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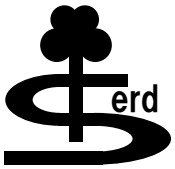

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Aims and Scope:

The International Journal of Environmental and Rural Development, IJERD, is an interdisciplinary journal concerning environmental and rural development research in the education for sustainable development, ESD. The IJERD is devoted to publishing peer-reviewed research article, review article and technical report in the fields of environmental and rural development, such as education for sustainable rural development, rural development, environmental management or agricultural systems. Every article or report in IJERD must be accepted by at least 2 reviewers and an editorial member.

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Infrastructural Systems:

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

Contents

Research article

Research article

Effect of Pre-Rice Mungbean and Cattle Manure Application on Growth and Yield of Organic Rice

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Abstract The objective of this research was to investigate the effect of different rates of organic fertilizers with or without mungbean crop residues incorporated into the soil after harvesting, on growth and yield of transplanted rice as well as economic return of mungbean as pre-rice crop. An experiment was conducted in a farmer's field in Muang Yai Village, Khon Kaen Province, Thailand, in 2011. A split-plot arrangement of treatments in a RCBD (randomized completed block design) was used, with pre-rice mungbean or fallow with weeds incorporated into the soil in main plots, and cattle manure at four rates (0; 3,125; 6,250; 9,375 kg/ha) as subplots. Incorporation of mungbean residue into the soil provided 3.2 t of dry matter per ha containing 50.2 kg N, 9.8 kg P and 166.2 kg K per ha. Incorporation of weeds in the fallow treatment provided 1.7 t of dry matter per ha containing 11.3 kg N, 2.8 kg P and 90 kg K per ha. Mungbean residues incorporated into the soil significantly increased plant height and tiller number per hill but had no significant effect on top dry weight per hill of the succeeding rice crop at panicle initiation stage (PI). At harvest, pre-rice mungbean significantly increased top dry weight per hill of rice. Application of different rates of cattle manure significantly affected plant height at PI and harvest. Cattle manure applied at the highest rate (9,375 kg/ha) had the highest plant height. Grain yield of rice was not significantly affected by pre-rice management. However, incorporation of mungbean residues produced an increase in rice grain yield over fallow treatment of 416 kg/ha (or 17%). Incorporation of mungbean significantly increased panicle number per hill. Incorporation of mungbean residue and application of cattle manure at 6,250 kg/ha produced the maximum panicle number per hill. Cattle manure application at the rate of 9,375 kg/ha resulted in the maximum rice grain yield (2,920 kg/ha). No significant interaction between pre-rice residue management and cattle manure application was found on rice grain yield. Growing mungbean before rice provides the advantage of marketable grain of mungbean to 1.6 t/ha. The net economic return was found highest in growing mungbean alone with transplanted rice later (2,855US $/ha) or three times higher than the fallow treatment.

Keywords animal manure, mungbean residue, organic rice

INTRODUCTION

The development and popularity of organic farming in Thailand have arisen due to issues that have been building in the country for several years. These include poverty among small farmers, the problem of agricultural chemical residues, and the increasing consumer need for organic agricultural products in the foreign market (Thanwa, 2001; Vitoon, 1994; Saetang et al., 2003).

Organic rice production has played an important role in recent years in boosting the income of farmers in Northeast Thailand, due to expanding market demand in European countries since 2003

(Economic Research Center, 2003). One of its conditions at the production stage is that organic rice must be cultivated without chemical fertilizer and pesticides. With regard to soil fertility, compost, green manure and animal manure play an important role in improving the crop yield from organic rice farming. However, there is little information about the use of pre-rice mungbean as green manure after pod harvesting. The objectives of the study were to investigate the effect of pre-rice mungbean management and the application of different rates of cattle manure fertilizers on growth and yield of organic rice under rainfed conditions, as well as economic return of mungbean as pre-rice crop.

METHODOLOGY

The experiment was conducted in a farmer's field in Muang Yai village, Khon Kaen province in 2011. The soil physio-chemical characteristics before planting mungbean and rice are shown in Table 1. In general, the soil texture is sand. Before growing mungbean, soil is strongly acidic and has low OM, total N, available P and exchangeable K. However, after incorporation of weed and mungbean residue most soil characteristics improved, particularly in the mungbean residues incorporation treatment.

A split-plot arrangement of treatments in a randomized completed block design with four replications was used. Pre-rice management (fallow with weeds incorporated into the soil and pre-rice mungbean in which residues were incorporated into the soil after pod harvesting) was the main-plot factor, while the application of different rates of cattle manure (0, 3,125, 6,250 and 9,375 kg/ha) were the sub-plot factors.

Table 1 Soil physio-chemical characteristics of the experimental field at 0-15 cm

Soil characteristics	Before growing mungbean	Before growing rice	
		Fallow	Mungbean residue incorporated
pH[a]	4.92	5.09	5.15
EC (mS/cm)[b]	0.03	0.015	0.024
Organic matter %)[c]	0.468	0.604	0.741
Total N (%)[d]	0.038	0.036	0.045
Available P (mg/kg)[e]	6.67	8.01	9.06
Exchangeable K(mg/kg)[f]	73.60	57.48	100.44
Soil texture[g]	Sand	-	-

[a]pH meter (1 : 1 H_2O); [b]EC meter (1 : 5 H_2O); [c]Walkley and Black method; [d]Kjeldahl method; [e]Bray II and molybdenum-blue method; [f]1N NH4OAc pH 7 and flame photometry method and [g]Hydrometer method

Table 2 Schedule of technical operations related to each treatment of the experiment in 2011

1st plowing	2nd plowing	Mungbean sowing	Mungbean harvest	Mungbean and weed incorporation	Application of cattle manure	Rice transplant-ing	Weed-ing	Flower -ing	Rice harvest
30 Apr.	7 May	11 May	11, 20 Jul.	23 Jul.	10 Aug.	12 Aug.	17 Sep.	23 Oct.	23 Nov.

Field managements of legume and succeeding rice crop are reported in Table 2. Before growing mungbean, soil was ploughed twice as in the farmers' usual cultivation practice from late April to the beginning of May. The main plots of each experiment were constructed by creating bunds surrounding areas of 4 x 17.5 m. Then cattle manure at the rate of 3,125 kg/ha were applied in the pre-rice mungbean treatment. The cattle manure application was done as the starter for the symbiotic fixation of N and favored the highest grain yield for mungbean. Mungbean was hand-seeded at a spacing of 20 × 50 cm. Pods of mungbean was harvested twice about 2 months after sowing. Before incorporation of weeds and mungbean residues into the soil, weeds and mungbean residues were randomly collected from 3 sites of 1 × 1 m to determine their dry weights (1,713 and 3,163 kg/ha, respectively). Total N, P and K contents of weeds and mungbean residues were also

analyzed (1.59%, 0.3% and 5.25% for dry weight of mungbean residue and 0.66%, 0.16% and 5.25% for dry weight of weed, respectively). The amount of nutrients returned to the soil by incorporating weeds and mungbean residues into the soil was calculated as in Eq. (1)

$$\frac{\text{Dry weight (kg/ha) x nutrient content (\%)}}{100} \quad (1)$$

Cattle manure at different rates was applied about 18 days after the incorporation of weeds and mungbean residues. Total N, total P and total K of cattle manure were determined (1.3%, 0.3% and 1.95% of dry weight, respectively). The amount of nutrients in the cattle manure applied to the soil was calculated as in Eq. (2)

$$\frac{\text{Rate of application (kg /ha) x nutrient content (\%)}}{100} \quad (2)$$

Rice seedlings were transplanted 1 day after the cattle manure application. Five seedlings per hill were transplanted in the pattern of 25 x 25 cm. Rice cv. KDML 105 was used in this study. Hand weeding was done once every 35 days after transplanting. No insecticide or fungicide was used in this experiment.

Five hills from each plot were measured to classify their height and tiller number per hill at panicle initiation (PI) growth stage and harvesting stage. Again, five hills from each plot outside the harvesting area were randomly selected and oven dried at 80 ℃ for 4 days to determine top dry weight at PI and harvest. The nitrogen, phosphorus and potassium contents of leaves were determined at PI. The numbers of panicles per hill in the harvesting areas were measured at harvest time. For the same samples, ten panicles from each plot were randomly selected to determine the number of filled and unfilled grains and the percentage of filled grains per panicle was calculated. The grain yield was taken from the 6 m^2 harvesting area of each plot and calculated as kg/ha at 14% moisture content. The filled grains were randomly selected from the grain yield sample to determine the weight of 1,000 grains. The data were analyzed using analysis of variance procedures and LSD was used to compare treatment methods when the F-test was significant.

RESULTS

Grain yield of mungbean and nutrient recycling to the soil

Grain yield of mungbean averaged 1,635 kg/ha. Incorporation of mungbean residues into the soil provided about 4 times higher N, P and K contribution than by weeds, 50.2 kg N, 9.8 kg P and 166.2 kg K per ha, respectively (Table 3). The amount of nutrients returned to the soil was further increased when cattle manure was applied and was higher in pre-rice mungbean treatment than fallow treatment. Application of the highest rate of cattle manure, 9,375 kg/ha, resulted in the highest N, P and K returned to the soil, 133.4 kg N, 71.1 kg P and 273.1 kg K per ha, respectively under fallow treatment and 172.3 kg N, 78.1 kg P and 349.3 kg K per ha, respectively under pre-rice mungbean. However, the ratio of increase of nutrients among cattle manure application rates was small in pre-rice mungbean treatment, i.e. N returned to the soil was only 3, 4 and 6 times higher than no cattle manure application when cattle manure was applied at the rates of 3,125, 6,250 and 9,375 kg/ha, respectively. In contrast to fallow treatment, N returned to the soil was 8, 15, and 22 times higher than no cattle application when cattle manure was applied at the rates of 3,125, 6,250 and 9,375 kg/ha, respectively (Table 3).

Growth of following rice

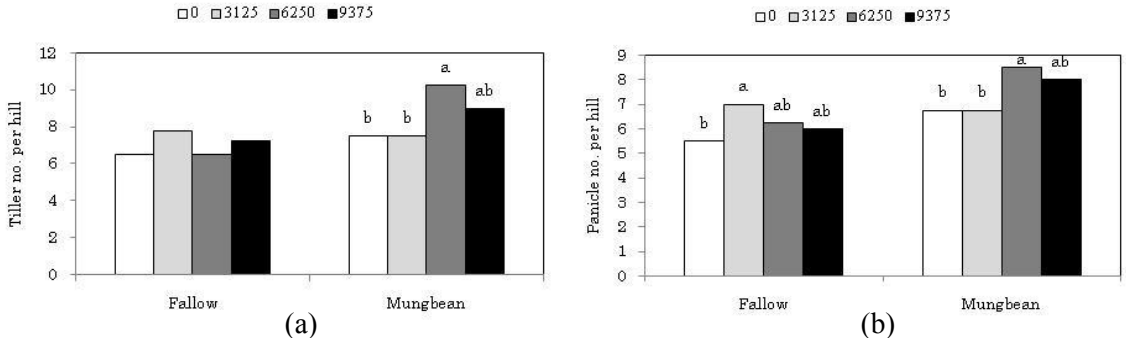
Incorporation of mungbean residues significantly increased plant height and tiller number per hill of succeeding rice but had no significant effect on top dry weight at PI growth stage (Table 4).

Application of different rates of cattle manure affected plant height at PI but not tiller number per hill and top dry weight. The maximum plant height was obtained at the highest rate of cattle manure application (9,375 kg/ha), but was not significantly different from the rates of 3,125 and 6,250 kg/ha. No interaction between pre-rice mungbean management and cattle manure application rate on plant growth at PI was observed (Table 4).

Table 3 Total N, P and K (kg/ha) returned to the soil by weed and mungbean residue at different cattle manure application rates before growing rice

Cattle manure application rate (kg/ha)	Nutrients returned to the soil (kg/ha)					
	Weed incorporation			Mungbean residue incorporation		
	N	P	K	N	P	K
0	11.3	2.8	90.0	50.2	9.8	166.2
3,125	52.0	25.6	151.0	90.9	32.6	227.2
6,250	92.7	48.3	212.1	131.6	55.3	288.3
9,375	133.4	71.1	273.1	172.3	78.1	349.3

N, P and K contents in plant tissues were analyzed by micro-kjeldahl method and indophenol blue method, wet oxidation method and yellow molybdovanadophosphoric acid method and wet oxidation method and flame photometry method, respectively.



(a) (b)

Fig. 1 Interactions between pre-rice management and cattle manure application rates on tiller number per hill (a) and panicle number per hill (b) of KDML 105 at harvest

Table 4 Plant growth of KDML 105 as affected by pre-rice managements and cattle manure application rates at panicle initiation stage and harvest

Treatment	PI			Harvest		
	Height (cm)	Tiller no. per hill	Top dry weight per hill (g)	Height (cm)	Tiller no. per hill	Top dry weight per hill (g)
Pre-rice management						
Fallow	78.8b	10b	11.13	121.8	7	31.65b
Mungbean	90.1a	12a	14.88	128.5	9	42.67a
F-test	*	**	ns	ns	ns	*
Cattle manure application rate						
0 (kg/ha)	80.4b	10	12.57	118.7c	7	30.99
3,125 (kg/ha)	83.5ab	11	11.69	123.3bc	8	36.45
6,500 (kg/ha)	85.8a	11	14.15	128.2ab	8	40.37
9,375(kg/ha)	88.0a	12	13.60	130.4a	8	40.81
F-test	*	ns	ns	*	ns	ns
Interaction						
F-test	ns	ns	ns	ns	*	ns
CV a (%)	8.44	8.60	28.59	7.05	19.76	16.77
CV b (%)	6.04	18.21	26.57	5.28	14.86	20.87

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

At the harvest stage, incorporation of mungbean residues significantly increased top dry weight of rice but had no significant effect on plant height and tiller number per hill (Table 4). Cattle manure application rates significantly affected plant height at harvest. Application of the

highest rate of cattle manure gave the maximum plant height but it was not significantly different from the rate of 6,250 kg/ha. Cattle manure application rates had no effect on tiller number per hill and top dry weight of rice. An interaction between pre-rice mungbean management and cattle manure application rate was found in tiller number per hill at harvest (Table 4). Under pre-rice mungbean treatment, application of cattle manure at the rate of 6,250 kg/ha resulted in the maximum tiller number per hill (10 tillers per hill) and was lowest in no cattle application treatment and at the rate of 3,125 kg /ha (7 tillers per hill). Under fallow treatment, application of different rates of cattle manure had no significant effect on tiller number per hill at harvest (Fig. 1(a)).

Table 5 Yield and yield components of KDML 105 as affected by pre-rice managements and cattle manure application rates at harvest

Treatment	Grain yield (kg/ha)	Panicle (no. per hill)	Grain (no. per panicle)	Filled grain (%)	1,000 grain weight (g)
Pre-rice management					
Fallow	2,433.5	6.19b	109.69	90.50	29.06
Mungbean	2,849.9	7.50a	106.81	90.13	29.14
F-test	ns	*	ns	ns	ns
Cattle manure application rate					
0 (kg/ha)	2,358.6b	6.13b	98.50	90.38a	28.90
3125 (kg/ha)	2,578.9ab	6.88a	111.13	88.63b	28.92
6250 (kg/ha)	2,709.3ab	7.38a	112.87	91.00a	28.94
9375 (kg/ha)	2,919.9a	7.00a	110.50	1.25a	29.63
F-test	**	*	ns	*	ns
Interaction					
F-test	ns	*	ns	ns	ns
CV a (%)	18.57	11.46	10.35	3.22	3.90
CV b (%)	10.32	10.37	15.34	1.78	3.13

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

Grain yield and yield components of succeeding rice

Grain yield of rice was not significantly affected by pre-rice management. However, incorporation of mungbean residues tended to increase rice yield up to 17% over the fallow treatment (Table 5). Cattle manure application rates significantly affected rice grain yield. The maximum grain yield was obtained at the highest cattle manure application rate (2.9 t/ha) but it was not significantly different from other two rates. There was no interaction between pre-rice mungbean management and cattle manure application rate in grain yield of rice (Table 5).

