Efficiency
B. RWSS AGENCY CAPACITY	1. Capacity to promote water supply and sanitation 2. Capacity to support institutional capacity building 3. Capacity to implement RWWS investments 4. Capacity for project management	Capacity building Replicability
C. INFORMATION, EDUCATION AND COMMUNICATION (IEC)	1. Focus group analysis of key IEC activities, including clean water sources, canal water treatment, looking after piped water sources 2. Focus group analysis of IEC healthy schools model 3. Reported cases of diarrhoea (Department of Health data)	Effective use
D. COMMUNITY ENVIRONMENTAL SANITATION ACTIVITIES	1. Activity is an appropriate solution, matches design and is well implemented 2. Number of direct beneficiaries disaggregated by activity type	Effective use

Source: CLDRWSS Project M&E Report

The indicators, the first ones applied in this field in Vietnam, were designed by an Australian M&E Specialist and project consultants in compliance with the Vietnam Monitoring and Evaluation Manual developed by the Vietnam Australia Monitoring and Evaluation Project 2005. The measurements of sub-indicators for these components are based on 5-point, 4-point or 3-point scale with scoring guidelines and checklists.

Theory-based Evaluation: Figure 1 shows reporting hierarchical structure. Different evaluation reports from four teams, i.e. household survey team, technical evaluation team, IEC evaluators and

school IEC evaluators, are compiled and summarized into an M&E Summary Report. Each evaluation team performed a different function using different data-collecting methods. Household surveys conducted by external consultants for rating customer-based water and service quality; technical site visits for standard-based system quality inspection; household surveys and interviews for IEC outcome auditing; school IEC team for school hygiene and water using checklists and interviews.

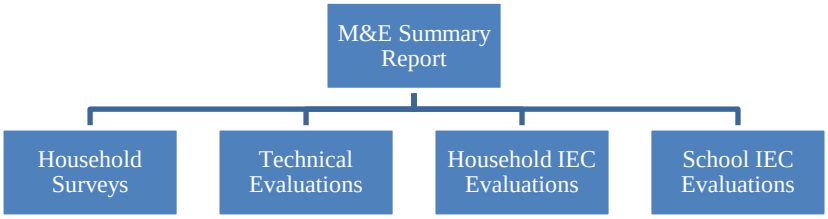

Fig. 1 The CLDRWSS Project's M&E Document Hierarchy
Source: CLDRWSSP

The above indicators and function structure are guidelines for conducting post-project evaluation. The Project also formed a core M&E team, comprised of an Australian M&E specialist, an M&E project officer, an IT officer and five provincial M&E liaison officers for both processes of evaluation and post-project evaluation.

Table 3 Potential Threats to Evaluation Results

Component	Summary Description	Threats to Evaluation Reliability
Logic Framework (Logframe)	Logframe consists of narrative summary at project, component outcome and output levels; verifiable indicators and means of verification; achievements (i.e. inputs).	**Possible missing inputs:** other health promotion interventions outside of project influence water use behaviour during 5 project years; such factors as social norms, behaviour control, service quality, price, etc would impact intention to use. **Missing assumptions**: food bacterial contamination controlled; diarrhoea seasonability **Unidentified intermediate outcome**: would the reduced incidence of diarrhoea be an impact or an outcome? The answer to it is not clearly found in the Project M&E IEC reports.
Process Evaluation	**Indicators**: investment information, IEC activities, performance progress, beneficiary number **Methods**: synchronized data files **Time**: monthly **Tools**: RUWASS Management Information System (MIS)	None
Post-project Evaluation	**Indicators**: See Table 2 for major indicators **Methods**: Site visits, surveys, interviews **Time:** 3 months upon completion **Tools:** checklists, questionnaires, records **Sampling**: for household survey, about 10% beneficiary households.	▪ No weighted factor scoring system. Specifically, the importance weight for system quality is 0.67 while that for coverage and access is only 0.04. ▪ Three months is too short to see a behaviour change in a context with deeply-rooted health practices ▪ Sample size (about 20 per commune) may be small as total beneficiary population per commune is 200. ▪ Good reports on achievements are more likely to be appreciated (political dynamics).

What are some threats to the validity of the evaluation results of the CLRWSS project?

In consideration of the theory-based evaluation model and other literature, the following table summarizes some threats to the evaluation results as perceived by the author.

Most of uncovered failure to mention assumptions falls on the information-education-communication (IEC) impacts. For example, one note is that prior to the Project, local people already had high demand for improved water hence the Project IEC delivery programs might be unlikely to have much impact on increasing the demand. Take another example of assumption. Safer drinking water is assumed to produce better health because it eliminates the risks of water-borne diseases (e.g., diarrhoea). In fact, some health studies conclude that other factors that cause diarrhoea in poorer countries include flies, poor hand-washing practices, food bacterial contamination, and diarrhoea seasonality (Blogg, 2005). Another point for justification is weighing importance to each evaluation indicators (Table 4).

Table 4 shows that the weighted factor of "Coverage and Access" component is only 0.04 (5/135), which is too low compared to that of system quality (0.67). This component should deserved a higher score because it is important to have more water users to prove that the water scheme is effectively used. Also, some sub-indicators are on 5-point measurement scale whereas the others on 3-point measurement scale. Some justification is needed to explain why.

Table 4 Score structure for evaluation in a rural piped water system

Components	Max Score (points)	Weighted Factor
System Quality	90	0.67
Coverage and Access	5	0.04
Costs and Affordability	14	0.10
Operation, Maintenance & Management	26	0.19
	135	**1.00**

Source: CLDRWSS Project M&E Report

CONCLUSION

An evaluation report should be read and applied hence its quality needs to meet some standards. This study proposes a new model for evaluation systems in a rural water supply and sanitation project. Firstly, it should measure the degree of capacity building achievement as a result of effective use, replicability and sustainability of the intervention. The evaluation system should stipulate that six months and even some years after water supply construction, site visits should be conducted to inspect if the water scheme is well functioning, if more villagers change their behaviour to the use of improved water and if the model of the project success could be copied to other rural locations. This inspection is critical because it is a waste of investment money if the water supply system breaks down just a short period of time after being constructed due to limited capacity in management. Previous studies have shown that a rural water supply activity is more likely to be sustainable with active participation of community members, especially women. Therefore, evaluation indicators should include the measurements of community participation, with considerations of gender issues, in the process of project implementation. Secondly, evaluation methodology should be based on participatory approach. Community members, as direct beneficiaries, would have more exact answers to evaluators' questions on the impacts of the water project. Lastly, a review on an evaluation report sticks to the logic framework of the project. Therefore, the design of an evaluation should include an adequate and clear logic framework. A logical framework, with clear description of inputs, outputs, outcomes and impacts, with stated assumptions and contexts would be critical in an evaluation system as they would be used as guidelines to steer evaluators to fairly assess the achievements of a project. Future evaluations should use these indicators to verify the robustness and soundness of evaluations in this sector. Generally, the evaluation reports of the CLDRWSS Project served the purpose of measuring the effectiveness and sustainability of the Project's activities. Several potential threats to the validity of

the evaluation, as described above, include the lack of some assumptions and intermediate outcomes, timing for mature outcomes and assigning more resources for larger sample size.