Growing mungbean before rice significantly increased panicle number per hill but had no significant effect on grain number per panicle, filled grain percentage and 1,000 grain weight. Cattle manure application rate significantly affected panicle number per hill and filled grain percentage. Cattle manure application at the rate of 6,250 kg/ha provided the maximum panicle number per hill but it was not significantly different from the other two application rates. Maximum filled grain percentage was obtained when cattle manure was applied at the highest rate (Table 5). Interaction between pre-rice mungbean management and cattle manure application rate was found. When mungbean residue was incorporated into the soil, application of cattle manure at the rate of 6,250 kg/ha gave the maximum panicle number per hill. However, when the field was left fallow, application of cattle manure at the rate of 3,125kg/ha resulted in the maximum panicle number per hill. No cattle manure application treatment provided the lowest panicle number per hill in both pre-rice managements with lowest in fallow treatment (Fig. 1b).

Nutrient concentration of rice at PI

Fallow and incorporation of mungbean residue into the soil had no significant effect on N and K concentrations of KDML 105 rice leaves at PI but had significant effect on P content (Table 6). Phosphorus concentration in rice leaves was higher in fallow treatment than mungbean residue

incorporation. Cattle manure application rates significantly affected N and P content in rice leaves but not K content. In terms of N concentration, application of the highest rate of cattle manure provided the highest leaf N concentration. Nevertheless, the highest P concentration was obtained when cattle manure was applied at the rate of 6,250 kg/ha (Table 6). There were interactions between pre-rice mungbean management and cattle manure application rate. When mungbean residues were incorporated into the soil, application of the highest rate of cattle manure provided the highest leaf N concentration. Under fallow treatment, application of different cattle manure rates had no significant effect on leaf N concentration (Table 7).

Table 6 Nutrient concentration (%) in leaf of KDML 105 as affected by pre-rice managements and cattle manure application rates at panicle initiation stage

Treatment	N (%)	P (%)	K (%)
Pre-rice management			
Fallow	1.977	0.229a	2.225
Mungbean	1.948	0.209b	2.323
F-test	ns	**	ns
Cattle manure application rate			
0 (kg/ha)	1.958b	0.212b	2.230
3,125 (kg/ha)	1.905b	0.222ab	2.222
6,250 (kg/ha)	1.946b	0.235a	2.333
9,375 (kg/ha)	2.041a	0.206b	2.310
F-test	*	*	ns
Interaction			
F-test	**	ns	ns
CV a (%)	8.27	1.12	5.72
CV b (%)	3.90	8.78	5.28

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

Table 7 Interactions between pre-rice management and cattle manure application rates on nitrogen concentration in leaf of KDML 105 at panicle initiation stage

Cattle application rate	N concentration in leaves of rice at PI	
	Fallow	Mungbean
0 kg/ha	2.019	1.896bc
3,125 kg/ha	1.973	1.836c
6,250 kg/ha	1.938	1.954b
9,375 kg/ha	1.976	2.1045a

*Means followed by the same letter in the same column had no significant difference by LS*D

Table 8 Yield, production cost, gross income and net income

Treatment	Yield (kg/ha)		Production cost (US $/ha)	Gross income (US $/ha)	Net income (US $/ha)
	Mungbean	Rice			
Fallow	0	1,995	26	966	940
Fallow+3125 kg CM per ha	0	2,502	176	1,211	1,035
Fallow+6250 kg CM per ha	0	2,427	327	1,175	848
Fallow+9375 kg CM per ha	0	2,810	477	1,360	883
Mungbean	1,635	2,722	297	3,152	2,855
Mungbean+3125 kg CM per ha	1,635	2,656	448	3,120	2,672
Mungbean+6250 kg CM per ha	1,635	2,992	598	3,282	2,684
Mungbean+9375 kg CM per ha	1,635	3,030	748	3,301	2,553

Note: CM = cattle manure; Planting material = mungbean seed 35 baht/kg, KDML 105 rice seed 26 baht/kg and cattle manure price 1.5 baht/kg; Market price of crop: mungbean seed 35 baht/kg and KDML 105 rice 15.1 baht/kg;
1 US$ =31.2 Thai baht
Production cost = Material cost + Land preparation for mungbean growing; Household labor is considered as farming labor

Economic return of growing mungbean before rice

All mungbean growing treatments provided higher net income than all fallow treatments. This is due to the additional income from selling mungbean grains. The net income of growing mungbean before rice without cattle manure application, however, yielded the highest net income because of low production cost. The net income was similar when growing mungbean as a pre-rice crop and application of different rates of cattle manure (Table 8).

DISCUSSION

The incorporation of mungbean residues into the soil did not significantly increase the grain yield of KDML 105 rice over the fallow treatment. However, pre-rice mungbean increased rice grain yield over fallow treatment by 416 kg/ha (or 17%). Suriyakup et al. (2007a) reported that grain yield of direct-seeded RD 6 rice variety was not significantly different when mungbean was incorporated into the soil at the flowering stage. However, grain yield of transplanted RD 6 rice with mungbean residues incorporated into the soil was increased by 355-1,399 kg/ha over the fallow treatment with weeds incorporated into the soil (Suriyakup et al., 2007b). In India, sown summer mungbean increased rice grain yields by 05-0.9 t/ha (Sharma et al., 2000) or 0.3 t/ha (Sharma et al., 1995). In the present experiment, the mungbean residue provided 3,163 kg/ha dry weight containing 50 kg N per ha, 10 kg P per ha and 166 kg K per ha. A similar amount of mungbean residue contributed to the soil of 2,810-4,170 kg/ha dry weight and 53-57 kg N per ha (Suriyakup et al., 2007b), 2.2-3.2 t/ha dry matter and 56.8- 70.2 kg N per ha (Sharma et al., 1995) have been reported. Bhuiyan et al. (2009) reported that mungbean residue accumulated 1.14-1.76 t of dry matter per ha which amounted to 14.6-43.1 kg N per ha, 1.26-3.66 kg P per ha and16.3-35.9 kg K per ha. Poomthaisong (2002) reported that the amount of nitrogen fixed by mungbean was 35-51 kg N per ha. However, in this study, the amount of nitrogen returned to the soil did not include nitrogen from fixation process.

Increase in the application rates of cattle manure significantly improved rice grain yield. Application of cattle manure at the highest rate (9,375 kg/ha) resulted in the maximum grain yield but did not make significant difference from other application rates. Polthanee et al. (2011) reported that application of cattle manure at 9,375 kg/ha with rice straw incorporated into the soil provided the maximum transplanted KDML 105 rice grain yield (3,820 kg/ha) (increased 717 kg/ha over no fertilizer plot). Grain yield of direct-seeded KDML 105 rice with cattle manure at the same rate was increased by 258 kg/ha over no fertilizer (Polthanee et al., 2008). Application of farmyard manure at 7 t/ha did not affect yield of rice and wheat in Bhutan but it increased organic carbon in the soil (Chettri et al., 2003). The maximum cattle manure rate in the study provided additional N, P and K to rice at122 kg, 68 kg and 183 kg, respectively. In the present study, calculated nutrients returned to the soil did not include nutrients from cattle manure being used as starter and nitrogen fixation process. Abe et al (1995) reported that cattle manure applied to the rice crop supported root growth at deeper soil layers by increasing root density and enhanced root growth.

The sufficient N concentration in leaves at the PI stage was about 2.6-3.2% of dry weight (Mikkelsen and Hunziker, 1971). In this study, the N in leaves at the PI stage was 1.905-2.041% of dry weight for all treatments. This indicates that the N in soil was not adequate for plant growth at PI. Dobermann and Fairhurst (2000) indicated that the N deficiency at the PI stage caused a reduction of grain numbers per panicle and filled grain percentage. The significant differences in tiller and panicle number per hill and filled grain percentage in this study may indicate that N is the limiting factor for rice crop production in sandy soils. Applied N may be lost by leaching, denitrification or remobilisation by microbiorganisms.

The sufficient P concentration value in leaves at the PI stage was about 0.17% of dry weight (Fageria et al., 1988). In the present experiment, P in leaves at the PI stage was 0.206-0.235% of dry weight for all treatments. This indicates that P in soil provided an adequate amount for rice growth at PI. Similarly, in the case of K, the sufficient K concentration value in leaves at the PI stage was about 1.0-2.2% of dry weight (Jones et al., 1991). In the present study, K in leaves at the

PI stage was 2.222-2.333% of dry weight for all treatments. This indicates that K in the soil was sufficient for rice growth at PI.

In the present experiment, even though rice grain yield from the mungbean-rice cropping system was not significantly different from fallow treatment, growing mungbean before rice provides the advantage of marketable grain of mungbean to 1.6 t/ha. Net income of all growing mungbean before rice treatments was 2.6-3.0 times higher than fallow treatment. Introduction of summer mungbean in the rice-wheat cropping system yielded 0.4-1.3 t/ha protein-rich grain in India (Sharma et al., 2000). Nevertheless, in terms of economic return for the whole cropping system, application of cattle manure at 3,125kg /ha at sowing date of mungbean may be sufficient to support mungbean growth and reduce the production cost of rice growing.

CONCLUSION

The incorporation of mungbean residue into the soil did not significantly increase the grain yield of KDML 105 rice over the fallow treatment. However, pre-rice mungbean increased rice grain yield over fallow treatment by 416 kg/ha (or 17%). In addition, the net economic return was found higher in all growing mungbean before rice cropping system than the fallow treatment. Application of cattle manure at 9,375 kg/ha resulted in the maximum grain yield (2,920 kg/ha) due to the effect on panicle number per hill and filled grain percentage. Incorporation of mungbean residue and cattle manure application at 9,375 kg/ha could not provide sufficient N to the rice crop in this experiment. Improvement of residue incorporation method, increase in cattle manure application rate or another rich N organic fertilizer source, as well as water management in the field need to be further studied to improve rice grain yield in sandy soil.

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Research article

Allelopathic Activity of Peruvian Corn Varieties

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Abstract Corn (*Zea mays* L.) is one of the three most important cereals in the world. Peru is one of the centers of biodiversity of corn in the world and has 35 ecotypes. In this study we compared the allelopathic activity of Peruvian native varieties of corn using the plant box method to evaluate the activity by root exudate and sandwich method to evaluate the activity by leaf leachate for sustainable weed managements. An experiment using native varieties of 6 Peruvian corn races (Cuzco, Amarillo ancashino, Morado, Piscorunto, Chullpy, Terciopelo) was conducted at National Agrarian University La Molina, Peru. Cuzco race (known as Giant corn) was the strongest with more than 75% of lettuce radicle inhibition. Besides, these samples were evaluated by sandwich method using 10 and 50 mg of dry leaves (24 hours at 60 °C). Another experiment to compare Peruvian and Japanese varieties was conducted at National Institute for Agro-Environmental Science, Japan. A total of 85 varieties (3 Peruvian varieties and 82 Japanese varieties) and 3 types of teosinte *Euchlaena mexicana* were evaluated by plant box method. From this evaluation, Peruvian varieties of Morado (known as Purple corn) and Maiz cancha, both varieties of soft corn type, showed a strong inhibitory activity. Kuromochikibi and other Japanese varieties of waxy corn type showed also strong inhibition of lettuce radicle growth. As a conclusion, we found that Peruvian native purple corn and varieties of soft corn and waxy corn types have potent allelopathic activity and promising crop for weed control at sustainable agriculture.

Keywords *Zea mays*, allelopathy, plant box method, sandwich method

INTRODUCTION

Allelopathy is a phenomenon of interaction between the compounds emitted by plants, which can cause inhibition or promotion effects to the organisms around. These compounds are called allelochemicals and nowadays are increasing interest in use of them to suppress weeds by natural exudation. This activity was reported from some crops and the evaluation of allelopathic potential in different varieties or related species could be important in areas like plant breeding or weed management (Wu et al., 2001).

Corn (*Zea mays*) is one of the most important crops in the world. The global corn production for 2011/12 is estimated around 867.5 million tons (USDA, 2011). This crop is native from Central America and was probably introduced to Peru in an early stage. The geographical diversity generates a high variety reflected in 51 Peruvian races and other 35 ecotypes (Abu-Alrub et al., 2004; Salhuana, 2004; Sevilla, 2005). Corn is generally produced in monoculture and some cases of low production related to allelopathic effect of this crop have been reported (Sarobol and Anderson, 1992). Another research of continuous cropping of corn for 3 years showed a decrease of 13% of production compared with a field with crop rotation (Lund et al., 1993). Most research related to corn allelopathy is done with a limited number of varieties. We compare the allelopathic activity of Peruvian varieties, as well as a large number of Japanese varieties and an ancestor of corn, teosinte.

METHODOLOGY

Plant materials

First experiment: The seedlings of varieties of 6 Peruvian corn races (Cuzco, Amarillo ancashino, Morado, Piscorunto, Chullpy, Terciopelo) were cultivated in sand substrate for one month in a greenhouse of Vegetable Program of National Agrarian University La Molina (UNALM). The seeds were provided from Maize Program of UNALM. The plant box and sandwich method experiments were conducted in laboratories of the Institute of Biotechnology of UNALM.
Second experiment: A total of 85 varieties of corn (3 Peruvian and 82 Japanese varieties) and 3 types of teosinte (*Euchlaena mexicana*) were evaluated by plant box method on laboratories of National Institute of Agro-Environmental Sciences (NIAES), Japan. The seedlings were cultivated in a greenhouse with sand substrate for one month.

Plant box method

Seedlings of around one month old were used for bioassay in a Magenta GA-7 vessel (6×6×10 cm, Magenta Co. Ltd., USA) called 'plant-box', for evaluating the allelopathic activity through root exudates (Fujii, 1992). After removal of seedlings from the pot, the roots were carefully washed with distilled water and inserted into a column of a nylon mesh (0.22 mm) that was subsequently placed at a corner of the plant box. Then, autoclaved agar 0.75% (w/v) (Nacalai Tesque Co. Ltd., Japan) was placed at 40° C into the plant box. After gelatinization of the agar, a total of 33 seeds of lettuce (*Lactuca sativa* L., Great Lakes No. 366, Takii Co.) were sowed at different distances from the corner with the donor plant. The box was covered with clear wrap to prevent evaporation, and then each box was put in a black vinyl pot to cover the roots of each seedling. Finally, all the plant boxes were kept at 20 ºC with a 12/12 h photoperiod for 5 days in an incubator (BITEC-500L, Shimadzu Instruments Co. Ltd., Tokyo, Japan). After incubation, the radicle and hypocotyl length of lettuce seedlings were measured. A plant box without donor plant was used as a control. The experiment was conducted with three replications.

Sandwich method

Sandwich method was developed by Dr. Fujii as a bioassay to determinate the allelopathic activity of the leaches from donor plant leaves (Fujii, 1994). A total of 10 or 50 mg of dried leaves were placed into 3 wells of the six-well (around 10 cm^2 area per well) multi-dish plastic plate (35mm×18mm, Thermo Fisher Scientific Inc.). Agar powder (Nacalai Tesque Inc.) was used as growth medium (0.75% w/v). In each well, 5 ml of agar solution was added on 5 ml agar to make two gelatinized layers in between and 5 seeds of the test plant lettuce (*L. sativa* L., Great Lakes No. 366, Takii Co.) were seeded on the surface. The multi-dish was covered with plastic tape, labeled, wrapped in aluminum foil and incubated in dark at 25ºC for 3 days. The length of hypocotyl and

radicle of lettuce seedlings were measured on the third day; these data were used to calculate the percent elongation to control.

RESULTS AND DISCUSSION

First experiment

The results of evaluation of varieties of 6 Peruvian corn races by Plant Box Method showed a strong inhibition in the lettuce radicle growth (11%) by variety of Cuzco race. The inhibition activity of other varieties ranged between 22 and 35% (Table 1).

Table 1 Evaluation of allelopathic activity of varieties of 6 Peruvian corn races by plant box method and sandwich method

Peruvian corn races	Percentage of radicle growth of lettuce(%)		
	Plant Box Method	Sandwich Method	
		10mg	50mg
Cuzco	10.9	50	21
A. Ancashino	21.9	40	17
Morado	26.6	45	21
Piscorunto	29.7	37	15
Chullpy	31.9	53	22
Terciopelo	35.0	42	13

Cuzco ('Giant corn') corresponds to the second derivation from primitive races of Peruvian corn. This race is cultivated on the Central Andes at an altitude of 2,300 to 3,300 m and was spread with the expansion of Inca Empire from Ecuador to the north of Argentina. In Peru it is mostly consumed by being boiled or as flour (Ortiz et al., 2008; Salhuana et al., 2004).

The allelopathy activity of leaves of the varieties of 6 Peruvian races was evaluated using 10 and 50 mg of dry leaves by sandwich method. By 10 mg most of them showed around 50% of inhibition of lettuce radicle growth; using 50 mg that was more than 80% in all varieties. Piscorunto showed higher activity in both concentrations; 37 and 15% growth of radicle respectively (Table 1). Piscorunto corresponds to the race derived from primitive races. This race is cultivated on the Southern Andes at an altitude of around 3,000 m (Salhuana et al., 2004).

Second experiment

The Peruvian corn varieties evaluated were Purple corn (from three commercial companies: El Shaday, Inca's Food, Peru Cheff), Cancha corn and Chullpe corn. The other group of 82 Japanese varieties was composed mostly by varieties of sweet corn. Another 3 types of teosinte, *E. mexicana*, (PI441932125, Ames8083, Ames21869) were obtained from North Central Regional Plant Introduction Station (NCRPIS).

To compare all varieties, we classified them using the description of types of corn related to the amount of starch in the grain (Tozawa, 2005).

Dent corn (*Z.mays* var. indentata): The grains have a depression on the top, with shape of tooth. Hard starch granules are accumulated in both sides and soft starch granules are accumulated from the top to the middle. Three-quarter of percentage of starch is soft.

Flint corn (*Z. mays* var. indurata): The grain has the form of hard flint, with a round shape. The soft starch is concentrated in small amount in the center covered by hard starch.

Sweet corn (*Z. mays* var. saccharata): Grain endosperm is mostly sugar. The sugar transported from leaves and stems is directly stored in the grain.

Pop corn (*Z. mays* var. everta): This group has a similar carbohydrate configuration of Flint

corn, but is different in that it contains hard starch in the endosperm and a small portion of soft starch inside.

Flour corn (*Z. mays* var. amylacea): It is a round type of Flint corn. The endosperm is mostly constituted by soft starch and the grain is light.

Waxy Corn (*Z. mays* var. ceratina): This type is a mutant from China. Most of the starch consists of amylopectin with low amylose.

Table 2 Evaluation of 85 corn varieties and 3 types of teosinte by plant box method

Corn variety	Type*	Radicle growth (%)	Corn variety	Type*	Radicle growth (%)	Corn variety	Type*	Radicle growth (%)
Purple corn (El Shaday)**	Sf	3.02	Honey Bantam Peter 445	Sw	12.0	Hazetomorokoshi	P	16.9
Purple corn (Inca's Food)**	Sf	3.58	Yumemi Dream	Sw	12.2	New Dent 100 LG3457	D	17.1
Kuromochikibi	W	4.35	Peter Corn	Sw	12.5	Taiyo no megumi	Sw	17.5
Cancha corn**	Sf	4.91	Gosaku	Sw	12.6	Gold Dent KD640 [RM114]	D	18.0
Peter 001	Sw	5.06	Spectra	P	12.6	Canberra 90	Sw	18.4
Ohisama corn 7	Sw	6.00	Kyokuwase Jelly Bantam	Sw	12.9	Teosinte PI4419321250	T	19.8
Big Summer	Sw	6.74	Mirai 390	Sw	13.0	Gold Dent KD670 [MR117]	D	20.1
Ajiichiban	Sw	6.95	Mochimurasaki	W	13.1	Gold Dent KD520 [RM105]	D	20.5
Cocktail E51	Sw	7.32	Miwaku no corn Gold Rush	Sw	13.4	Canberra 86	Sw	21.6
Amaindesu	Sw	7.43	White Queen	Sw	13.8	New Dent 90 days ANJOU259	D	21.7
Oomono	Sw	7.65	Popcorn	P	14.4	Dodeka corn Yusaku	Sw	23.2
Marukajiri	Sw	8.16	Chullpe corn**	Sw	14.5	Picnic corn	Sw	23.6
Purple corn (Peru Cheff)**	Sf	8.17	Harmony Chocolate	Sw	14.9	Silage corn NS-118	D	23.7
Sunny Chocolate	Sw	8.42	SnowDent Onatsu SH9904	D	15.0	Gold Dent KD772 Super [MR130]	D	24.0
Diachi no megumi	Sw	8.79	Cocktail 600	Sw	15.0	New Dent 85 days LG3263	D	24.9
Cocktail 83L	Sw	9.23	Gold Rush	Sw	15.3	New Dent 85 days Richmond	D	25.3
Shiromochikibi	W	9.25	Woody corn	Sw	15.3	Pioneer 106 days 36B08	D	26.7
Kiimochikibi	W	9.85	Fleet	Sw	15.3	Bikkuri Sweet	Sw	27.2
Sakichan	Sw	9.94	Sweets Megumi 86	Sw	15.5	Salad corn	Sw	27.3
Ohisama corn	Sw	10.0	Honey Bantam Peter 610	Sw	15.5	Honey Bantam Wase 200	Sw	27.5
Kiihachiretsuurukibi (Longfellow)	F	10.1	Snow Dent 118 DKC61-24	D	15.5	Baby corn	P	27.7
Cocktail 84EX	Sw	10.3	Miwaku no corn	Sw	15.6	Pioneer 115 days Cecilia	D	28.4
Honey Bantam Peter corn	Sw	10.5	Teosinte Ames8083	T	15.7	Yawaraka Gold	Sw	29.3
Yume no corn	Sw	10.9	Golden Honey	Sw	15.9	Harmony Festival	Sw	29.7
Amamichan	Sw	11.2	White Popcorn	Sw	16.2	Super Suite Big	Sw	31.7
Lucy 90	Sw	11.4	Honey Bantam Peter 235	Sw	16.5	Gold Dent KD850 [MR135]	D	36.1
Sunny Fest	Sw	11.5	Cynthia Neo Dent 90 SL9945	D	16.5	Pioneer 135 days 30D44	D	40.3
Honey Bantam 20	Sw	11.7	Pioneer 88 days Deer HT	D	16.5	Pioneer 120 days 31P41	D	44.7
Yellow Popcorn	P	11.8	Super Sweet bicolor	Sw	16.8	Teosinte Ames21869	T	49.8
Honey Bantam	Sw	11.8	Amairo	Sw	16.9	Strawberry corn	P	51.1

*D Dent Corn, F Flint Corn, P Pop Corn, Sf Soft Corn, Sw Sweet Corn, W Waxy Corn, T Teosinte ** Peruvian varieties

From the total of varieties and species evaluated, the lettuce radicle growth ranged from 3 to 50%. Peruvian purple corn (El Shaday) showed the strongest inhibition effect in lettuce radicle growth (3%). Other Peruvian varieties of soft corn also showed a strong inhibition. Purple corn is considered as one of the most important Peruvian native varieties. The main characteristic of this variety is the deep purple color due to anthocyanin, present in the grains and some other parts of the ear and plant. It is cultivated from 1,200 to 4,000 m of altitude from the Coast to the Andean region. The purple corn is used to make a traditional Peruvian sweets and the pigment is used in the food industry. In recent years this compound attracts attention as a health food. (Salhuana et al., 2004; SIRA, 2005; Tenorio, 2007). The second variety with a strong inhibition was Kuromochikibi from the group of waxy type (Kuromochikibi, Shiromochikibi, Kiimochikibi). These two varieties, Purple corn and Kuromochikibi have same characteristic of dark color but it was not possible to know the relation with their inhibitory activity.

From the 82 Japanese varieties evaluated, 63% of them (52 varieties) were sweet corn type and the percentage of growth of lettuce radicle ranged from 5 to 30%. As for dent corn type, most of the varieties showed low inhibitory activity. However, to clarify whether the differences in allelopathic activity is due to genetic differences, it is necessary to explore the ancestral lineage.

Among the features in plant breeding is mentioned the reduction of the chemical components of protection (Pickersgill, 2007).

Teosinte (*E. mexicana*) is considered an ancestor of corn (Galinat, 1995). Three varieties were evaluated and two of them (Ames8083 and PI4419321250) showed a percentage of lettuce radicle growth of 16 and 20% respectively. Just Ames21869 reported a low activity (50%) compared to other types of this group.

CONCLUSION

In the evaluation of varieties of 6 Peruvian corn races by plant box, the growth of lettuce radicle fluctuated from 11 to 35% and the strongest variety was from Cuzco race. The evaluation by sandwich method of the same samples did not show significant differences.

The second evaluation of 85 varieties by plant box showed lettuce radicle growth percentage from 3 to 51%. The strongest varieties were from the group of soft and waxy corn with varieties of Purple corn (3%) and Kuromochikibi (4%) respectively.

Peruvian varieties evaluated in these two experiments showed high allelopathic activity under the plant box method. Based on these results we can affirm that allelochemicals are exuded by the roots and activity differs according to varieties. However, it is necessary to confirm the relationship between varieties and allelochemicals released from this species.

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Research article

Introduction and Adoption of Rice Intensification System towards Low-Input Agricultural Production in Vietnam

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Abstract This paper illustrates the viewpoints of the government, farmers' organizations, namely Agricultural Production Cooperatives (APCs), and individual farmers in relation to the introduction and adoption of a System of Rice Intensification (SRI) in Vietnam. It also identifies factors that can promote or impede the social shift towards fewer agricultural inputs through the SRI method. The qualitative analysis is based on field studies in three communes in the Red River Delta as well as interviews with relevant actors in Vietnam in order to describe each actor's viewpoints and the realities of farmers' behaviors towards agricultural inputs. We demonstrated that farmers could correct their overuse of pesticides and herbicides by SRI adoption through training opportunities provided by a Farmer Field School (FFS), inducing farmers to recognize the positive effects of SRI on pest damage and plant protection. However, we also found that the attitude and mental barriers of some governmental bodies and APCs narrowed the opportunities of SRI introduction at a community level. In addition, farmers often faced initial mental barriers and managerial difficulties in adopting the full elements of SRI even if they were trained in the SRI method, leading them to adopt a "modified" SRI in order to meet their personal needs. Nevertheless, the rapid extension of SRI in Northern Vietnam can be explained by: (i) the government's acknowledgement of SRI, together with an administrative focus on the integrated pest management with the extension tool of the FFS, (ii) the role of APCs in coordinating farmers to lower the entry barriers for them to adopt new techniques, and (iii) communities' involvement in SRI adoption in order to manage agricultural production collectively without pesticides and herbicides as well as increasing the product's value, suggesting possible approaches for small-scale farmers to improve their livelihoods while saving agricultural input costs.

Keywords system of rice intensification, Vietnam, low input agriculture, farmer field school, integrated pest management

INTRODUCTION

The rapid growth of agricultural production in Vietnam has often been accompanied by a heavy use of agricultural inputs, bringing serious problems of food safety and environmental stress (Van Hoi, 2009; Khanh, 2006). For many developing Asian countries, the difficult challenges of adopting alternative agricultural methods that have less environmental burden in a sustainable manner remain (Kada, 1998).

Aiming to identify factors behind a social shift towards low input agriculture in Asian developing countries, this paper explores the realities of the uptake and spread of the System of Rice Intensification (SRI) in Vietnam, as one of the low external-input technologies (LEIT) (Tripp, 2006). SRI was first tested in Vietnam in 2002, and it has been drastically popularized in Northern Vietnam since 2007. Approximately 780,000 farmers practiced SRI within an area of about 286,000 ha in 2010 (Plant Protection Department, 2010). The principles of SRI in Vietnam include: (i) transplanting young seedlings with two or three leaves, (ii) transplanting seedlings individually and spacing them widely, giving them maximum access to the sun and room to grow to their full potential, (iii) managing water carefully, providing intermittent irrigation to keep fields moist, but

not continuously flooded, (iv) weeding frequently, either by hand or with mechanical weeding devices, and (v) using organic fertilizers, such as animal and plant waste, to promote the development of a healthy soil ecosystem (http://vietnamsri.wordpress.com/). SRI enables plants to grow efficiently by means of more fertile soil and to produce healthier plants with greater root growth.

The objective of this paper is to illustrate and analyze the viewpoints of different actors and to describe farmers' actual behaviors on pesticides and herbicides in relation to SRI introduction and adoption. The experience of SRI extension in Vietnam will be discussed in order to identify factors to promote or impede the introduction and adoption of SRI as a low-input cultivation method.

METHODOLOGY

This paper is based on field studies conducted in November 2009, August and October 2010, and January-February and June-July 2011. The sample population consists of three communities under the management of three Agricultural Production Cooperatives (APCs) in the Red River Delta (RRD), namely the APC "A" of the Chuong My district and "B" and "C" of the My Duc district in the Ha Noi City (former Ha Tay Province). This paper is supplemented by interviews with different actors and informants and a literature review. The qualitative research method is used for analysis, which is supported by semi-structured and open interviews and questionnaire surveys to target actors, namely farmers, managers of APCs, government officials of key agencies, and donors. In addition, the participant observation method is applied as the researcher enters the lives of farmers.

RESULTS

Introduction of SRI to rural communities by government

SRI was first tested in 2002 and 2003 at a small scale and then at a larger scale in 2005 and 2006 under the scheme of the Integrated Pest Management (IPM) program implemented by the Plant Protection Department (PPD), MARD (Ministry of Agriculture and Rural Development). Results from 2005 and 2006 tests indicated that a significant reduction in input use was possible without yield drops: seed and nitrogen volume was reduced by 70-90% and 20-25%, respectively, while average yield increased by 9-15% (Plant Protection Department, 2010). The crop also showed good resistance against pests. Such results were reported to the Council for Science and Technology of MARD for evaluation, sharing with other state management agencies that manage crop production, extension, science and technology and water resource management.

Several agencies, however, interpreted that some principles of SRI contradicted their policies. For instance, the extension policy was focused more on disseminating the direct seedling method nationally with continued herbicide use for rice cultivation to decrease labor intensity. These agencies considered that SRI was applicable to the "transplanting" technique only, requiring more labor, meaning that it was not suitable to extend SRI to southern areas where direct seedling were generally applied and promoted. Political contradictions perceived by several agencies of MARD implicitly influenced the actual dissemination of SRI to limited areas (mainly Northern Vietnam), even though MARD officially admitted the technical advantages of SRI, issuing a decision in 2007. In spite of the negative attitudes of some governmental agencies, PPD, the only state management agency that actively disseminates SRI, considered the SRI method to be compatible and effective with the IPM approach, and therefore determined to extend it through its own extension tool, the Farmer Field School (FFS), which was often used to promote IPM in Vietnam. Moreover, many IPM officers were stationed across the nation in order to teach farmers about SRI methods through the FFS.

It should also be noted that MARD's decision to acknowledge SRI provided new opportunities through additional support with more fund availability. In addition, some international NGOs included SRI extension activities in their own projects in Vietnam, as they observed that SRI could be an effective tool to build farmers capacity because testing SRI at the

FFS requires farmers' openness and confidence towards the new method in addition to a risk-taking attitude.