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Research article

Assessment of Sustainable Energy Potential of Non-Plantation Biomass Resources in Sameakki Meanchey District in Kampong Chhnang Province, Cambodia

VIBOL SAN*
Faculty of Science, Royal University of Phnom Penh, Phnom Penh, Cambodia
Email : san.vibol@rupp.edu.kh, sanvibol@gmail.com

DALIN LY
Faculty of Agro-Industry, Royal University of Agriculture, Phnom Penh, Cambodia

NEANG IM CHEK
Faculty of Science, Royal University of Phnom Penh, Phnom Penh, Cambodia

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Abstract Biomass has always been a major source of energy for mankind, and accounts for about 14% of the world's total energy supply. Biomass is a clean energy resource, considered neutral on CO_2 emissions, that has a high potential for meeting increasing energy demands as a substitute for fossil fuels. Biomass energy sources are abundant in Cambodia. We assess the energy potential of the following non-plantation biomass resources: (1) agricultural residues, (2) animal manure. The production of agricultural residues and animal manure was based on the production of crops obtained from the National Census 2008 and one study site. This information was categorized into: (i) primary residues (paddy straw, sugarcane tops, maize stalks, empty coconut bunches and fronds, palm oil fronds and male bunches etc.) and, (ii) secondary residues (paddy husks, bagasse, maize cobs, coconut shells, coconut husks, coir dust, saw dust, palm oil shells, fiber and empty bunches, etc.), and (iii) animal manure. The estimation of residue generated can be calculated from the residue to product ratio (RPR). To estimate the potential for deriving additional energy from a residue, it is important to establish the present utilization pattern of the residue. The results of energy potential analysis indicate that agricultural residues could have produced 212.11 GJ in 2010. The total annual potential of biogas from animal manure in 2006, 2007 and 2008 was 1357.96 thousand m^3, 1432.89 thousand m^3 and 1452.66 thousand m^3, respectively, and the corresponding energy potential was 29.87 GJ, 31.52 GJ and 31.96 GJ, respectively. If this energy potential can be developed in order to meet the demand for energy, it can reduce the pressure on natural forests, the impact on human health, especially of women and children, and the amount of greenhouse gas emissions.

Keywords biomass, conservation, energy potential, residues, sustainable energy

INTRODUCTION

Biomass has always been a major source of energy for mankind, and accounts for about 14% of the world's total energy supply. The term biomass refers to all organic materials that originate from living organisms e.g. wood, agricultural residues, animal manure etc. Biomass sources are therefore diverse(Bhattacharya et al. 2005). Biomass is a clean energy resource that shows high potential as a substitute for fossil fuels and to meet the world's increasing energy demand.

Biomass energy sources are abundant in Cambodia. Fuelwood is the most common source of energy for the majority of the population in the Kingdom. Firewood and charcoal are often referred to as traditional fuels, yet they remain the dominant source of energy for cooking within the domestic sector, and are used extensively by industry and the service sector. The Statistical Yearbook 2008 published by the National Institute of Statistics reported that fuelwood was by far

the most commonly used fuel for cooking purposes; 85.0% of Cambodian households in 2007. Around 98.2 percent of rural households used fuelwood and charcoal.

In Sameakki Meanchey district in Kampong Chhnang province, fuelwood is the main energy source for cooking, boiling water, preparing animal feed and protecting cattle against insects. Approximately 96% of the households in the district depend on fuelwood as a primary energy source for cooking along with other energy types such as charcoal, animal dung, crop residues, LPG, kerosene, and biogas(San et al. 2012a). Kerosene was the main energy source used by local people (60.5%) for lighting (San et al. 2012b). Other energy sources used for lighting among the 767 households interviewed were rechargeable batteries, 57.9%, and electricity, 5.1%.

Although wood biomass is important for people in Sameakki Meanchey district, non-plantation biomass is an alternative energy source that could reduce pressure on natural forests by reducing fuelwood dependency for cooking and boiling water and reduce greenhouse gas (GHG) emissions.

OBJECTIVE

The objective of this study is to assess the sustainable energy potential of the following biomass resources in Sameakki Meanchey district, Kampong Chhnang province, Cambodia: (i) agricultural residues, (ii) animal manure, and (iii) fuelwood saving potential through improved efficiency.

METHODOLOGY

Site description

Sameakki Meanchey District located in the south western Kampong Chhnang Province was selected as the study area. The district lies in the south of the province and shares a border with Kandal and Kampong Speu Provinces to the south. The district is subdivided into 9 communes (*Khum)* and 85 villages *(Phum)*. The total number of households in 2010 was 15,516 households of which the total population was 73,303 people (NCDD, 2010). The average household size was 5.37 (Mode = 5) (San et al. 2012a).

Non-plantation energy potential assessment

This section presents the methodologies used to assess the potential of the different non-plantation resources considered in this study. These can be categorized into: (i) primary residues (paddy straw, sugarcane tops, maize stalks, coconut stalks and fronds, palm oil fronds and male bunches etc.) and, (ii) secondary residues (paddy husk, bagasse , maize cobs, coconut shells, coconut husks, coir dust, saw dust, etc.), (iii) animal manure, and (iv) fuelwood released through efficient improvement. The production data of each non-plantation biomass resource was obtained from the homepage of the National Committee of Sub-National Democratic Development (NCDD, 2010).

Primary and secondary residues: The term agricultural residue is used to describe all the organic materials which are produced as by-products from harvesting and processing of agricultural crops. Agricultural residues, which are generated in the field at the time of harvest are defined as primary or field based residues (e.g. rice straw, sugar cane tops), whereas those co-produced during processing are called secondary or processing based residues (e.g. rice husk, bagasse). The availability of primary residues for energy applications is usually low since collection is difficult and they have other uses as fertilizer, animal feed etc. However secondary residues are usually available in relatively large quantities at the processing site and may be used as captive energy sources for the same processing plant involving little or no transportation and handling cost. The energy potential of various primary and secondary residues was estimated.

Energy potential of the residues: The estimation of residue generated was calculated on the basis of the residue to product ratio (RPR). To estimate the potential of deriving additional energy from a residue, it is important to establish the present utilization pattern of the residue (Bhattacharya et al.

1999).

$$ARG = \sum(RPR \times AH),$$

$$EP_{residue} = ARG \times (SAF + EUF) \times LHV_{residue}$$

Where ARG is the amount of a residue generated annually (t yr^{-1}), RPR is the residue production ratio, AH is the annual harvest of the crop or product (t), $EP_{residue}$ is the total energy potential of residue (J t^{-1}), SAF is surplus availability factor (dimensionless), EUF is the energy use factor (dimensionless), and $LHV_{residue}$ is the lower heating value of residue (J t^{-1}).

Fuel characteristics: Moisture content of residues normally varies widely at different stages of harvesting and storage. The moisture content of a residue influences its fired heating value and should be known. A review of RPR values at different moisture content and lower heating values (LHVs) for different residues was carried out by Bhattacharya et al. 1996. The RPR values reported by them can be used for estimating the energy potential of agricultural residues; however, country-specific RPR and LHV values should be used wherever possible.

Animal manure: Animal manure is principally composed of organic material, moisture and ash. Decomposition of animal manure can occur either in an aerobic or anaerobic environment. Under aerobic conditions, CO_2 and stabilized organic materials (SOM) are produced. Under anaerobic conditions, CH_4, CO_2, and SOM are produced. Since the quantity of animal manure produced annually can be substantial, the potential for CH_4 production and hence energy potential of animal manure is significant. Energy potential of recoverable animal manure is estimated by Bhattacharya et al. 1997. A preliminary estimation of energy potential of animal manure was reported by Bhattacharya et al. 1997. The amount of dry matter from an animal, recoverable fraction of animal manure, volatile solid fraction, and biogas yield values reported by them, could be used for estimating the energy potential of animal manure.

Fuelwood released through efficiency improvement: In the household sector, large amounts of fuelwood are consumed, normally in inefficient traditional stoves, for cooking and water boiling purposes. Energy saving through improved cooking stoves is discussed in this paper. A methodology for estimation of fuelwood released through efficient improvement was reported by Bhattacharya et al. 1999.

RESULTS AND DISCUSSION

The potential for energy production from crop residues

The main occupation of households in the study is farming. Rice paddy is the main crop in the study area. The other major crops grown in the study area are corn, peanuts, and cassava. During the dry season, farmers in the research area could not grow rice because they lacked a water source for irrigation. Rice production per ha in 2008 ranged from 1ton to 2.5 ton. It is necessary to note that total production of corn, peanuts and cassava increased in 2007 but declined in the following year because production demand decreased.

Table 1 Types of crop residues, RPR and calorific value for agricultural residue

Crop	Residue	Moisture (%)	RPR	Energy use Factor	Surplus availability factor	LHV (MJ kg^{-1}) (as received)
Rice	Straw,	8.17	0.447	0.000	0.684	8.83
	Rice husks	8.83	0.230	0.531	0.469	12.85
Corn	Stover, cobs	8.65	0.250	0.193	0.670	16.63
Peanut	Straw, leaves, shell	--	2.663	0.007	0.760	18.00
Cassava	Stalks	--	0.088	0.000	0.407	16.99

Source:(Sajjakulnukit et al. 2005)

The crops grown in the study area produce various types of crop residues. These residues arise from the harvesting of these crops and their subsequent processing into various products. The data in Table 1 shows the types of crop residues found at the study site. The estimated energy potential is performed based on residue product ratio (RPR) and as received calorific values as shown in Table 1.

Greater rice production in comparison to other crops in the study area contributed to high availability of rice residues such as rice husk and rice straw. Rice husk, also called rice hull, is the outermost layer of the paddy grain. It is separated from brown rice during the first step in the milling process. The unutilized rice husk mainly causes waste disposal problems and breathing problems because of its low density but could be an option for biomass energy systems. The use of rice husk as a solid fuel may be a promising way to avoid these problems and provide considerable amounts of useful energy (Chungsanguit et al. 2010). Rice straw is another by-product of rice and a great bio-resource since it is one of the richest materials in terms of its lignocelluloses (Yoswathana et al. 2010). However, it is important to note that rice straw is also an import fodder for animals in Cambodia. Table 2 shows the estimated energy potential from agricultural residues in 2008. The production of agricultural residue is calculated based on the production of crops obtained from the National Committee for Democratic Development in 2010. Total of estimated energy potential from crop residues is approximately 212.11 GJ in 2008.

Table 2 Energy potential of agricultural residues in 2008

Product	Residue	Production (tonne)	Residue available for energy (tonne)	Energy potential (GJ)
Rice	Straw,	31,537	14,097.00	85.14
	Rice husks		7,254.00	93.21
Corn	Stover, cobs	35	8.75	0.13
Peanut	Straw, leaves, shell	913	2,431.32	33.57
Cassava	Stalks	95	8.36	0.06
			Total	212.11

The potential for energy production from animal manure

In the study area the most important animals are cattle/buffalo, pigs, chickens and ducks. Other livestock includes goats, sheep and horses, but the numbers are comparatively small. Livestock farms produce polluting wastes. Traditionally their disposal has been by direct use as fertilizers or in some instances as landfill. These methods cause severe environmental problems such as odour, contamination of water, methane emission etc. The present study focused only on cattle/buffalo, pigs, chickens and ducks. Livestock populations over three years were obtained from the National Committee for Democratic Development 2010 (NCDD 2010).

Table 3 Dry matter, recoverable fraction, and volatile solid of animal waste

Animal	Number (head)			Fresh Waste* (kg head^{-1} d^{-1})	Recoverable fraction*	Dry mater* (DM) (%)	Volatile solid* (%)
	2006	2007	2008				
Buffalo/cattle	37,922	40,773	40,960	12.40	0.50	17.77	13.64
Pig	15,319	13,900	15,190	1.50	0.80	35.22	24.84
Chicken	42,402	43,368	46,282	0.03	0.80	33.99	22.34
Duck	2,462	2,780	2,151	0.03	0.40	26.82	17.44

**Source: (Sajjakulnukit et al. 2005)*

Values for different characteristics of animal manures considered in the present study, such as dry mater, fraction recoverable as well as physical and chemical properties are given in Table 3. The heating value of biogas is taken as 22 MJ m^{-3} (IPCC, 2006). The estimated amount of animal manure recoverable, the potential of biogas production and the total potential of energy from animal manure are presented in Tables 4 and 5. The total annual potential of biogas from animal manure in 2006, 2007 and 2008 is 1357.96 thousand m^3, 1432.89 thousand m^3 and 1452.66

thousand m^3, respectively, and the corresponding energy potential is 29.87 GJ, 31.52 GJ and 31.96 GJ, respectively.

Table 4 Biogas yield and recoverable DM of animal manure

Animal	Number (head)			Recoverable DM (tonne DM yr^{-1})			Biogas yield (m^{-3} kg^{-1} VS)
	2006	2007	2008	2006	2007	2008	
Buffalo/cattle	37,922	40,773	40,960	30499.53	32792.51	32942.91	0.286
Pig	15,319	13,900	15,190	2953.53	2680.33	2929.08	0.217
Chicken	42,402	43,368	46,282	157.82	161.41	172.26	0.242
Duck	2,462	2,780	2,151	7.23	8.16	6.32	0.310

Table 5 Energy potential from animal manure

Animal	Number (head)			Amount of biogas (Tm^{-3} yr^{-1})			Energy potential (GJ)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Buffalo/cattle	37,922	40,773	40,960	1189.80	1279.25	1285.12	26.18	28.14	28.27
Pig	15,319	13,900	15,190	159.23	144.48	157.89	3.50	3.18	3.47
Chicken	42,402	43,368	46,282	8.53	8.73	9.31	0.19	0.19	0.20
Duck	2,462	2,780	2,151	0.39	0.44	0.34	0.01	0.01	0.01
			Total	1357.96	1432.89	1452.66	29.87	31.52	31.96

Fuelwood saving through efficiency improvement

The New Lao stove, known as the Cambodian improved stove, is the most frequently used stove type in the study area (33%), followed by the Three Stone stove (18%), the Siam and Lao Kompong Chhnang stove (13%), the Traditional Lao stove (10%), the Korng Rey stove (9%), the self-made or clay stove (2%) and the Samaki stove (2%) (San et al. 2012a). The study conducted by San et al. (2012) reports that more than 50% and 35% of households in the study area owns 2 stoves or 1 stove, respectively. Some households use two different types of stove in their household. Therefore, we assumed that households were using the same type of traditional stove in their household in order to calculate fuelwood saving by switching from inefficient traditional cooking stoves to improved cooking stoves (Table 6). We also assume that all traditional cooking stoves are replaced by New Lao Stove, which is a more energy-efficient cooking stove. The average fuelwood consumption rate per family per year for cooking and boiling drinking water in study area is 1.87 and 1.02 tonne (San et al. 2012a).

Table 6 Biomass saving potential in residential cooking and boiling drinking water

Type of stove	Fuelwood consumption (tonne $family^{-1}$ $year^{-1}$)	Efficiency (%)		Saving potential	
		Traditional stove	Improved stove	(t)	(GJ)
Three Stone	2.89	10	25	0.61	27.74
Siam	2.89	15	25	0.40	18.50
Loa Kampong Chhnang	2.89	16	25	0.36	16.65
Traditional Loa	2.89	11	25	0.57	25.89

CONCLUSION

All biomass residues including primary and secondary residues have the potential to provide 244 GJ in 2008. Rice straw and rice husks have higher energy potential compared to other crop residues because of their ready availability in large quantities. Animal manure, which produces 31.96 GJ in 2008, is considered to be the main resource for biogas production. Improving the efficiency of biomass use for cooking and boiling drinking water through improved cooking stoves can save huge amounts of fuelwood per family per year. More than 16 GJ per family per year were saved

when local households in the study area switched from inefficient traditional to energy-efficient cooking stoves.

The results of the study clearly indicate that non-plantation biomass residues provide a promising potential energy source for local people in the study area. If this potential energy source can be developed to meet their energy demands, it could reduce; the pressure on natural forest, the impact on human health, especially women and children, and greenhouse gas emissions.