APCs' agricultural management and organization of the FFS for SRI introduction

Characteristics of agriculture and the role of APCs: Through the policy reform in 1988 and the revised land law in 1993, the land use right of farmland was distributed equally to farmers in Vietnam. For instance, 3-6 pieces of scattered land with a total size of 0.3-0.4 ha were allocated to each household in the RRD. Several farmers use parts of the same paddy plots and operate and manage farming jointly through an agreement on water management and other cultivation activities. APCs typically operate and manage the irrigation system and provide agricultural services in the RRD. They were originally set up as the center of collective agricultural production regime at the end of the 1950s, but transformed to become service providers for farmers along with the Cooperative Law in 1996.

Because of the characteristics of agriculture in the RRD, especially the presence of many small-scale farmers, APCs can be the first contact point to coordinate farmers to introduce the new method. In the case of introducing SRI at community level, the Provincial PPD first asked APC managers if they wanted to introduce SRI to their communities. APC managers were given opportunities to visit the SRI test sites in order to make decisions. Table 1 shows the different characteristics (management style, attitudes towards new techniques and social relations with farmers in the communities) of each APC. Only APCs A and B, but not APC C, were willing to introduce SRI to farmers.

Table 1 Characteristics of APCs and SRI introduction to farmers

	APC A	APC B	APC C
No. of households	1,400	750	1,860
Paddy field area	240 ha	180 ha	436 ha
SRI introduction	2007	2006	Not yet
APC's objectives	Economic development through agricultural activities	Economic development through agricultural activities	Accomplishment of assigned task
APC's attitude towards SRI	Interested in testing SRI after being convinced by the effect during site visit	Interested in testing any new techniques (including SRI) on a small plot	Understood SRI's effect but technically difficult to adopt
Social relation with farmers	Small local production groups are invited to take part in APC management	APC directly coordinates and negotiates with farmers	Lack of trust between APC and farmers observed

Attitudes: (i) APC A introduced SRI to its community after the APC confirmed its performance by visiting other SRI sites. The government's approval of the SRI method also provided a mental ease to the APC A in disseminating the new method to communities with governmental authorization. (ii) APC B was the pioneer of SRI introduction at a community level. The APC wished to experiment any new technique even if it was not well recognized. The early experiment was perceived to be possible in the APC B, as the experiment was always started with a small area to evaluate the results first, lowering potential loss. (iii) APC C also had opportunities to visit SRI sites, and observed that the SRI method would give better results than the conventional method did. However, it decided not to introduce SRI because of perceived technical difficulties.

Relations with farmers: (i) APC A had seven Production Groups, which have been the social and economic core of local communities with historically developed territorial bonds. The APC coordinated well with leaders of each Production Group and arranged core farmers of the Production Groups to participate in SRI experiments at the FFS site that the APC rented from farmers. The APC influenced Production Groups to self-manage the production process while suggesting strategies to produce high-value products, providing fertilizers and high-quality rice varieties. (ii) In APC B, not all farmers necessarily supported the introduction of SRI at the beginning because it was an unconventional agricultural method and the APC had to negotiate well and to guarantee the productivity of SRI for farmers in advance. In addition, APC B risked its

reputation if the new method was to fail. However, it gained its confidence on the SRI method as the rice grew, and eventually gained further trust from farmers after achieving higher yields with reduced inputs. (iii) APC C felt difficulties attracting farmers to challenge SRI or any kind of new techniques under the guidance of the APC. It provided services to the administrative area, which had been established by merging three villages, and as a result local farmers had little attachment to the new "commune" and the agricultural activities of the three villages were not managed easily in a unified manner. Severe criticism about the performance of the APC and farmers was typically heard from both sides, reflecting a lack of trust between them.

Adoption of SRI and use of external inputs by farmers

Adoption of SRI: Core farmers from APC A participated in the FFS without hesitation as it was a pure learning opportunity and did not sacrifice their own fields. Those farmers were given opportunities to evaluate rice growth through the SRI method by themselves and found that the SRI method brought about higher benefits despite reducing labor and input costs. The difficulties that farmers generally felt came mainly from the technical side, such as handling small seedlings at transplanting, careful land preparation, and controlling water. Even with such difficulties, farmers who participated in the FFS were satisfied with SRI because of its cost advantages. Core farmers who were impressed by the advantages of SRI then became farmer-trainers in order to transfer SRI techniques to those who did not participate in the FFS. As core farmers had been selected from leaders of small-scale communities in which neighboring farmers have close relationships, they tended to believe and follow what the leaders learnt at the FFS. Furthermore, farmers who lived near the FFS site had easy access to observe the progress of the SRI experiment despite not being officially involved in the FFS's training activities. Farmers who lived near the FFS site started to adopt SRI right after its introduction in 2007, followed by neighboring farmers.

Farmers in APC B recalled their feelings of the difficulties in accepting SRI at the beginning, as they could not believe its effects (especially not believing in using small seedlings, transplanting with space and not keeping flooded water), and even remembered disputes among neighbors that disagreed with SRI adoption. With compensation deals offered via the APC for any possible losses associated with testing SRI, farmers finally accepted testing SRI through the FFS using some portions of their own land but not taking any financial risks. The SRI experiment was started from 4 ha in 2006, then expanded to 15 ha in the spring of 2007, 50 ha in the autumn of 2007, and all fields, 180 ha, in the spring of 2008. Farmers were confident about adopting SRI in their own land without having any compensation deal in 2009, while making flexible and innovative adjustments to overcome their technical and mental difficulties of SRI adoption. Modifications to the SRI method in 2010 and 2011 were: 15-18 cm space between ridges (narrower than the FFS's best results but wider than the conventional method) and the transplantation of seedlings few days older than originally recommended. Narrower transplanting was preferred by farmers with larger farmlands because they preferred to lessen the weeding cost, reducing weed growth with less sunshine.

In the commune C, farmers were unfamiliar with SRI and typically conducted their own cultivation activities, believing in the conventional method.

Use of agricultural inputs: The reduced use of seedlings and water resources is a widely recognized characteristic of SRI because of its SRI principles. In order to understand actual farmers' behaviors in terms of pesticide and herbicide use, Table 2 summarizes the interviews and observation results. Farmers in A and B reduced or stopped using pesticides as they learnt through the experience of the FFS and SRI adoption that healthier roots with wider spaces between plants brought about fewer occurrences of pests and diseases. By contrast, farmers in C who had not received any opportunities to adopt SRI believed that the more pesticides they sprayed, the more they could protect their rice from pest attacks. These farmers tended to use pesticides in every crop season regardless of the degree of pest damage.

Table 2 Pesticide and herbicide use by farmers

	Village X(*) APC A	Villages Y1 and Y2 APC B	Villages Z1 and Z2 APC C
Pesticides	No use	・Spring rice: No use ・Summer-autumn rice: no use or spray once if heavy damage is expected	Spray more than twice for any crop season
Herbicides	No use	Use sometimes to cover labor shortage	Always use (at least once) to cover labor shortage

Note: Based on (i) repeated interviews with six farmers in the Village X, three farmers in the Village Y1 and Y2, and three farmers in the Villages Z1 and Z2, (ii) interviews with APCs to confirm general behaviors and perceptions of farmers, and (iii) participatory observation results in villages.
(*) FFS site for SRI experiment was located in the Village X of the commune A.

Farmers' use of herbicides were more complex because of the trade-offs with labor costs. As seen in APC B, farmers kept using herbicides even though they realized that earlier weeding practice made the work easier and also acknowledged the negative influence on their own health. If farmers decided to weed completely by hands instead of using herbicides, farmers with larger land needed to employ additional labor for weeding. Increasing labor cost in Vietnam was a serious burden for farmers, and therefore farmers in APC B still preferred to use herbicides to save labor costs. On the other hand, farmers in the Village X of the commune A had already become accustomed to using no herbicides, establishing an easier way of weeding by strictly following SRI guidance while they were advised not to use pesticides and herbicides to obtain a certificate so that the Production Group as a whole could sell the rice at a higher price. In addition, farmers in the same Production Group in the village had close family-like relationships, and such united farmers' Production Groups worked together to maximize their community's profit by producing high-quality rice without using pesticides and herbicides, planting the same varieties in order not to mix with other varieties in the area. Farmers were able to achieve higher profits this way with less use of pesticides and herbicides and caring for community members' health at the same time.

DISCUSSION

From the experience in Vietnam regarding the introduction and adoption of SRI, multi-layered barriers - government, farmers' organizations (i.e., APCs), and farmers - were found. First, the government's belief in SRI's limitation (i.e., labor-intensiveness or incompatibility with direct seedling) led to narrowing areas of SRI introduction to Northern Vietnam. Second, the introduction of SRI into local communities was influenced by management capacity and attitudes of APCs who could act as coordinating agencies to promote the uptake of SRI in their communities. Finally, farmers' attitudes and their managerial difficulties (e.g., preference to use herbicides over weeding by hands to save labor costs for large fields) could cause farmers not to adopt some elements of SRI. By contrast, the rapid extension of SRI in Vietnam since 2007 can also be explained by efforts made by the government, farmers' organizations (APCs), and farmers. The approval of SRI in Vietnam added confidence to the PPD to disseminate it widely in Vietnam, lowering the political risk for local adopters to implement techniques backed by the government. APCs' strategic support to farmers to test SRI lowered risks while the extension tool of the FFS together with IPM experience gave opportunities for farmers to examine the effect of SRI by themselves, which helped them make rational decisions about whether to adopt SRI, overcoming their initial prejudice against it. Moreover, the introduction of SRI to the community did not only test the APC's managerial capacity but also provided further managerial opportunities. As seen in APC A, rice that was grown without the use of pesticides and herbicides was differentiated by high price, which was realized by a small-scale community's bond and thus secured social and economic profit for the overall community. Such a system to reward the effort of both individuals and the community, together with strong community relations, worked as positive factors to reduce the use of herbicides.

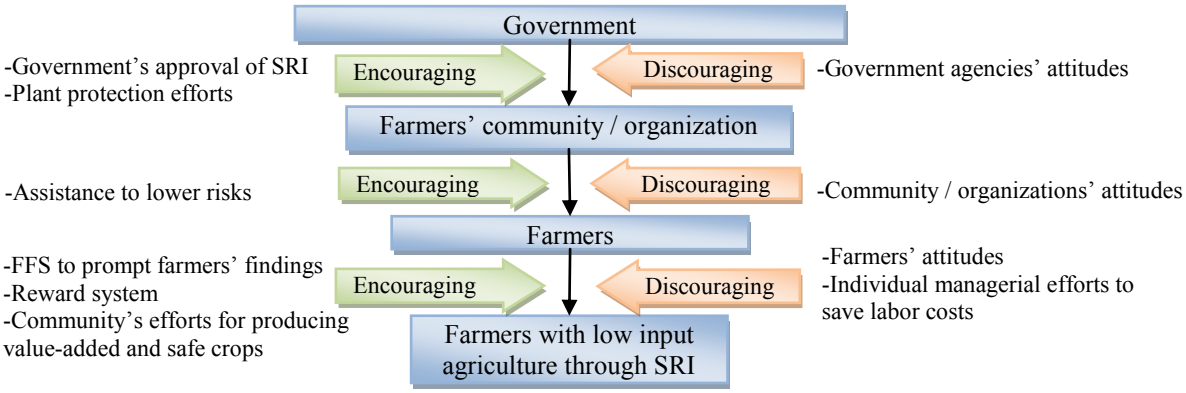

Fig. 1 Multi-layered actors and factors influencing SRI introduction and adoption

CONCLUSION

This research found that two communities (namely areas under APC A and B) that introduced and adopted SRI experienced community-based shifts toward lower agricultural inputs. The case of APC A especially indicated that it was possible for a community as a whole to manage the production of value-added rice without using pesticides and herbicides. Factors that promoted the introduction of SRI included the government's initiative, especially through the IPM program with the FFS and the management efforts of farmers' organizations to lower farmers' entry barriers to adopt SRI, even though the political attitudes of some government bodies as well as the limited capacity and attitude of agricultural organizations could also become barriers to SRI introduction. This research also demonstrated that the social solidarity of rural communities in the RRD could be a source of competitive advantage because it could allow the Production Group to supply high-quality crops without the use of pesticides and herbicides.

Although small-scale farmers in the RRD have limited capacity in the face of the market-oriented economy in Vietnam, this research suggests possible approaches to raise their competitiveness with community-level efforts towards safe crop production while tackling issues related to the overuse of agricultural inputs.

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Research article

Effects of Eri-Culture on Promoting Environmental Awareness in Greater Phnom Penh of Cambodia

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Abstract Currently in Greater Phnom Penh of Cambodia, the majority of famers apply agricultural chemicals such as chemical fertilizers or pesticide to maintain high levels of crop yield. However, agricultural chemicals released from farmlands are causing severe problems, such as the health damage of famers or the degradation of soil and water environment. So, an attention has been paid to approach sustainable rural development as regional challenges in the Education for Sustainable Development, ESD. This research dealt with the evaluation of the effects of eri-culture on promoting environmental awareness of local farmers, especially regarding the reduction of chemical pesticide applied. As eri silkworm is sensitive to agricultural chemicals, research interests have been focused on how eri-culture affects the environmental awareness of local farmers who rear eri silkworm. Eri silkworm, a kind of wild silkworms that inhabit south Asia, has been introduced to local villages in Kampong Cham province since October 2010 for a part of the activities of Regional Centre of Expertise in Greater Phnom Penh. The workshops have been organized 2 times for local farmers including the demonstration of eri-culture in November and December 2010. Also, the training on eri-culture was conducted to each local farmer who has started rearing eri silkworms. After 6 months from introducing eri-culture in Kampong Cham province, the questionnaire survey was conducted in March 2011 to evaluate the effects of eri-culture on promoting environmental awareness of local farmers. The results showed that rearing farmers wanted to reduce 92.5% of chemical pesticide compared to the conventional way. While local farmers who just participated or who have never participated in the workshops showed only 72.3% or 66.9% of chemical pesticide to be reduced. So, there was a tendency the expected percentage of chemical pesticide to be reduced for rearing farmers was remarkably higher than that for local farmers who just participated in the workshop or who have never participated in the workshops. Accordingly, it was considered that eri-culture has educational function for local farmers regarding the reduction of chemical pesticide application. However, other trainings such as sustainable farming practices may be indispensable to reduce the amounts of chemical pesticide applied with minimizing the insect damage to agricultural products.

Keywords: eri-culture, sustainable rural development, ESD, environmental awareness

INTRODUCTION

Greater Phnom Penh is composed of Phnom Penh city and six surrounding provinces of Kampong Cham, Kandal, Prey Veng, Kampong Speu, Kampong Chhang and Takeo provinces. The total population of those areas is 7,250,881 and the area of Greater Phnom Penh is 34,641 km2 (Source:

General Population Census of Cambodia 2008). More than 70 % of population is engaged in agriculture and related sectors.

Population increases rapidly in Cambodia, which causes many problems in environment, quality of life, education and human health. Education is always the key to develop human resources that is necessary for the country's development. However, there are many obstacles that make things difficult in Cambodia, for examples, lacking teachers, lacking school facilities, low income of the people and lacking of educational awareness. According to the statistics 2010/2011 of Ministry of Education, Youth and Sport, Cambodia (MoEYS), while the net enrollment ratio for primary school in Kampong Cham province is 96.8 %, the ratio for lower secondary school is 28.3% and for higher secondary school only 14.4%. As a whole, the situation in rural area is much worse than that in urban area. After the enrollment to school, the statistic shows that the severe situation for children to continue their study. The percentage of dropout in primary school (grade1-6) is 10.1%, in lower secondary level (grade7-9) is 22.4% and in upper secondary level (grade10-12) is 13% (Education Indicators, 2010/2011) in Kampong Cham province, and the situation is quite same in other areas of Cambodia.