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Research article

Farmer's Awareness and Factors Affecting Farmer's Acceptance to Grow Straw Mushroom in Mekong Delta, Vietnam and Central Luzon, Philippines

NGO THI THANH TRUC*
Cantho University, Cantho, Vietnam
Email: ntttruc@ctu.edu.vn

ZENAIDA M. SUMALDE
University of the Philippines Los Baños, Laguna, Philippines

FLORENCIA G. PALIS
International Rice Research Institute, Laguna, Philippines

REINER WASSMANN
International Rice Research Institute, Laguna, Philippines

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Abstract The study aimed to determine the current utilization practices of rice straw, to describe farmers' awareness and perception about using rice straw to produce straw mushroom, to determine factors affecting farmers' acceptance to use this technology, and identify the enablers and constraints in adopting straw mushroom production technology To achieve these objectives, a survey of 417 respondents and focus group discussions were conducted in four villages in Mekong Delta, Vietnam and Central Luzon, Philippines. Interviews of current adopters and key informants of straw mushroom production were also done at those two study sites. The survey showed that majority of rice straw in Mekong Delta, Vietnam and Central Luzon, Philippines was burned. In Mekong Delta, a small percentage of rice straw was used to grow mushroom, left in the field and used to feed cattle while rice straw in the Central Luzon was left in the field, used as feed for cattle and for mulching. The study found that farmers have good knowledge of this subject even low percentage of adopters. Using the Logit model, yet the significant factors affecting the acceptability of the straw mushroom production in the Mekong Delta, Vietnam include household income and household size whereas in Central Luzon, Philippines are household income, farm size and willingness to attend additional trainings related to straw mushroom production. On the other hand, the key informants and straw mushroom growers identified the requirements to enhance farmers adoption of straw mushroom culture such as 1) good quality of mushroom spore, 2) mushroom production site, 3) supply a whole-year production cycle (if mass production), 4) techniques to grow mushroom, 5) available labor, 6) knowledge in pre-processing mushroom in case farmers are unable to sell fresh mushrooms, and 7) mushroom marketing.

Keywords rice straw, rice straw burning, straw mushroom, *Volvariella volvacea*, Mekong Delta, Central Luzon

INTRODUCTION

Rice straw, a by-product and considered as a waste material in rice, contains 41% C, 0.5 - 0.8 % N, 0.05 - 0.1% P, 0.3 - 2.0% K, 12% silica, and 10% lignin (IRRI Knowledge Bank, 2003). The problem of disposing rice straw is generated during the intensification in rice production and due to limited alternative uses and lack of time and resources to dispose this by-product, it accumulates and becomes wastes.

Straw mushroom (*Volvariella volvacea*) production introduced in Vietnam and Philippines in the last twenty years is a promising strategy to mitigate greenhouse gas emission comparing to other alternative uses of rice straw (Truc, 2011). The questions are on the current usage of rice straw, farmer's awareness of straw mushroom, the factors affecting their acceptance and the benefits/constrains of using rice straw to grow straw mushroom as perceived by non-adopters and faced by adopters. Answering these questions would help identify appropriate recommendations to enhance adoption of this alternative uses of rice straw. Thus, this study was conducted to a) determine the current utilization practices of rice straw; b) describe farmer's awareness and perception about using rice straw to produce straw mushroom; c) determine the factors affecting farmer's acceptance to use this technology; and d) identify the enablers and constraints in adopting straw mushroom production technology.

METHODOLOGY

The study sites and methods of data collection

A total of 417 farmer-respondents were interviewed using a structured questionnaire in four villages, namely, Truong Lac Commune, O Mon District, Can Tho City and My Thanh Nam Commune, Cai Lay District, Tien Giang Province in Mekong Delta, Vietnam in June 2008 and Barangay Matingkis, Science City of Muñoz and Barangay Santo Rosario, Santo Domingo Municipality, Nueva Ecija Province, Central Luzon, Philippines in June 2009 (Fig. 1).

The key informant interviews were done by using checklists with face to face interviews of representatives of current adopters of straw mushroom production, local authorities, agricultural extension officers, and other related institutional organizations in the study sites.

The focus group discussions (FGDs) were also conducted in each site after completing the survey and key informant interviews for adopters to provide and share information on straw mushroom production as well as their advantages and disadvantages, to assess the possibility of introducing straw mushroom production and to identify the mechanisms of growing the crop at the studies sites.

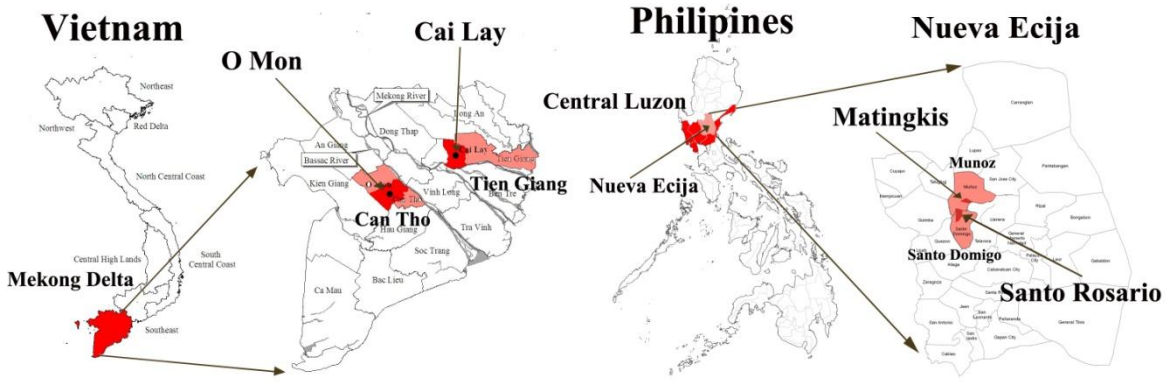

Fig. 1 Map of study sites in Mekong Delta, Vietnam and Central Luzon, Philippines

Data analysis

The survey data were analyzed descriptively using frequency, descriptive and cross tabulation and mean comparison adapting t-test in SPSS 13.0 (Statistical Package for Social Sciences).

Literatures show that socio-economic characteristics, farmer's awareness and perception of the technologies are major determinants affecting farmer's adoption of agricultural technologies (Palis, 2006; Palis, 1998; Somda et al. 2002; Ghadim and Pannell, 1999; Oladele and Fawolde, 2007; Adegbola and Gardebroek, 2007 and Corrales and Serrano, 1999). Basing on those literature, findings and the information observed at the study sites, the following factors were chosen to

identify the factors affecting farmer's acceptance of straw mushroom (explained in Eq.(1) and Table 1). The factors affecting the probability of adoption were estimated by the logistic regression or the Logit model.

$$A_F = \ln \frac{(Pi)}{(1-Pi)} = \beta iXi + \alpha \quad (1)$$

Table 1 Descriptions of variables in the Logit model

Variables	Description	Unit / Value	Expected signs
A_F	Farmers' acceptance to use the technology (straw mushroom)	A_F = 1: accept A_F = 0: not accept	
X_1	Household income per year	USD/household/year	–
X_2	Farm size devoted to rice production	Ha/household	–
X_3	Household size	Persons	+
X_4	Age of respondent/person involve in rice production	Years	–/+
X_5	The educational level of respondent/person involve in rice production	Number of years schooling	–
X_6	Dummy variable of farmers' awareness about straw mushroom	X_6 = 1: aware or have heard about straw mushroom, otherwise X_6=0	+
X_7	Dummy variable of farmers' need training about straw mushroom	X_7 = 1: respondent wants to learn about straw mushroom, otherwise X_7=0	+
X_8	Dumpy variable of distance (d) from house to the rice field	X_8 = 1 if d < 0.5 km, otherwise X_8 = 0	–
α	Constant		

RESULTS AND DISCUSSION

Rice straw uses in Mekong Delta, Vietnam and Central Luzon, Philippines

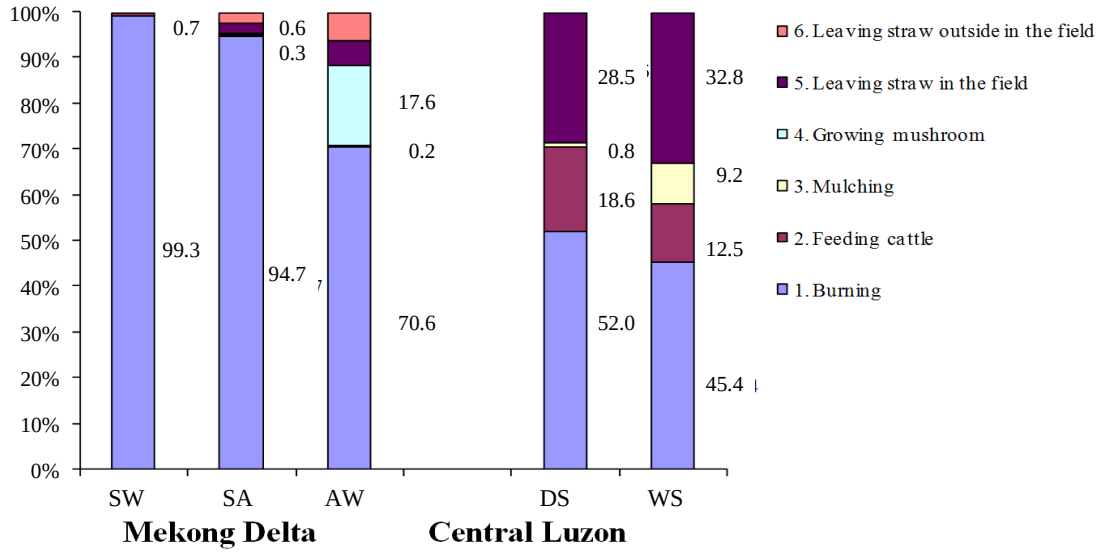

Fig. 2 Current uses of rice straw in Mekong Delta, Vietnam, 2008 and Central Luzon, Philippines, 2009