Also the majority of farmers apply agricultural chemicals, such as chemical fertilizers or pesticides to achieve and maintain high levels of yield. However, the overuse of agricultural chemicals caused the degradation of water regime that is released from farmlands to downstream. Therefore, the education for sustainable development (ESD) is necessary to approach sustainable rural development.

Regional Centres of Expertise (RCE) is a network for existing formal and non-formal organizations to deliver ESD to local communities in respective countries. RCE Greater Phnom Penh (RCE-GPP) has been established to promote ESD through the food, agriculture and environment education for sustainable development in the area of Greater Phnom Penh and was officially acknowledged by the Global RCE Centre of the United Nations University, Institute of Advanced Studies (UNU-IAS) on December 26, 2009. RCE-GPP aims to enhance the food, agriculture and environment education not only for primary schools but also for local communities through organic farming activities under the cooperation of government, universities, local NGOs and local communities in Greater Phnom Penh.

So, in above activities, cultivating eri silkworms called "eri-culture" has been introduced to local villages in Kampong Cham province since October 2010 for a part of the activities of RCE-GPP, which is aiming to promote the Education for Sustainable Development (ESD).

OBJECTIVE

The objective of this paper is to evaluate the effects of eri-culture on promoting environmental awareness, especially the environmental awareness in terms of the reduction of chemical pesticide application in local villages in Kampong Cham province, which is located in Greater Phnom Penh, Cambodia. Due to the characteristic of eri silkworm, the usage of chemical pesticide should be concerned. Through the introduction and implementation of eri-culture in local villages, it was discussed how eri-culture affect to the local people for changing and improving their environmental awareness.

METHODOLOGY

Eri-culture

Eri silkworm, *Samia Cynthia ricini*, is one kind of wild silkworms that inhabit south Asia (Photos. 1-3), and it is said that its origin is Assam province, India. Now not only in India, eri-culture has been conducted in various countries, such as Thailand, Vietnam, China, Philippines, Ethiopia and Cambodia. Wild silkworms inhabit all over the world with more than 500 varieties, and each has very different unique characters.

Not only eri silkworm but also other kinds of wild silkworms have a very unique characteristic

with cocoon, so called 'nano-tube structure' (Akai and Nagashima, 2001, 2002). This nano-tube structure makes eri silkworm very unique with high functionalities as material, such as high ultraviolet protection and high moisture absorbency.

Specializing about eri silkworm, it has very high potential to be used as hybrid yarn with other materials, such as silk, cotton and others. As the fiber of eri silkworm is very soft like wool or cashmere, an attention has been paid on cocoon of eri silkworm by private sectors around the world.

Photo. 1 Eri silkworm

Photo. 2 Castor leaves as host plant

Photo. 3 Eri cocoon

Eri silkworm is multivoltine and it hatches around 6 times per year (Kawabe, 2010). One lifecycle is about 45 to 50 days. One female moth produces more than 200 eggs per time. Host plants of eri silkworm are leaves of castor (*Ricinus communis*), cassava (*Manihot esculenta*), papaya and a few kinds of leaves which can be found in rural areas of south Asia, and actually considered as "just leaves" with no utilization. Without any input or special care, those leaves are grown naturally, especially near rivers or damping sites. So, farmers can easily start eri-culture without any change of their land use. While using the natural resources in villages, farmers find themselves to acknowledge their farming practice gradually change to sustainable agricultural way. Eri-culture is one of the possibilities to promote sustainable agriculture, due to the sensitivity of eri silkworm to any kind of chemical substances so that farmers started to realize the harm of chemical pesticides, smoke of cigarette, smoke of burning plastics and so on. To conduct eri-culture, farmers need to quit using chemical substances or at least reducing the amount of usage. That is a reason why eri-culture could be one of educational materials for sustainable rural development and also a solution to reduce chemical pesticide, which has been causing severe illness to farmers and strain their living.

However, to promote sustainable agriculture on ESD, it is necessary to provide something as incentive for local farmers, as their poverty level is quite high and they are eager to do another work for income generation except farming, especially during the dry season, farmers go to urban areas to look for a job for living. So, not only providing workshops or seminars regarding sustainable rural development but also providing opportunity for income generation is the essential factor to motivate farmers and it leads to promoting sustainable rural development in their daily life and initiative could be taken by local farmers.

Research sites

The research sites to conduct eri-culture are located at Wat Chas village and Roung Kor village in Baray commune, Prey Chhor district in Kampong Cham province, Cambodia (Fig. 1). Since October 2010, eri-culture has been introduced and promoted in Wat Chas village and a little after in Roung Kor village.

In Wat Chas and Roung Kor villages, main economic activity of farmers is rice cultivation, and some amounts of vegetables in upland fields are also cultivated. There are some serious problems related to the agricultural situation. Average area of farmland is around 0.45 ha in Wat Chas village and Roung Kor village, which is below the average of other areas of Kampong Cham province, thus the amount of agro-production is very limited in the small land and poverty level is higher than other province of Cambodia (Table 1). To yield the large amount of crops, it is common to apply chemical fertilizer and chemical pesticides into farmlands, although it causes severe

degradation of soil and water environment in farmlands and serious health problems for farmers (Mihara and Fujimoto, 2007).

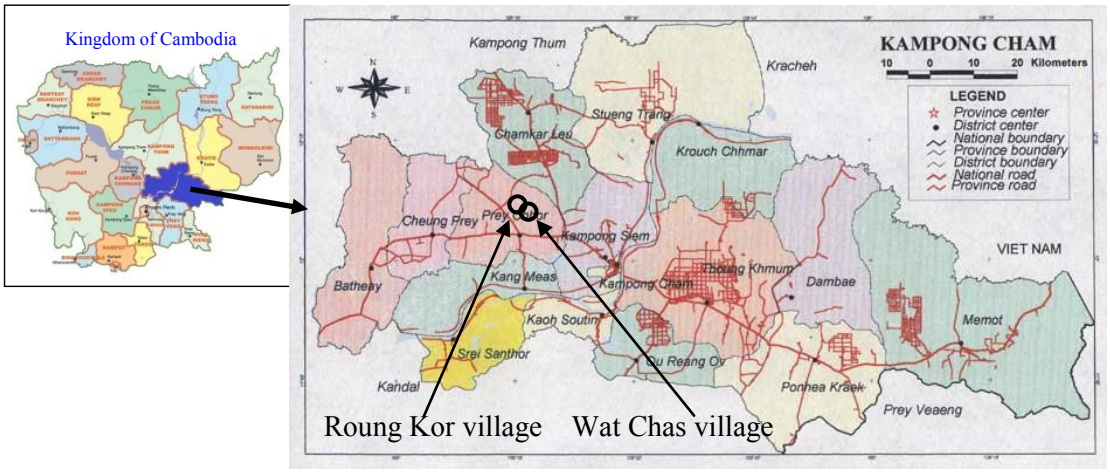


Fig. 1 Location of Wat Chas and Roung Kor villages in Baray commune, Prey Chhor district in Kampong Cham province

Table 1 Agricultural land per rural household in Kampong Cham

Agricultural land per rural household (a)	Cambodia	Kampong Cham	Wat Chas	Roung Kor
No agricultural land (landless)	15%	17%	7%	3%
0.01 ha ≦a <1.0 ha	49%	55%	80%	82%
1.0 ha ≦ a < 3.0 ha	30%	23%	13%	15%
a ≧ 3.0 ha	6%	5%	0%	0%

Source: MAFF 2004

For the first trial, two farmers have selected and started conducting eri-culture in October 2010, and then four more farmers in Wat Chas village and two farmers in Roung Kor have started to conduct eri-culture since January 2011. Its activity has been expanded in those villages, and the number of farmers who have already started conducting eri-culture is increasing in each village (Photo. 4).

Photo. 4 Rearers in Wat Chas village

Workshops and questionnaire survey

Eri silkworm, a kind of wild silkworms that inhabit in south Asia, has been introduced to local villages in Kampong Cham province since October 2010 for a part of the activities of Regional Centre of Expertise in Greater Phnom Penh. As shown in Photo. 5, the workshops have been organized 3 times for local farmers including the demonstration of eri-culture in October, November and December 2010. Also, the training on eri-culture was conducted to each local farmer who has started rearing eri silkworms. After 6 months passed from introducing eri-culture in Kampong Cham province of Cambodia, the questionnaire survey was conducted in March 2011 to evaluate the effects of eri-culture on promoting environmental awareness of local farmers. The questionnaire includes the following questions:

- Whether you have already initiated eri-culture.
- Whether you have ever participated in the workshop on eri-culture.
- How much you want to reduce chemical pesticide compared to conventional way.
- How much you enhanced communication compared to before starting eri-culture.
- How much you expect that eri-culture contributes to income generation per year.

Photo. 5 Eri-culture demonstrations in workshop held at Wat Chas in November, 2010

RESULTS AND DISCUSSION

Local acceptability of eri-culture

The first workshop conducted in October 2010 was a very small one where only two farmers have participated in. By showing and touching eri-silkworms in effect, farmers understood the process of rearing and active discussion was made naturally.

The second workshop conducted in November 2010 was much bigger than the first one, because more farmers were motivated by the first trial farmers and many came to see their rearing way. Since one farmer for the first trail succeeded, she was acknowledged as “Good Practice” in the village. Although another farmer failed to rear, due to smoke of cigarette and feeding wrong plant such as Jatropha, the farmer took this as an opportunity to understand how chemical substances affected eri silkworm that led to fatal event.

Totally, 45 farmers participated in the second workshop and among the participants, other four farmers started eri-culture. Most of them failed to rear for their first time and many worms have died because of the chemical pesticide that was contaminated in the rearing net. New rearers tried to figure out the reason of their sudden death. Naturally, communication among farmers became more active than before to exchange and share knowledge and experiences on eri-culture, and it seemed their awareness to chemical substances has improved. They asked whether perfume is acceptable to worms or not, because young women wear perfume a lot in daily life in Cambodia.

Farmers implement ESD (education for sustainable development) by themselves without being ordered to do so. Moreover, many other farmers from other villages in Kampong Cham province showed their strong interest to start eri-culture since they consider it as a high potential work which can be conducted easily in their villages. After second and third workshops, communication level became high in the network formed naturally and the information and knowledge were spread. Even no support by providing necessary materials, there were many farmers who wanted to start eri-culture.

Table 2 shows the typology of participation. According to attitude of local participants or way to be related or involved in the project, the degree of participation can be evaluated. Based on Table 2, the change in participation level from October 2010 to March 2011 for 6 months was discussed.

When the first workshop was conducted in October 2010, only two farmers participated in it. It was a unilateral announcement without any listening to local responses. So, it could be evaluated as Level 1, passive participation, at the initial stage in October 2010. However, through the second and third workshops including demonstration on eri-culture, many farmers were motivated. Also, they showed their strong and positive passion to start eri-culture. Based on attitude of local participants and way to be related to eri-culture, it could be evaluated as Level 6, interactive participation, as local people participated in eri-culture with forming local network to enhance eri-culture with systemic learning processes based on the local communication.

Table 2 A typology of participation

Typology	Characteristics of Each Type
1. *Passive participation*	People participate by being told what is going to happen or has already happened. It is a unilateral announcement by an administration or project management without any listening to people's responses. The information being shared belongs only to external professionals.
2. *Participation in information giving*	People participate by answering questions posed by extractive researches using questionnaire surveys or similar approaches. People do not have the opportunity to influence proceedings, as the findings of the research are neither shared nor checked for accuracy.
3. *Participation by consultation*	People participate by being consulted, and external agents listen to views. These external agents define both problems and solutions and may modify these in the light of people's responses. Such a consultative process does not concede any share in decision making, and professionals are under no obligation to take on board people's views.
4. *Participation for material incentive*	People participate by providing resources, for example labor, in return for food, cash, or other material incentives. Much on-farm research falls in this category, as farmers provide the fields but are not involved in the experimentation or the process of learning. It is very common to see this called participation, yet people have no stake in prolonging activities when the incentives end.
5. *Functional participation*	People participate by forming groups to meet predetermined objectives related to the project, which can involve the development or promotion of externally initiated social organization. Such involvement does not tend to be at early stages of project cycles or planning, but rather after major decisions have been made. These instructions tend to be dependent on external initiators and facilitators, but may become self-dependent.
6. *Interactive participation*	People participate in joint analysis, which leads to action plans and the formation of new local institutions or the strengthening of existing ones. It tends to involve interdisciplinary methodologies that seek multiple perspectives and make use of systemic and structured learning processes. These groups take control over local decisions, and so people have a stake in maintaining structures or practices.
7. *Self-mobilization*	People participate by taking initiative independent of external institution to change systems. They develop contacts with external institutions for resources and technical advice they need, but retain control over how resources are used. Such self-initiated mobilization and collective action may or may not challenge existing inequitable distribution of wealth and power.

Source: Pretty (1994), adapted from Adnan et al. (1992)

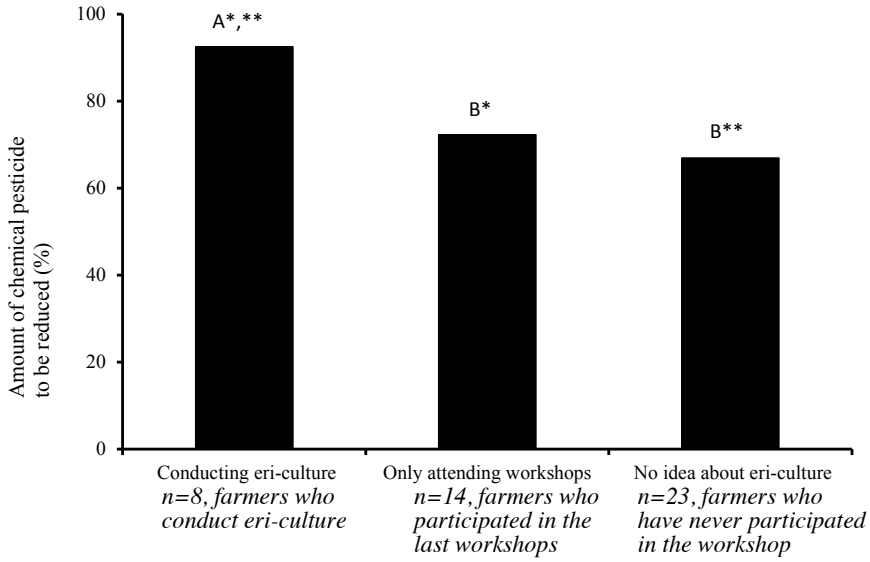
Evaluation on the effects of eri-culture on promoting environmental awareness

The workshops have been organized 3 times for local farmers including the demonstration of eri-culture in October, November and December 2010. Also, the training on eri-culture was conducted to each local farmer who has started rearing eri silkworms. After 6 months passed from introducing eri-culture in Kampong Cham province of Cambodia, the questionnaire survey was conducted in March 2011 to evaluate the effects of eri-culture on promoting environmental awareness of local farmers.

The results of the questionnaire survey showed that local farmers who rear eri silkworms wanted to reduce 92.5% of chemical pesticide compared to the conventional way (Fig. 2). While local farmers who just participated in the workshop or who have never participated in the workshops showed only 72.3% or 66.9% of chemical pesticide to be reduced. So, the expected percentage of chemical pesticide to be reduced for local farmers who rear eri silkworms was

significantly higher than that for local farmers who just participated in the workshop or who have never participated in the workshops.

Accordingly, it was considered that eri-culture has educational function for local farmers regarding the reduction of chemical pesticide application. However, other trainings such as sustainable farming practices may be indispensable to reduce the amounts of chemical pesticide applied with minimizing the insect damage to agricultural products.

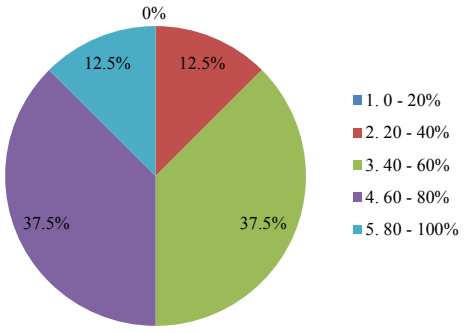


Different letter indicates the significant difference at 99%(**) or 95%(*).