Note: SW: Spring Winter crop, SA: Summer Autumn crop, AW: Autumn Winter crop in Mekong Delta DS: Dry Season crop, WS: Wet Season crop in Central Luzon, Philippines

There are differences between Mekong Delta, Vietnam and Central Luzon, Philippines in the cropping pattern. The survey was conducted at the three paddy crops per year in the Mekong Delta (Spring Winter (SW) - October/November – February, Summer Autumn (SA)- February - April and Autumn Winter (AW) - April - July/August). In Central Luzon, there are only two paddy crops per year (Dry Season crop (DS) - January to April and Wet Season crop (WS) - July to October).

Majority of the rice straw in Mekong Delta, Vietnam was burned (SW-99%, SA-95% and AW-71%) while a minimal percentage is used for growing straw mushroom, leaving in the field and feeding cattle. In Central Luzon, rice straw was burned (DS-52% and WS-45%), left in the field (DS-29% and WS-31%), used to feed cattle (DS-19% and WS-23%) while the rest was used for mulching (DS-1% and WS-9%) (Fig. 2).

Farmer's awareness about straw mushroom production

Straw mushroom has been introduced in Mekong Delta and Central Luzon as a means to augment farmer's income since the 1990s. Thus, the technology is no longer new to farmers. However, more than half (60%) of the respondents in Central Luzon have never heard about straw mushroom. All the farmer-respondents in Mekong Delta knew about straw mushroom since it is their daily vegetables (Table 2). However, about 88% of the total respondents have never grown straw mushroom with only 12% and 7.6% of the households in Mekong Delta and Central Luzon, respectively, stating that they had grown the crop. However, none of the surveyed households in Central Luzon grew straw mushroom in 2008 – 2009.

Table 2 Farmer's awareness about straw mushroom in Mekong Delta, Vietnam, 2008 and Central Luzon, Philippines, 2009 (% responses)

ITEMS	VIETNAM			PHILIPPINES		
	O Mon (n=120)	Cai Lay (n=126)	Mekong Delta (n=246)	Muñoz (n=70)	Santo Domingo (n=101)	Central Luzon (n=171)
Never heard about straw mushroom	-	-	-	77.14	48.51	60.23
Heard about straw mushroom but never grown it	75.80	100.00	88.20	14.26	44.59	32.17
Heard about straw mushroom and used to grow the crop	24.20	-	11.80	8.60	6.90	7.60

Farmer's acceptance of growing straw mushroom

Farmer's attitude towards attending trainings on straw mushroom production and their intent to grow straw mushroom after the training were investigated in the survey. Central Luzon farmers were less likely to attend trainings and to grow straw mushrooms after participating in the trainings with only 57% compared with 76% of the farmers in Mekong Delta (Table 3).

Table 3 Willingness to attend training in straw mushroom production in Mekong Delta, Vietnam, 2008 and Central Luzon, Philippines, 2009

ITEMS	VIETNAM			PHILIPPINES		
	O Mon (n=120)	Cai Lay (n=126)	Mekong Delta (n=246)	Muñoz (n=70)	Santo Domingo (n=101)	Central Luzon (n=171)
Willing to attend training and at least one person decided to after attending training	69.17	83.33	76.42	65.71	50.50	56.73
Do not want to attend training or attend training but not grow after training	30.83	16.67	23.58	34.29	49.50	43.37

Factors affecting farmers' acceptance of growing straw mushroom

The result of the Logit model that analyzes the factors affecting respondent's attitude towards using rice straw for growing mushrooms is shown in Table 4. However, the awareness and information needs variables were deleted in the regression for Mekong Delta since the level of awareness about straw mushroom in this country is already 100%.

Among the six factors tested in Mekong Delta, two factors (household income and household size) appeared to have significant negative effect on farmer's decision to use rice straw in growing mushrooms. Lower income and smaller households were more likely to grow mushrooms than those with higher income and bigger households. The results on the household size relative to the acceptance of mushroom growing were unexpected as the author anticipated the opposite. Mushroom growing is labor-intensive, thus, it would have been logical that bigger households would be more receptive to growing straw mushroom. However, in practice, bigger households tend to send their children to work or study outside the communes. They also might have to take care their children, so they have no more vacant time for straw mushroom growing.

Table 4 Factors affecting respondents' acceptance of growing straw mushroom in Mekong Delta, Vietnam, 2008 and Central Luzon, Philippines, 2009

VARIABLES	Xi	β_i	Mekong Delta		Central Luzon	
			Coefficient	z value	Coefficient	z value
Household income	X_1	β_1	– 0.0001925 **	–2.22	0.0001574 **	2.19
Farm size	X_2	β_2	0.3086298	0.88	–0.759491 0**	–2.41
Household size	X_3	β_3	–0.2538631 **	–2.45	–0.1191921	–1.00
Age	X_4	β_4	–0.0020682	–0.11	–0.0058102	–0.33
Educational attainment	X_5	β_5	0.0499579	0.78	–0.0639080	–0.91
Awareness	X_6	β_6			0.2019690	0.52
Need	X_7	β_7			2.3617420 ***	5.98
Distance	X_8	β_8	–0.4778684	–1.47	–0.5649210	–1.40
Constant		α	–2.993046 **	2.48	0.7589256	0.51
Number of observation				242		171
Percent of acceptance (%)				76		57
Pseudo R^2				0.1187		0.2422

*Note: ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively*

Among the eight factors tested for Central Luzon, only three factors significantly affected the decision to grow straw mushroom (household income, farm size and willingness to learn more about straw mushroom). Households with higher income and smaller farm size were more receptive to grow straw mushroom. Growing straw mushroom is considered a small business in Central Luzon rather than a livelihood, as opposed to the culture in Mekong Delta wherein poor farmers engage in mushroom production to augment their household income. This cultural difference in mushroom production may explain why the household income coefficients differed between the two regions. The results show that higher income households in Central Luzon had higher acceptance of mushroom production. Likewise, results showed that households with smaller farm size were more likely to accept the technology as they would want to earn more to compensate for the small income they get from producing rice within their small farm areas.

Further, those who were willing to learn about straw mushroom were also more likely to adopt the technology after training. The results from focus group discussions and interviews highlighted the importance of the product's outcome in promoting mushroom growing. Because of the high perishability of straw mushrooms, farmers need to sell their products within a day in the market, farmers or women union, cooperatives or any group in the commune who help mushroom growers connect with the market within a day and secure their minimum selling price.

With regards to the conditions to learn about straw mushroom, Cai Lay and Muñoz farmers showed more interest than O Mon and Santo Domingo farmers did. Data from the survey, FGDs, and interviews showed that trainings on mushroom growing should be conducted in these two areas. Central Luzon farmers also needed good quality and available supply of spores. This factor may

encourage them to grow mushrooms in this region. Growing mushrooms is simple yet requires a lot of labor. To encourage them, farmers can make use of the free and simple labor available in the commune or can work in groups to help each other to save on labor. Lastly, market access and better selling price were among the most important factors to succeed in promoting straw mushroom to farmers.