Fig. 2 Difference in expected percentage of chemical pesticide to be reduced between rearers and others

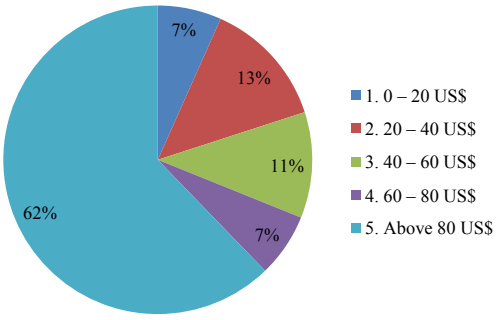
Evaluation on the effects of eri-culture on rural development

Through the second and the third workshops in November and December 2010, including demonstration on eri-culture, many farmers were motivated. Also, they showed their strong and positive passion to start eri-culture and participated in eri-culture with forming local network to enhance eri-culture with systemic learning processes based on local communication. Corresponding to forming local network to enhance eri-culture, they deepened communication compared to before starting eri-culture.



n=8, only farmers who conduct eri-culture

Fig. 3 Increase of communication comparing to before starting eri-culture



n=45, all responded farmers

Fig. 4 Expected income generation through eri-culture per year

As shown in Fg. 3, 38% of rearers acknowledged that the communication increased 40 to 60% compared to that before starting eri-culture, and other 38% of rearers responded increasing up to 60 to 80%, while only 13% acknowledged 20-40%. Accordingly, it was evaluated that the communication in the network has been increased through eri-culture. In addition, Fig. 4 shows the

expectation of income generation through eri-culture. Over 62% of rearers expect more than 80 US$ of income increase per year. It means local famers expected that their income would increase through eri-culture in the village.

CONCLUSION

Eri silkworm, a kind of wild silkworms that inhabit in south Asia, has been introduced to local villages in Kampong Cham province since October 2010 for a part of the activities of Regional Centre of Expertise in Greater Phnom Penh. Because of the characteristics of eri silkworm, eri-culture was considered that it has an educational function for local farmers regarding the reduction of chemical pesticide application. This paper dealt with the effects of eri-culture on promoting environmental awareness of local farmers, in terms of the reduction of chemical pesticide application. After 6 months passed from the introduction of eri-culture, the questionnaire survey was conducted for evaluating local awareness on the reduction of chemical pesticide application. In the results, the farmers who rear eri silkworms waned to reduce 92.5% of chemical pesticide compared to the conventional way. On the other hand, farmers who only participated in the workshops or who never participated in the workshops wanted to reduce only 72.3% or 66.9%. The results of the survey clearly showed that the environmental awareness of the local farmers who reared eri silkworm was significantly higher than that of rest farmers. Accordingly, it was considered that eri-culture could be one of solutions for reduction of chemical input in agricultural land that leads to conservation of natural resources and farmlands, but also poverty reduction to create job opportunity in the village. However, other trainings such as sustainable farming practices may be indispensable to reduce the amounts of chemical pesticide applied with minimizing the insect damage to agricultural products.

ACKNOWLEDGEMENTS

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Research article

Effects of Burning Crop Residues on Soil Quality in Wenshui, Shanxi of China

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Abstract Large amount of crop residues are produced every year in China. Although crop residues are rich in organic matter, nitrogen, phosphorus, potassium, calcium and magnesium, local farmers tend to burn residues in the fields in order to simplify preparation for following cultivations and to enhance the development of economic conditions. Thus, attention has been paid to the effects of crop residues burning on soil environment. The objectives of this study are to observe changes in burning density and to evaluate changes in soil quality caused by burning practices in Wenshui, Shanxi of China. Burning density was analyzed based on the Fire Information for Resource Management System (FIRMS). In addition, onsite experiment on residue burning was conducted in Wenshui and soil samples were collected for evaluating the change of soil quality and soil fauna. It was observed that the burning density in Wenshui of Shanxi in 2009 was much larger at 0.0467 events/km^2/year than that in 2001 at 0.00141 events/km^2/year. Also, the results of onsite experiment on residue burning conducted in Wenshui indicated that soil surface temperature rose to 415 degrees Celsius resulting in the sudden decrease of microorganism population. In addition, values of electrical conductivity (EC) and pH increased to 219 mS/m and 9.04, respectively. However, there was a slight decrease in soil permeability. Burning crop residues on farmland may accelerate nitrogen loss. Besides, concentration of phosphorous in soil tended to increase with the burning process. Therefore, it was concluded that the burning of residues significantly affects soil ecosystem and its quality.

Keywords burning crop residues, soil quality, microorganism

INTRODUCTION

In China, the yield of crop residues is 79,454.4×10^4 tons per year and increases steadily at a rate of 1,251.2×10^4 tons every year (Zhong et al., 2003). Crop residues were important sources of energy in many parts of China, where crop residues were mainly utilized as domestic fuel. However, crop residues utilized as domestic fuel has been disregarded due to the adaptation of other fuel sources (Yan et al., 2005). This situation causes a significant increase of crop residues in fields as Song et al. (1995) breported that crop residues used as domestic fuel decreased about 50%. Therefore, local farmers tended to burn residues in the field in order to simplify the preparation for the following cultivation. Although there were many reports on the effects of crop residue burning on soil quality, few studies have been conducted in China, especially in Shanxi. Therefore, this study has been proposed. The objectives of this study are to observe changes in burning density and to evaluate changes in soil quality caused by burning practices in Wenshui, Shanxi of China. On the other hand, Srimuang et al. (2004) reported that the burning process affects soil physical and chemical

properties up to 15 cm deep from soil surface. In addition, high soil temperatures may kill soil microbes and plant roots, destroy soil organic matter, and degrade soil nutrients as well as water holding capacity (Srimuang, 2006).

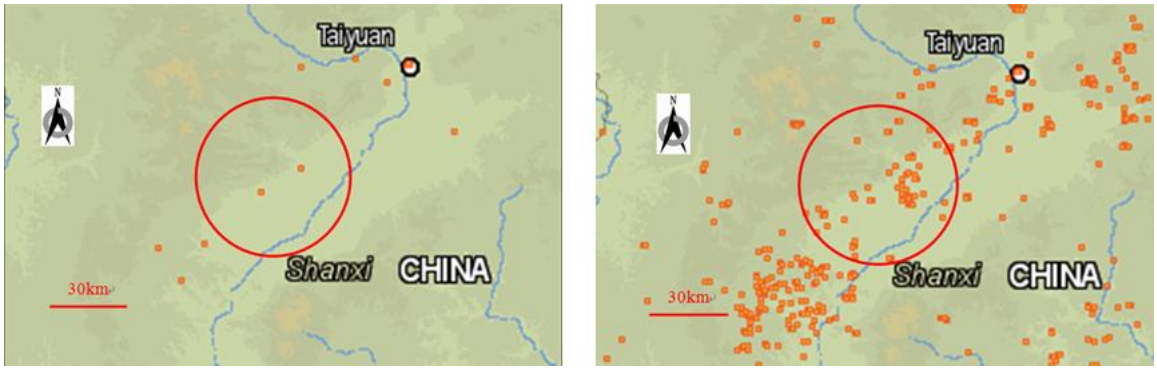
METHODOLOGY

The research site is located in Xiaqu Village, Wenshui of Shanxi Province, in the central part of China (37°26'N, 112°01'E, 767 m above sea level). The region has a continental monsoon climate and is rather arid having an average annual precipitation around 350-700 mm. Upland field farming is the main agricultural activity in Shanxi Province. The total area in Wenshui is 1,064 km^2 in which upland field occupies about 400 km^2 or about 40% of the total area. The dominant soil type in the study is SL as shown in Table 1.

Table 1 Soil texture of Wenshui, Shanxi, China

Depth (cm)	Specific gravity	Particle size distribution (%)					Soil texture
		Gravel	Coarse sand	Fine sand	Silt	Clay	
0-20	2.77	0	0.38	66.54	23.80	9.28	SL

The burning density was analyzed based on the Fire Information for Resource Management System (FIRMS). FIRMS integrates remote sensing and GIS technologies to deliver global MODIS hotspot/fire locations and burned area information to natural resource managers and other stakeholders around the world (Web Fire Mapper, 2010). The area monitored was comprised in a 30 km radius from the center of Wenshui, Shanxi of China. Data were gathered in a yearly basis from 2001 to 2009.



2001 2009

Fig. 1 Changes in burning density around Shanxi of China

For the field burning experiment, an observation pit of 1 m wide, 1 m long and 1 m deep was excavated in the corn field, near a burned pile of crop residues for observing soil temperature and volumetric water content. Dried corn residues were burned within 30 minutes right beside the pit as shown in Fig. 2-a. Soil temperature and moisture were measured by using a thermocouple and a water content reflect meter inserted into the wall of the pit (Fig. 2-b) at different depths of 1, 5, 10, 20, 30 and 40 cm from soil surface. Measurements were done at 5, 10, 30, 60, 120, 180, 240, 300, 320, 360 and 420 minutes passed after burning.

For laboratory analysis, two different types of soil were collected from field site: unburned soil and burned soil. Both soils were collected from the same field. However, burned soil was collected from a burning experimental plot. To observe the effects of burning on general microorganisms, some amounts of unburned soils were burned by oven at 415 degrees Celsius

within 30 minutes to correspond to the condition of soil during the burning at the field site. For burned soil as well as unburned soil, analysis of general microorganisms was carried out with an agar plate.

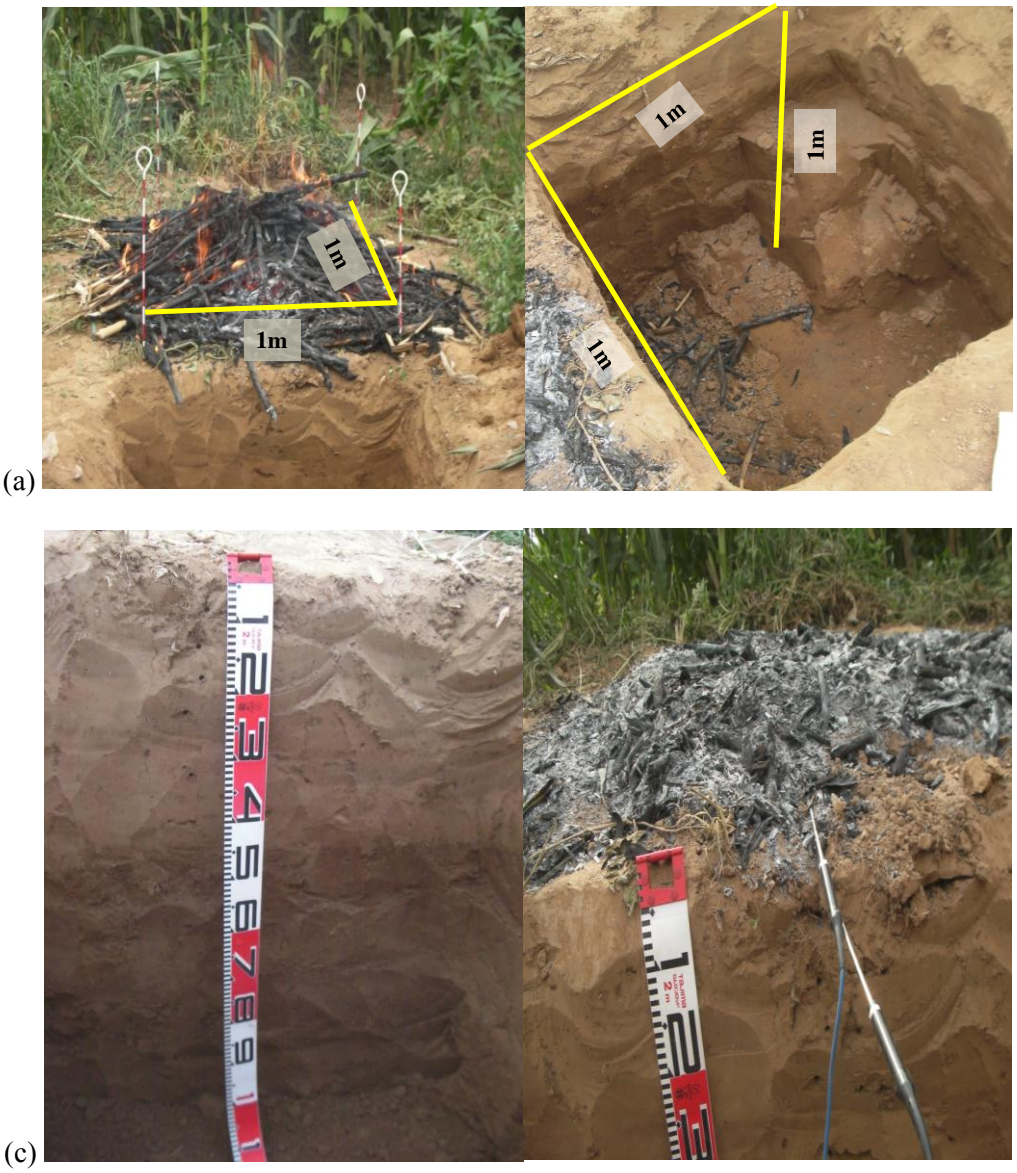


Fig. 2 Field burning experiment conducted in Wenshui Shanxi of China

In addition, saturated permeability test was conducted by falling head method. Both unburned and burned soils were undergone for soil general bacteria, electrical conductivity (EC) and pH, to make out the effects of residue burning on soil chemical and physical properties. Also, changes in total nitrogen and total phosphorous in soil were analyzed under different temperatures.

RESULTS AND DISCUSSION

Burning density was analyzed on the basis of the Fire Information for Resource Management System (FIRMS). Results from the analysis on changes in burning density showed that burning density in Wenshui of Shanxi in 2009 at 0.0467 events/km^2/year was much larger than that in 2001 at 0.00141 events/km^2/year. It was observed that burning density in 2009 was 33 times higher than that in 2001 as shown in Fig. 3.

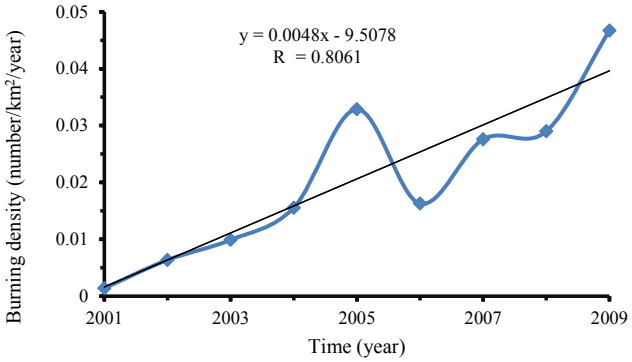


Fig. 3 Burning density occurred from the year 2001 to 2009

On site burning was conducted to measure soil volumetric water content (VWC) and soil temperature in a corn field located at Wenshui, Shanxi of China. Experimental results indicated that temperature of surface soil rose to 415 degrees Celsius (Fig. 4) immediately after starting the burning, and then it decreased gradually with time after ceasing the burning. Also, it was observed that soil volumetric water content at depths of 1 cm to 40 cm decreased with burning. However, this decreasing tendency of soil volumetric water content at 1 cm deep lasted until the end of the observation. In addition, at other depths, there was some fluctuation of soil volumetric water content as shown in Fig. 5.

For evaluating changes in soil quality with the burning, values of EC and pH were analyzed. The changes in EC and pH values were measured by glass electrode method. The values of pH increased from 8.23 to 9.04 with the burning and there was a significant difference between pH values of unburned and burned soils at 99% confidence interval (Fig. 6). Also, values of electrical conductivity (EC) increased to 219 mS/m from 128 mS/m with the burning (Fig. 7).