Enabling factors and constraints in straw mushroom production

The major motivating factors of growing mushroom cited by farmers in Central Luzon and Mekong Delta were significantly different from each other. For the Mekong Delta, the major advantages of growing mushroom in the two famous growing areas (Thom Rom, Can Tho city and Tan Hoa, Dong Thap province) in Mekong Delta were 1) the availability of materials (rice straw and spore), 2) availability of labor, and 3) ease of production. On the contrary, mushroom production in Central Luzon is still at the infancy stage and farmers were unable to market their products even when the demand was very high in this region. The biggest enabling factor of growing mushroom in Central Luzon was the availability of materials and labor.

Despite the numerous motivating factors in the two main study sites, mushroom growers still encountered several difficulties in mushroom growing such as 1) limited market, 2) limited spore supply, especially in Central Luzon, and 3) increasing labor cost.

CONCLUSION

The holistic approach of determining the factors affecting farmer's acceptance in growing straw mushroom from both non - adopters and adopters as well as related key informants provided a whole picture of straw mushroom adoption in Mekong Delta, Vietnam and Central Luzon, Philippines. This study also confirmed the importance of socio-economic characteristics, their knowledge and perception of the technology significantly affecting their choice.

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Research article

Effects of Retting Treatment on Coconut Husk Buffer Strips for Eliminating Nutrient Losses

JULIAN E. TORILLO, JR.
Graduate School of Agriculture, Tokyo University of Agriculture, Japan

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan
Email: m-mihara@nodai.ac.jp

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Abstract Coconut husk has been applied as buffer strips for soil erosion control on slope upland fields in Bohol of the Philippines. However, attention has been paid to the losses of nitrogen and phosphorus components not only those leached from synthetic fertilizer applied in upland fields but also those components released from coconut husk buffer strips. Thus, pretreatment of coconut husk by retting before its installation into the field has been proposed. The objective of this study is to find out the effect of ret treating the coconut husk utilized as buffer strips on eliminating its releasing nitrogen and phosphorus components. Coconut husks were trimmed then minor pounding by hammer were applied to meet the desired porosity of the material as buffer. Retting treatment of 41.34 g in dry mass of coconut husk was carried out by soaking into 1,300 ml of distilled water for 10 days to extract its nitrogen and phosphorus components. Ret treated coconut husk were installed into stainless slope model plot filled with Philippine soil and set at 8 degrees in slope. Another plot was also prepared and installed with untreated coconut husk then rainfall simulation was carried out into both plots. The experimental results showed that the amount of nitrogen released from the plot installed with ret treated coconut husk buffer strip was significantly lower than that of untreated husk buffer strip at 99% significant level. Therefore, it was concluded that 10 days retting treatment of coconut husk for buffer strips was effective on eliminating the release of nutrient particularly on nitrogen from leaching.

Keywords coconut husk, retting, nitrogen, phosphorus, bio-fertilizer

INTRODUCTION

Upland fields with protruding stones and rocks on ground surfaces as well as abandoned farmland are dominant particularly in the southwestern part of Bohol, Philipines (Torillo and Mihara, 2011). Moreover, these lands are mostly located on sloped-areas with 8-18% and even some portions with more than 18% slope, particularly for subsistence agriculture (OIDCI, 2006). Together with high squalls, uplands in the island are susceptible to soil erosion causing rapid degradation of land.

Meanwhile, about 5 million coconut trees are cultivated in the island of Bohol (OIDCI, 2006) producing large amount of coconut husk. These coconut husks were considered as waste residue and left rotten in the site. In this study, utilizing coconut husk, a locally available material has been focused from a view point of conservation agriculture in Bohol. However, coconut husk that were installed as buffer strips for soil erosion control tended to release nitrogen and phosphorus. This tendency was observed during the slope modeling under artificial rainfall simulator (Torillo and Mihara, 2011). Those nutrients released from the coconut husk may leach through percolation and surface runoff resulting water pollution into downstream. Therefore, treating of coconut husk before its installation as buffer strips through retting has been recommended.

The objective in this study is to find out the effect of retting treatment of coconut husk for buffer strips on eliminating its nitrogen and phosphorus release.

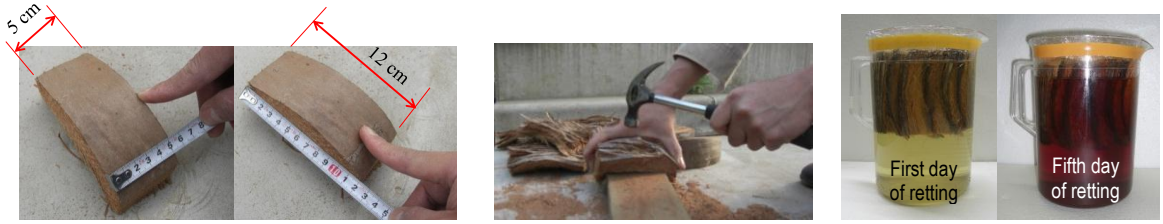
MEHODOLOGY

Retting treatment of coconut husks

Nutrient component particularly on phosphorus can be extracted from the coconut husk by retting method (Torillo and Mihara, 2012). Thus, retting treatment of coconut husks has been applied by soaking into distilled water.

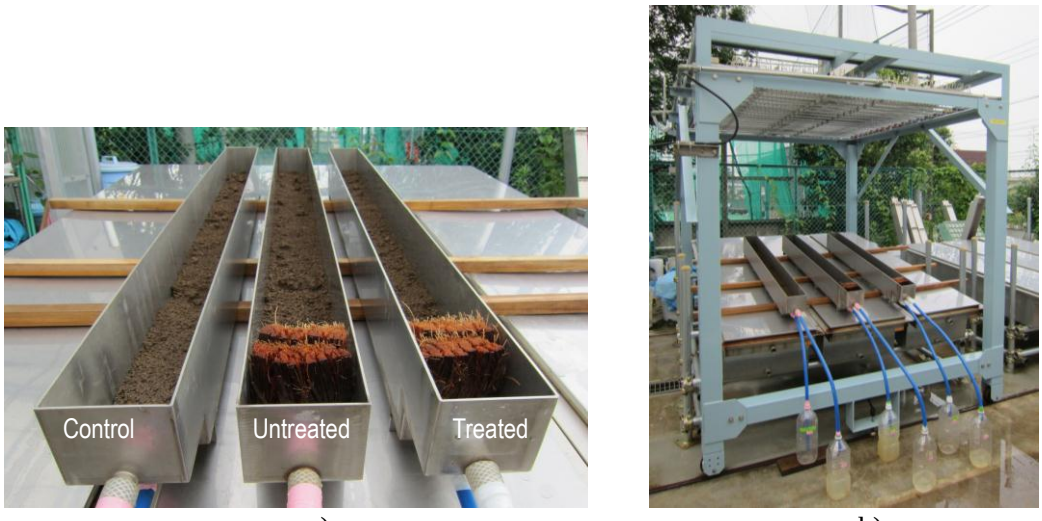
Coconut husks were cut and trimmed into 5 cm wide and 12 cm length then minor pounding by hammer was done to make into a porous material similar to that being installed into the site as buffer strips. Four pieces of pounded coconut husks were prepared while two of them were intended for retting treatment and the other two pieces were retained as untreated coconut husks. Small amount of coconut husk`s sample was taken for analyzing total nitrogen (T-N) and total phosphorus (T-P) component after the decomposition with sodium hydroxide (NaOH) and potassium peroxodisulfate ($K_2S_2O_8$). Concentrations of T-N and T-P were measured by spectrometric methods (Mihara and Ueno, 2000).

Pounded two pieces of coconut husks weighing 41.34 g in dry mass for retting treatment were then soaked into 1,300 ml of distilled water. Retting treatment was carried out up to ten days as Torillo and Mihara (2012) reported that the optimum period of releasing nutrient components from coconut husk was at the tenth day of retting. After ten days passed of soaking, coconut husks were taken out and ret liquor was sampled for analyzing the released amount of T-N and T-P from the coconut husk.



a) b) c)

Fig. 1 Procedures in preparing the coconut husks for retting treatment such as a) cutting, b) pounding and c) retting



a) b)

Fig. 2 Slope model plots in a) controlled, untreated husk buffered and treated husk buffered plots and b) slope model plots under artificial rainfall simulator

Slope modeling with coconut husks buffer strip

It was proven that there was no significant difference between the two rows of coconut husk buffer strip and the two rows coconut husks buffer strip with 25 cm husk mulch on mitigating soil losses (Torillo and Mihara, 2011). Therefore, in this study two rows of coconut husk buffer strips have been installed into slope model plots.