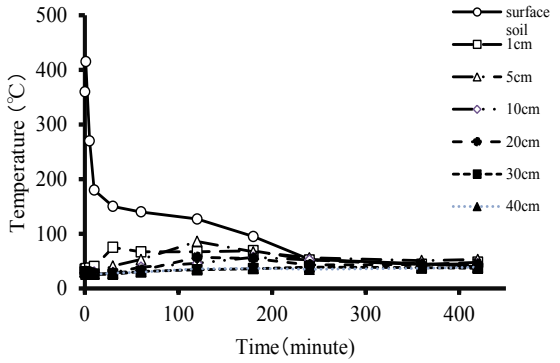


Fig. 4 Changes in temperature with burning

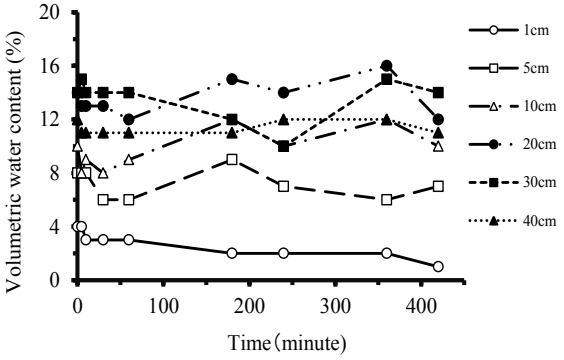


Fig. 5 Changes in VWC with burning

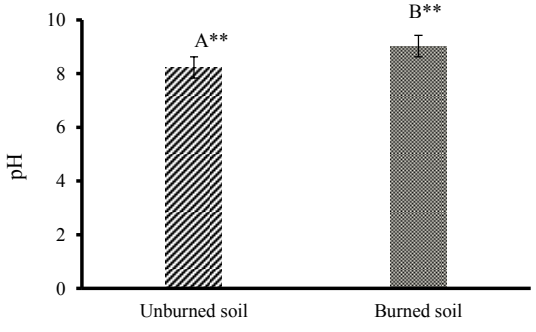


Fig. 6 Changes in pH with burning

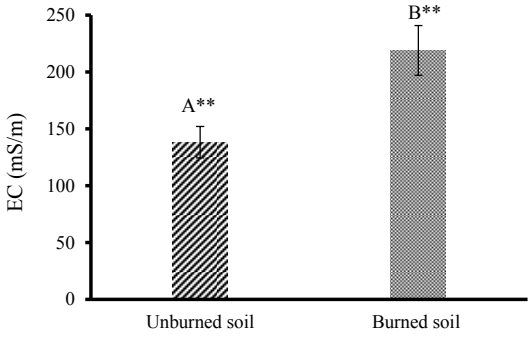


Fig. 7 Changes in EC with burning

The population of general microorganisms in unburned and burned soils was measured employing an agar plate. Results indicated that general microorganisms existing in unburned soil were 3.0×10^7 cfu/g while there was no general bacteria found in the burned soil (Fig. 8). Results indicated that general bacteria cannot live at 415 degrees Celsius that was observed in the field burning experiment in Wenshui, Shanxi of China. Thus, the effect on the destruction of soil microorganisms is a big concern for soil environment researchers.

However, no significant change was observed in permeability between unburned and burned soils. Also, a significant difference was not observed as shown in Fig. 9.

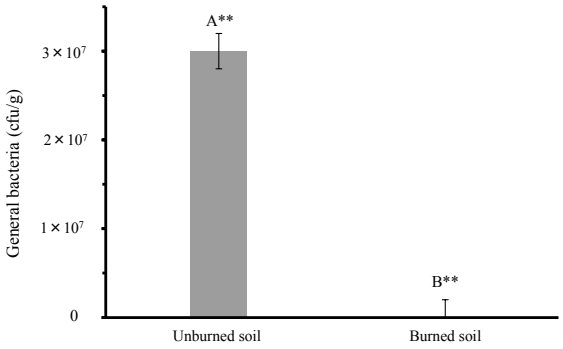


Fig. 8 Changes in general bacteria with burning

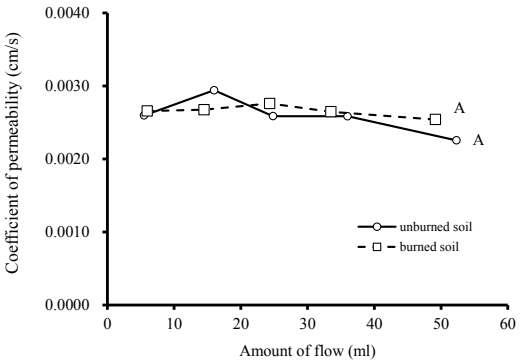


Fig. 9 Changes in water permeability with burning

The changes in total nitrogen and total phosphorous concentration with the burning are shown in Fig. 10 and Fig. 11. A tendency for total nitrogen to decrease with the burning temperature was observed. This tendency may be caused by the release of nitrogen components into the air with the burning (Fig.10). However, total phosphorous tended to increase with the burning temperature due to the decomposition of phosphorus component in soil.

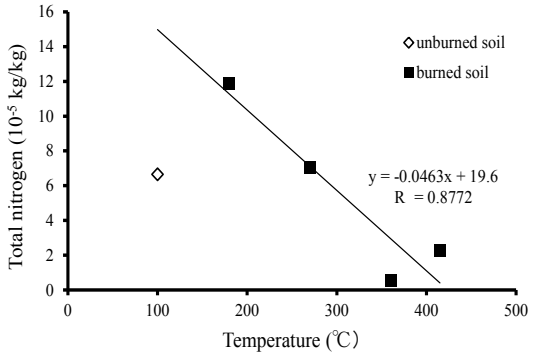


Fig. 10 Changes in total nitrogen with burning

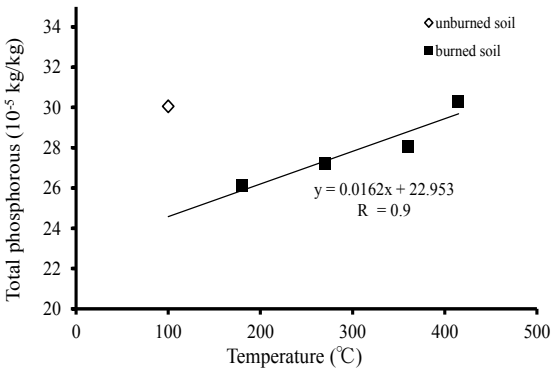


Fig. 11 Changes in total phosphorous with burning

CONCLUSION

The results from the observation of changes in burning density showed that burning density in Wenshui of Shanxi in 2009 at 0.0467 event/km^2/year was much larger than that in 2001 at 0.00141 event/km^2/year. Also, the results of onsite experiment on residue burning conducted in Wenshui indicated that when soil surface temperature rose to 415 degrees Celsius, it caused the decrease of microorganism population. Therefore, burning of crop residues significantly affects the micro fauna in the soil. In addition, burning of crop residues also influenced the acidity of soil as

indicated by the increase of soil electrical conductivity (EC) and pH. Moreover, a significant decrease of total nitrogen component in the soil was observed. However, burning of crop residue has no significant effect on soil permeability as observed in the permeability test.

It was concluded that the burning of crop residues influenced the degradation of soil ecosystem and its quality. Therefore, treating of crop residues such as composting, for bio-fertilizer on crop is strongly recommended.

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Research article

Payment for Environmental Services (PES): Case Study on Conservation Agreement on Forest and Biodiversity Conservation in Central Cardamom Protected Forest, Thmar Baing District, Koh Kong Province

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Abstract Cardamom mountain of Cambodia was classified as *Burma's hotspot* of biodiversity by UNESCO in 2006. It includes watershed, air filtering and many other natural resources such as timber and non-timber forest products (NTFPs), food, medicine and construction materials. Forest has been severely degraded by chronic war and over exploitation of wood by concession companies. Conservation International (CI) has collaborated with Royal Government of Cambodia (RGC) to reform forestry laws and establish the Central Cardamom Protected Forest. Payment for Environmental Services (PES), which is an effective concept for biodiversity conservation. The *win-win* approach of PES mechanism provides benefit to all villagers in return for sustainable conservation. For this reason, an overall goal of the research is to compare Conservation Agreement (CA) features and mechanisms of CI to those of PES. This research intends to describe CA mechanism through PES periscope, analyze institutional design and explain institutional arrangement as well as to indicate factors inducing changes in resident behaviour. This study was conducted inside and around the protected zone of Central Cardamom Protected Forest (CCPF) and it covers three communes of the district. Interviews were conducted on site with the participation of 59 people, including farmers, authorities and NGOs in the study area. Besides, states and NGO officers involved in this research were informally interviewed. The results of this study showed that CA as a mechanism is similar to PES, but it is not just PES due to its features. Although there are many features similar to PES mechanism, it is totally a not voluntary transaction because villagers live in state forests, so they don't have a legal land title. They don't have a right to manage the state forests which are controlled by forestry laws. On the other hand, CA design lacks institutional interaction between involved institutions so it is not legally recognized. All changes in local behaviours may be caused by the restriction imposed by the forestry laws and aids for community development that stop land encroachment. Conservation Agreement enhances the community development and alleviates poverty of local settlers inside and around CCPF by providing development training and incentives such as establishing microcredit, NTFPs processing and providing agriculture instruments. Overall Conservation Agreement is not pure PES but has affected participatory conservation and poverty alleviation.

Keywords: PES, conservation, incentive, conservation agreement, voluntary

INTRODUCTION

Ecosystem sustains human life by providing food and drinking water, maintaining stock of continuously evolving genetic resources, preserving and regenerating soils, fixing nitrogen and carbon, recycling nutrients, controlling floods, filtering pollutants, pollinating crops and more other services. The ecosystem is facing severe degradation caused by human activities in agriculture expansion (FAO, 2007a). Ecosystem degradation in Cambodia is also severe due to over exploitation of timber by concession companies after civil war (USAID, 2001). Cardamom

Mountain was defined as Indo-Burma biodiversity hotspot by UNESCO in 2006 which consists of hundreds of endangered plant and wildlife species. Many NGOs and state agencies which are working in biodiversity conservation are concerned about biodiversity and ecosystem degradation in Cardamom Mountains (CI, 2009). Within this wide context, Conservation International (CI) Cambodia has initiated the Conservation Agreement (CA) by paying for contribution to natural sustainability in Cardamom Mountain area through formation of PES due to its framework and features. Within this framework, a market-based mechanism, at least one service buyer, who is the beneficiary, pays for environmental services to ecosystem service providers under conditions specified in a contract facilitated by intermediate agents or intermediate buyers who are found as states in many implements of PES in other countries of the world. Due to Forestry Reform since 2002, institutional arrangement and its interaction have contributed to accelerate CA and promote it into a national level to be recognized by the states (CI, 2009). In addition, benefits from incentives l helped to make large changes in land use practices and made the living of people better. This research has made an overall attempt to define and explain the importance of institutions and their institutional interactions in the design and performance of PES (Wunder, 2005) within three main objectives: 1) To describe the CCPF Conservation agreements mechanism through the PES (indirect). 2) To analyse the institutional design and explain the current institutional arrangement (process of elaboration, factors explaining the current framework). 3) To identify the factors that induce changes by the practices of CAs on people (development) and on natural resources (conservation).

METHODOLOGY

Study Area: Selection of the study area was made after an exploratory trip in three communes (Thmar Dan Pouv, Russei Chrum and Tatai Leu). This study has been carried out within the scope, objectives and availability of time for investigating the most crucial part of informative data obtained from the target area in response to the main goal of this research.

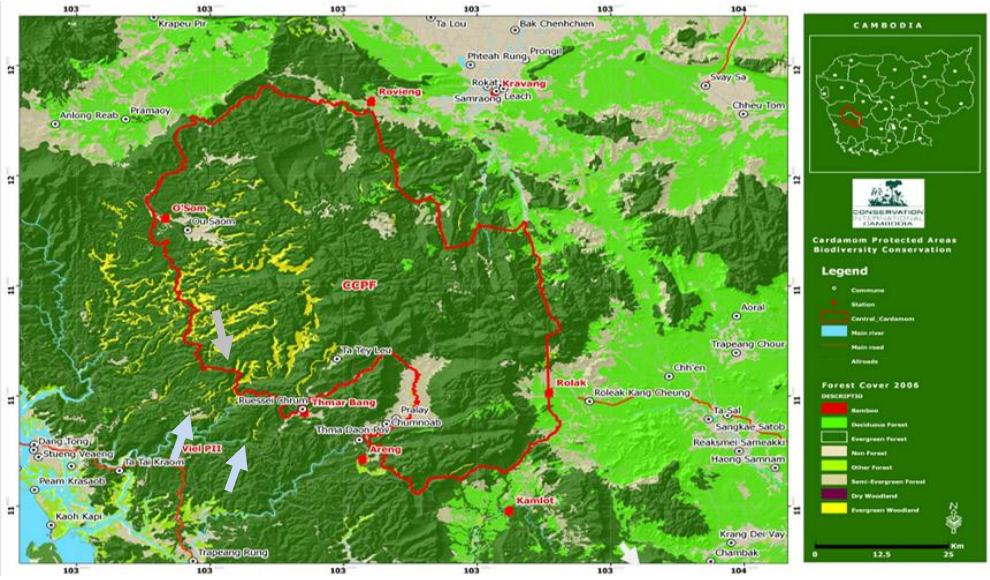

Fig. 1 Map of study areas in CCPT
Source: CI (2009)

The study area covers three communes inside the buffer zone of Central Cardamom Forest Protected, Thmar Baing district, Koh Kong Province. The three communes were chosen as the target area according to the implementation of CI's Conservation Agreement, which is the core of the present research objective and geographical and social diversity. The research areas are briefly shown in Fig. 1 above.

The red line indicates boundary of CCPF which is classified as state forest and controlled by FA in cooperation with CI. There are two target located outside the CCPF boundary and one located inside the protected zone.

Sampling size and methods: The number of interviewees was defined based on real situation of exploratory trip. Stratified sampling method was used as principle to define the number of interviewees, and then classified according to their involvement in social activities and knowledge of Conservation Agreements. Commune chiefs met and were informed of the present research in their commune boundaries and the objectives of the survey, and were asked for general information regarding the commune and villages (demographic, social, and economic data). A random sampling method for villagers was chosen due to the impossibility of preliminary stratification according to a set of criteria. However, as long as we got to know the villagers in the area, we tried to stratify the interviewees according to:

- **Age criteria** – Farmers actively engaged in social life, agricultural practices, and active household members in age groups of 20-40, 40-75
- **Period of stay in the commune** – Villagers living in the community for a sufficiently long time, both indigenous (born in the area) or migrants, as they were involved in the key events;
- **Occupation criteria** - Resident teachers, village/commune policeman, among other activities, as they are important beneficiaries according to the Conservation agreements. The design of sample size has been changed several times to be flexible to the real situations on field and available to villagers and other interview targets.

Eventually, 44 households, 8 community committee members and 7 commune councils or commune chiefs have been interviewed as shown in Table 1.

Table 1 Number of ground respondents of research interview

Commune name	Total interviews	Villagers	Village and commune chiefs and/ or members of their council	Natural resource management community committee members
Thmar Danpouv	27	21	3	3
Tatey Leu	19	13	3	3
Russey Chrum	13	10	1	2
Total	59	44	7	8

Besides on site interviews, many other states and NGOs officers involved in conservation of the research area were interviewed to understand their views about agreement and to look for an alternative approach in biodiversity conservation.

RESULTS

After many months of field study, results answer to objectives of this research in the study area. The conservation agreement of CI has been designed with its own nature and criteria and then implemented by local people inside and around Central Cardamom Protected Forest. These results also express the institutional arrangement and its interaction in the context of conservation agreement as well as the comparison to the mechanism of PES. Finally, factors that induced changes within and around the implementation of CA are also highlighted to elaborate the right response to real local needs of community and help them get better off as well as to motivate them to be voluntarily involved in biodiversity conservation.