Three stainless slope model plots were prepared as controlled plot, treated coconut husk buffered plot and untreated coconut husk buffered plot. Each slope model plot (130 cm long and 11 cm wide) were filled up with Philippine soil having clay percentage at 63.8%, silt at 8.1% and sand at 28.1% (Torillo and Mihara, 2011) of around 7.5 kilograms. Ret treated and untreated coconut husks were installed at the lower toe of the plots as treated coconut husk buffered plot and untreated coconut husk buffered plot, respectively. Those two slope model plots along with controlled plot were set at degrees in slope. Rainfall simulation was carried out at rainfall intensity of 60 mm/h within two hours. Suspended water samples from surface discharge were collected every 15 minutes for the first hour then every 30 minutes for the second hour. Percolation water was collected at each plot after 24 hours from the end of rainfall simulation. Surface water discharge and percolated water samples were analyzed for total nitrogen (T-N) and total phosphorus (T-P). Surface water discharge samples were also measured for soil losses by oven drying method. Three repetitions of rainfall simulation were carried out in separate days.

RESULTS AND DISCUSSION

Total nitrogen and total phosphorus released from coconut husk during retting treatment

Minor pounded coconut husks of 41.34 g in dry mass were soaked into 1,300 ml of distilled water within ten days. In the tenth day of soaking, distilled water soaked with coconut husks or called ret liquor (Fig. 1-c) were sampled then analyzed for total nitrogen (T-N) and total phosphorus (T-P). The amounts of T-N and T-P in coconut husk before soaking into the distilled water were also analyzed to determine the released amounts of these nutrients from coconut husk by retting.

Analysis data showed that the amounts of T-N and T-P in raw coconut husk were 0.792 mgN/g and 0.863 mgP/g, respectively (Table 1). During the tenth day of soaking or retting, the amount of T-N in ret liquor was 0.119 mgN/g and 0.729 mgP/g of T-P. Those values indicated that 15.02% of T-N component and 84.47% of T-P component from coconut husks were released into ret liquor within ten days of retting. The tendency of high released of T-P from coconut husk was supported by Havis and Alberts (1993) which nutrient leaching dynamics from partially decomposed corn residue was examined in a laboratory simulation experiment. They found out that more PO_4-P leached than NO_3-N and NH_4-N.

Table 1 Amounts of T-N and T-P in coconut husks and in ret liquor

	Amounts of nutrients in coconut husk	Amounts of nutrients released into ret liquor	Percentage of nutrient released from coconut husk
Total nitrogen (T-N)	0.792 ± 0.045 mgN/g	0.119 ± 0.028 mgN/g	15.02%
Total phosphorus (T-P)	0.863 ± 0.011 mgP/g	0.729 ± 0.188 mgP/g	84.47%

Effects of coconut husk buffer strips on mitigating soil losses

Two pieces of coconut husks at 41.34 g in dry mass were ret treated while other two pieces were retained as untreated coconut husk. To observe the effects of retting treatment on eliminating total nitrogen (T-N) and total phosphorus (T-P) in coconut husks for buffer strips, those pieces of coconut husk were installed into slope model plots then simulated under artificial rainfall.

Mihara (2001) reported that nitrogen and phosphorus components were transported by sediment and suspended solids which was observed in USLE plots under natural rainfall. In this connection, the amount of soil losses was also observed in this study. As shown in Fig. 3 that the

trend of cumulative amount of soil losses is increasing with the repetition of rainfall simulation among slope plots. This tendency is due to the accumulation of transported soil with the repetition of rainfall at the lower toe of the plots. Hence, the depth of the sediment deposited at buffer strip increases with time and substantially altering the geometry and gradient of the surface (Rose et al., 2003). This trend results smaller soil particles to be runoff and passes through voids in buffer strips.

The results showed that the amount of soil losses at treated and untreated coconut husk buffered plots were lower at an average of 29, 35 and 42% than that of controlled plot during the first, second and third rainfall simulation, respectively (Fig. 3). It was clearly indicated that coconut husk buffer strips mitigated soil losses which significant differences at $p<0.01$ were observed.

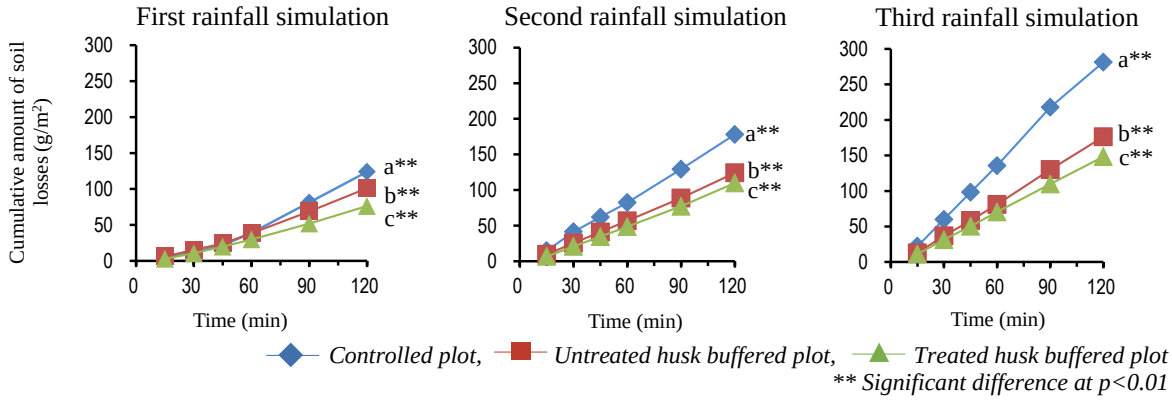


Fig. 3 Cumulative amount of soil losses with time during the first, second and third rainfall simulation

Effects of retting treatment on eliminating total nitrogen and total phosphorus in coconut husk utilized as buffer strips

Fig. 4 shows the amounts of T-N and T-P losses through surface discharge and percolation. It is indicated in the diagram at the right side of the figure showing the values plotted in histogram from zero x-axis and up is the amount of T-N losses. Meanwhile, values plotted in histogram from zero x-axis and down is the amount of T-P losses. Darker colors in histogram are the amounts of T-N and T-P losses through percolation and lighter colors are the amount of T-N and T-P losses through surface discharge.

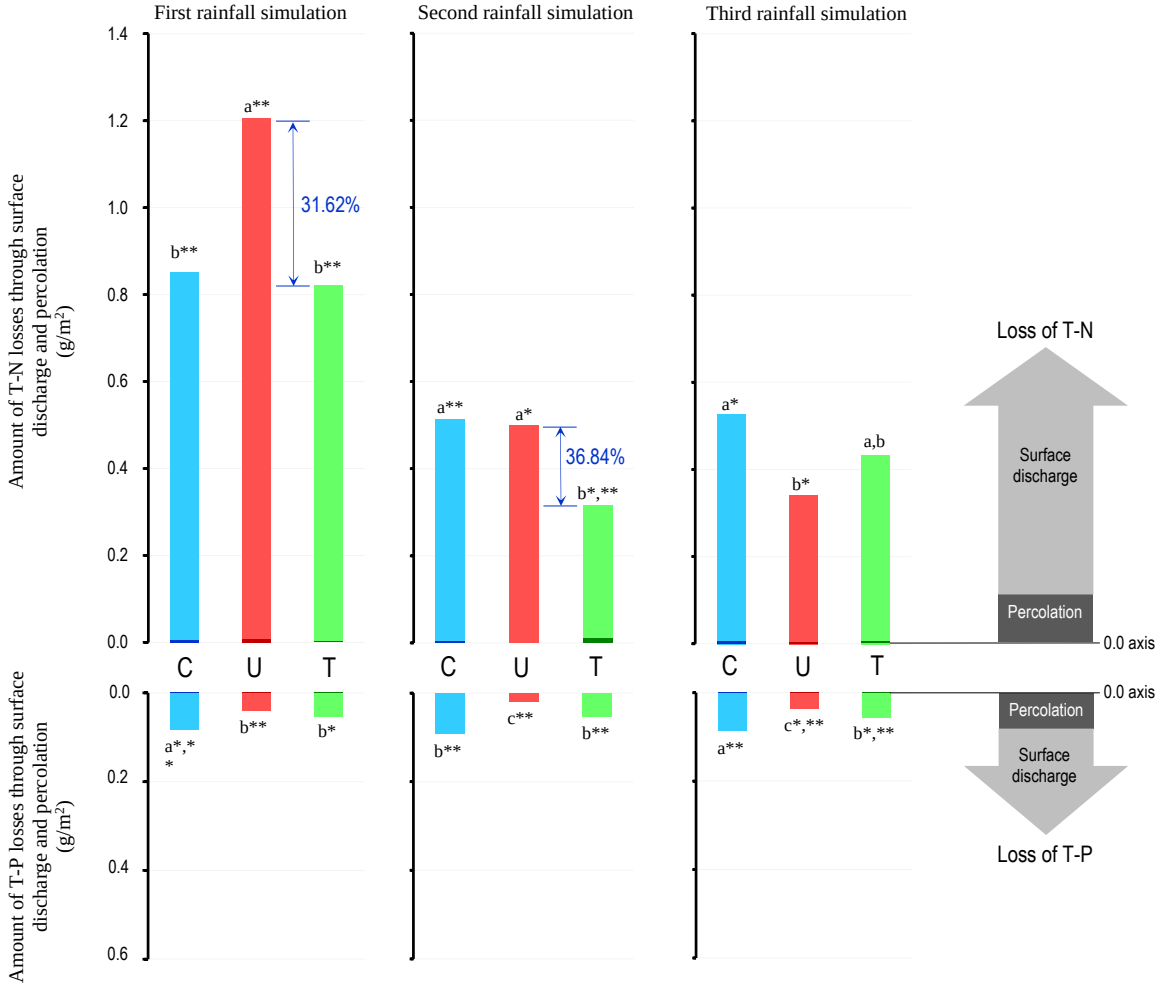
The amount of T-N losses through percolation and surface discharge are shown both (Fig. 4) to observe the balance losses of this nutrient. However, the amount of T-N losses through percolation was averagely 95 times lower than that of T-N losses through surface discharge. For instance in the case of (T) treated coconut husk buffered plot during the first rainfall simulation, T-N losses through percolation was 0.004 g/m^2 compared to 0.817 g/m^2 of T-N losses through surface discharge. Thus, T-N losses through percolation were insignificant that it did not affect in the statistical quantification of T-N losses.

During the first rainfall simulation, the (U) untreated coconut husk buffered plot showed higher amount at 0.378 g/m^2 accounting 31.62% of T-N losses higher than that of (T) treated coconut husk with a significant difference at $p<0.01$. This trend indicated that T-N component in coconut husk has been eliminated by retting treatment. However, (T) treated coconut husk buffered plot showed no significant difference than that of (C) controlled plot. This signifies that treated coconut husk buffer showed less effective on mitigating T-N losses from the plot.

A sudden decrease of T-N losses among three plots was observed from first rainfall simulation to second rainfall simulation test. This might be due to most of T-N component in soil that are susceptible for runoff had been transported during the initial rainfall simulation. During the second rainfall simulation, (U) untreated coconut husk buffered plot also showed higher amount at 0.161 g/m^2 accounting 36.84% of T-N losses higher than that of (T) treated coconut husk buffered plot. Although, only $p<0.05$ of significant difference was observed. It was also showed that treated

coconut husk buffer were able to mitigate T-N losses since (T) treated coconut husk buffered plot has 0.173 g/m^2 of T-N lower than that of (C) controlled plot with significant difference at p<0.01.

During the third rainfall simulation, although (T) treated coconut husk buffered plot appeared to be higher losses of T-N than that of (U) untreated coconut husk buffered plot, it was indicated that there was no significant difference between the two plots. Therefore, based on the experimental results, retting treatment of coconut husk influences in eliminating T-N losses.



C:*Controlled plot* **U**:*Untreated coconut husk buffered plot* **T**:*Treated coconut husk buffered plot*
** Significant difference at p<0.05, ** Significant difference at p<0.01*

Fig. 4 Amounts of total nitrogen (T-N) and total phosphorus (T-P) losses through surface discharge and percolation

The amount of T-P losses are also shown in Fig. 4 which is below the zero x-axes. It was also observed that the amount of T-P losses through percolation is significantly lower than that of T-P losses through surface discharge. For instance, the amount of T-P losses through percolation from (T) treated coconut husk buffered plot was 1×10^{-4} g/m^2 accounting 450 times lower than that of its surface discharge which is 0.045 g/m^2. Thus, the amount of T-P losses through percolation is also very insignificant to affect the statistical quantification of T-P losses.

The trend of T-P losses from all of the plots showed almost no changes from first to third rainfall simulation test. Although coconut husk buffered plots (U and T) had lower amounts of T-P losses than that of (C) controlled plot, T-P losses from (T) treated coconut husk buffered plot tended to be higher than that of (U) untreated coconut husk buffered plot where in significant differences at p<0.01 and p<0.05 were observed during the second and third rainfall simulation tests, respectively. This tendency might be due to the longer contact time of coconut husk with

distilled water during retting treatment. As Cermark et al. (2004) reported that more amount of PO_4-P was leached from corn residue with longer time of immersing into the solution of distilled water and inorganic salt. Thus, leaching of T-P from coconut husk residue has similar trend to that of corn residue which releases more amount of phosphorus component. The experimental results signified that with and without ret treating of coconut husk have less influence on eliminating T-P losses.

On the other hand, even though retting treatment of coconut husk tended to be less effective on eliminating T-P losses, it was observed that quantitatively the amount of T-P losses were very much lower than that of T-N losses. As shown in Fig. 4 that the amount of T-P losses from (T) treated coconut husk buffered plot were 18, 6, and 8 times lower than that of T-N losses during the first, second and third rainfall simulation tests, respectively. In addition, the amount of T-P at 0.863 mgP/g (Table 1) being released into the distilled water during the retting treatment is significantly larger than that of T-P which loss from treated coconut husk buffered plot at an average amount of 0.046 g/m^2.

CONCLUSION

This study dealt with the effect of retting treatment of coconut husk for buffer strips on eliminating its nitrogen and phosphorus components. It was indicated that around 15% of total nitrogen (T-N) and 85% of total phosphorus (T-P) component from coconut husk were released into distilled water within 10-day period of retting treatment. It was also proven that retting treatment was able to eliminate T-N losses at 31.62% and 36.84% during the first and second rainfall simulation tests, respectively. Thus, this amounts of T-N that were eliminated is important to taken into consideration as a benefit of retting treatment. In addition, although retting treatment tended to be less effective in eliminating T-P losses during the slope modeling test, the amount of T-P that was released into the distilled water during the retting was very high than that of T-P being loss from treated coconut husk buffer. The amount of T-P released into the distilled can be efficiently utilized for liquid bio-fertilizer. Therefore, retting treatment of coconut husk not only eliminates T-N losses but also it is an effective method to extract T-P component in the coconut husk.

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International Society of Environmental and Rural Development

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Institute of Environment Rehabilitation and Conservation (ERECON)
2987-1 Onoji Machida-Shi, Tokyo 195-0064, Japan
Tel/Fax: +81-42736-8972
E-mail: iserd.secretariat@gmail.com
Webpage: www.iserd.net

Collaborated with

Association of Environmental and Rural Development (AERD)
93/64 Moo.3, Sinsab village 2, Bungyeetho sub-district, Thanyaburi district,
Pathum Thani 12130, Thailand
Tel/Fax: +66-2957-8064
E-mail: iserd.secretariat@gmail.com
Webpage: www.iserd.net

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