Design of Conservation Agreement

Conservation Agreement is a new approach of community engagement implemented by Conservation International in order to earn trust and engage local people living in and around the CCPF in forest and wildlife conservation in a sustainable way, with balance between development and conservation. The logic scheme of CA in Fig. 2 shows the typical logic of conservation agreement implemented by Conservation International in Cambodia at grassroots level and in assisting the ministry of agriculture forestry and fishery (MAFF) and Forestry Administration (FA) in CCPF management plans.

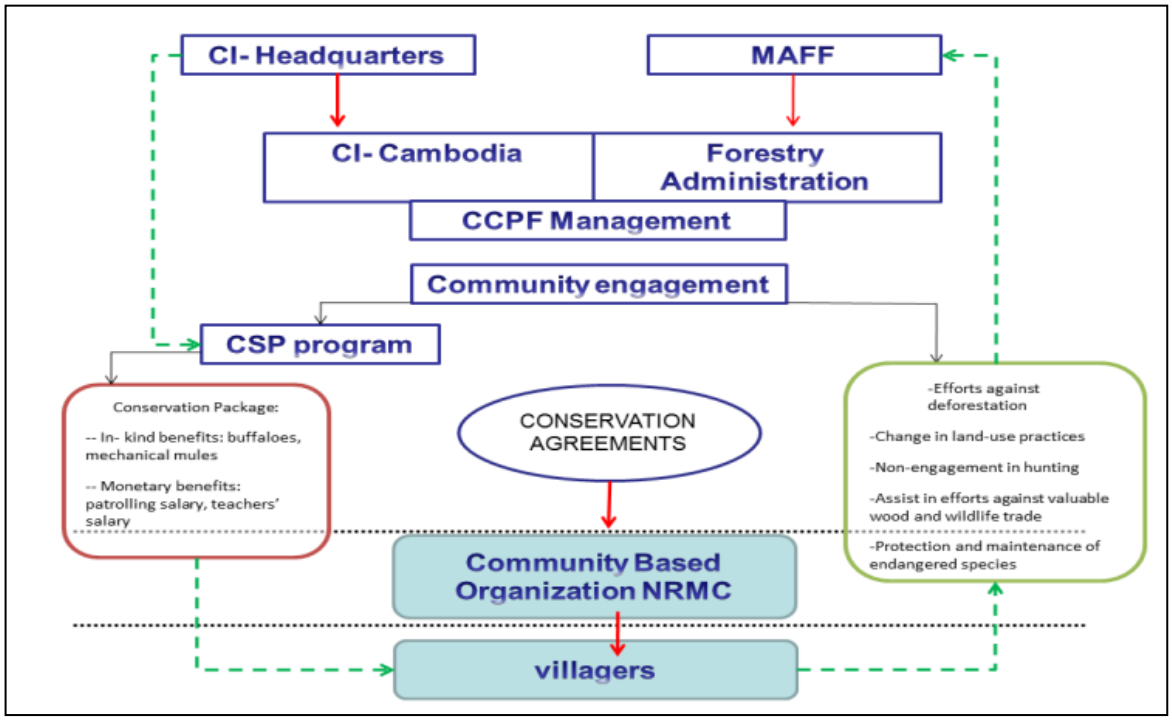

Fig. 2 Logic scheme design of agreement

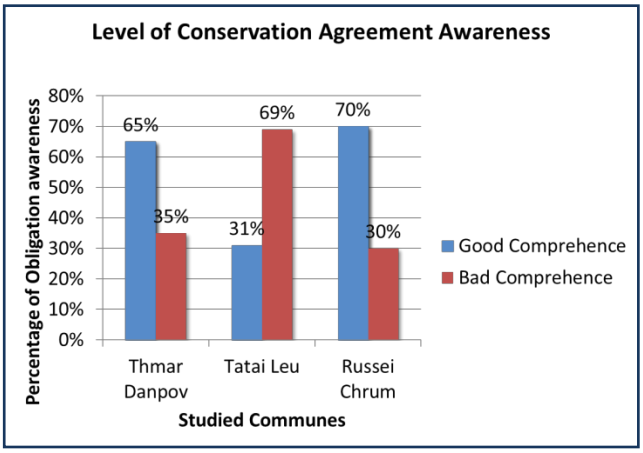

Fig. 3 Level of Awareness in obligation and benefit of CA

This logic framework of Conservation Agreement make local community cooperate within *conditionality* in conservation for incentives. It makes them cultivate in a fix land and end shifting agriculture which is similar to *conditionality and additionality in PES* (Muradian, Corbera, Pascual, Kosoy, and May, 2009). In contrast, the majority of villagers seem to have very low competence on obligation and responsibility of CA because most of them have not clearly distinguished between CA and forestry laws. Fig. 3 above shows the level of understanding in regulation and benefits of CA.

Institutional design and interaction of conservation agreement

The institutional arrangement in an agreement context indicates that implementation of CA was initiated at grassroots level and quickly spread from commune to commune. The study found that the organization of this agreement has a good design at grassroots levels, where all local needs and suggestion have clearly been recognized. However, it has never been implemented at a national level due to the lack of technical works establishing cooperation between involved institutions, identifying land use planning mapping, legal principles and so on. According to the results of interviews, involving stake holders on CA with local authorities, CI, FA and MoE show that there is no clear legislation document supporting participatory land use planning (PLUP) of CA. On the contrary, most of the villagers expect the so-called PLUP made by CI to be a legal process of land entitlement. The interviewing of local villagers shows low level of understanding around all the institutional design of CA. Another cause of poor design on conservation process could be institutional interaction between involved stakeholders.

Conservation opportunity cost and distribution:

Opportunity cost was established firstly on forest land conservation. Villagers promised to stop land encroachment in return for some amount of money for commune development. Formula of opportunity cost was made absolutely by CI. The calculating formula for forest opportunity cost is **OCF = FL x ARy x MP** (**OCF**: Opportunity cost for forest, **FL**: Size of forest encroachment per year (ha), **ARy:** Annual rice/crops yield from FL (Kg/ha), **MP**: crops market price ($/kg))**.** New forms of conservations have been expanded every year after the end of CA contract which was made annually. The benefits provided by agreements can be divided into 2 categories: Conservation package- a monetary sum that reflects the opportunity cost of the foregone activities such as forest clearing for farming activities, wildlife hunting and trading; Conservation Agreement Management and Monitoring costs- such as patrolling salary, administrative salary for NRMC committee, patrolling equipment and first aid kits and individual incentives for confiscated snares and animals. Decisions on spending the Conservation Package are made jointly by CI's CE team and NRMC members in consultation with villagers. The main part of the Conservation Package benefits are provided in-kind, such as mechanical mules (hand tractors), spare parts (cart), etc.

DISCUSSION

This design of Conservation Agreements does not identify final ES beneficiaries. It is not a beneficiary- pay scheme. NGO stands as a donor- buyer, local populations as ES providers.

Payments are conditional to the performance of the obligations rather than to the provision of ES. The conditionality criterion is weakly enforced and sacrificed to maintaining good relations with local communities - working with people is more important, than applying the contracts to the letter. The survey with local people showed that they have realized that they were living in states forest controlled by FA. Most of them experienced many huge conflicts with FA law enforcement team over the past years. They are obligated to respect the forest law against land encroachment and wild life hunting and trading. Most of the villagers still confuse CI and FA officers.

The additional value of CA's has not been prioritized. Baselines on forest cover and wildlife populations do not exist. CI acknowledged this weak point of the program and is to launch flagship species' population monitoring programs. The data on net increase of the forest cover or a

flagship species population could be obtained from other sources, but these evolutions can't be considered as agreement-contingent.

Agreements are not truly voluntary and seen as another beneficial NGO intervention. Local populations don't have legal rights on the land and resource use, their rights are restricted by law and any intervention providing additional benefits is a priori welcome. The principle of "voluntariness" is ambiguously perceived: so most of the interviewees accepted that the agreements are voluntary, which could be explained that it does not imply big changes in their livelihood strategies, that it is not "serious" enough, and that they don't care if it exists or not.

Opportunity costs are not based on market mechanism and represent amounts negotiated between CI and the community. They have been negotiated once and have not been changed.

Due to **The scale of "opportunities' loss" is yet small.** Relatively lower population in the uplands, difficult access to the area makes that the demand for land is less than in the lowlands of Cambodia. Indigenous populations don't perceive yet the land restrictions, thus land-use plans introduced by Conservation agreements.

Agreements - instruments of diplomatic conciliation in the battle for law enforcement. CI stays as a "conservation-oriented" organization and the primary objective is to enforce the protected zone management. Agreements in principle enforce the law, rather than represent the holistic voluntarily negotiated market transactions between resource beneficiaries and ES providers.

Field trips allowed understanding the local perception and revealing such problems as limited social activeness, limited awareness on quid-pro-quo mechanism (Wunder, 2005) of the agreements, unequal access to benefits, elite's capture, and governance issues specific to the Cambodian "patronage" systems. CI's Community Engagement actions on the field stay quite relevant in helping and to responding to the imminent development needs. Their initial design as of a strong institution based on principles of civil society met limitation in the context. Nominally, CA's are based on a wide participatory approach, in practice for a successful implementation they have to be negotiated respecting strict hierarchical order of the Khmer local governance. In-kind benefits from CA's were intended to promote environmentally improved productive sustainable fixing agriculture. CE team worked with local communities to restore old paddy rice fields and gave mechanical mules and water buffaloes as means of plowing. This was with an aim to increase crops yields and support the livelihoods. Basically, only those who have rice fields could effectively use agriculture instrument, while others prefer traditional practices in their plots of land (planting without plowing, hand plowing hoes, abandoning land for a fallow period, shifting cultivation). Although it is not always possible, trend should be developed in supporting such activities as agro-forestry, ecotourism and developing local agricultural and NTFP markets. This would provide people with good sources of additional income and their livelihoods would rely less on subsistence agriculture and illegal activities. Few of environmental services provided are paid depend on forest environmental service, wildlife species protection and dragon fish protection. Rewards have been provided without any conditionality for conservation. For instance, conservation package provided on dragon fish conservation was made without real baseline study on the increasing number of dragon fish fingerling.

CONCLUSION

Overall, result and discussion have clearly distinguished CA agreement as PES based on its features and mechanism. Anyway, CA has provided a crucial lead to PES implementation in Cambodia in the future because it clearly contributes to poverty alleviation in context of development and biodiversity conservation through an approach of environmental economics, providing benefit for livelihood and community development through market-based mechanism. Establishing a legal PLUP is the most important lead for land entitle which is crucial component of PES in the future. Institutional interaction should be improved to provide a helpful process of establishing legal framework for natural resources conservation and community development.

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Research article

Safety of Drinking Water Source and People's Choice Behavior in Rural India

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Abstract The objective of this study was to reveal the causes of damages by diarrhea in India. In particular, this study focused on the safety of drinking water sources and people's preference for it in rural India because spread of toilets is difficult there at the moment. Two villages in Andhra Pradesh, India were selected as survey sites of this study. Concentrations were measured for coliforms, general bacteria and iron in all water sources and surface waters. Interviews and questionnaire surveys were conducted at a public school in the village. People in one village used wells and hand pumps while people in another village used a pond for drinking purpose. It was revealed that pump was the safest water source according to the results of measuring concentration of coliforms. Pond water, which is a surface water source, and well water, which is drawn from unconfined aquifers, were all contaminated by excreta. On the other hand, pump water, which is pumped up from confined aquifers and can be defined as safe water, was not contaminated considerably. However, people did not have proper risk perceptions and tended to hesitate to drink pump water because of its metallic taste and smell. Actually, concentration of iron of pump water was higher than those of the others. The pond and wells represented a high risk of diarrhea and it was difficult to improve them because hygiene education was not enough at schools; thus wide spread of toilets seemed difficult. In order to encourage people to use pumps, they should be made of materials which do not erode and affect the taste and smell of water. It is also important that people have proper risk perceptions about each water source.

Keywords drinking water, toilet, sanitation, hygiene, diarrhea, India

INTRODUCTION

About 1.5 million children of age five and below die from diarrhea every year. This is the second cause of death for children (WHO, 2008). The most seriously affected country is India, in which about 0.39 million children die from diarrhea (UNICEF and WHO, 2009).

Pathogens which cause diarrhea are spread from excreta to new patients through hands, animals, water, etc. (Carr et al., 2001). Building toilets, developing water sources, improving water quality, and improving hygiene habits can reduce the risk of diarrhea relatively (Fewtrell, 2005). In order to prevent children's death by diarrhea, the United Nations set a goal to "halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation" in Millennium Development Goals (MDG), and many kinds of activities were conducted all over the world. But in India, especially in rural areas, about 79% of people still do not have basic sanitation and 69% do open defecation (WHO and UNICEF, 2010). Previous researches indicate that this is because people are not in the habit of using a toilet (Banda et al., 2007), and that building a toilet is too expensive for them (Jha, 2003).

The objective of this study was to reveal the causes of damages by diarrhea in India. In particular, this study mainly focused on the safety of drinking water sources and people's

preference for it in rural India. It is very important to keep safe drinking water sources and use them properly in rural India, where usage of toilets is difficult to spread.

METHODOLOGY

Two villages (P-village and T-village) near Sompeta city of Srikakuram district of Andhra Pradesh state of India were selected as survey sites of this study (Fig. 1). Andhra Pradesh state is in the southeastern part of India, and its average income is Rs 23,700 which is almost equal to that of the entire India, Rs 23,200. 21.9% of the population in the urban areas as well as 81.9% in the rural areas, do not have a toilet at home. The percentage in rural areas is higher than the average of all of India; 78.1%. Sompeta city has a population of 17,400; it is the smallest of all 6 cities in Srikakuram district. P-village is about 1.5km away from Sompeta city and T-village is about 13km away from it. On-site survey was conducted from 28th October to 11th November in 2011. The survey consisted of a water quality survey, interview survey, and a questionnaire survey.

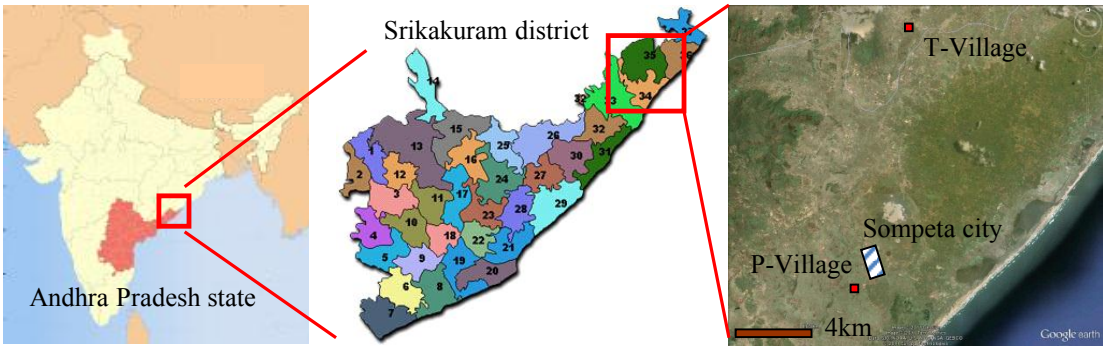

Fig. 1 Survey site

In water quality surveys, concentrations of coliforms, general bacteria and iron of each water source were measured on 21 points of P-village and 15 points of T-village (Fig. 2). Two hand pumps in T-village, 'Y' and 'Z', could not be measured because they were broken. The types of points measured were hand pumps, public wells, private wells, a container, ponds, and streams. Hand pumps, public wells and containers were supplied by Rural Water Supply, which is a state department. Public wells were the oldest water facilities and hand pumps were the newest ones. Container was a huge water tank with some taps at the bottom. Private wells were a kind of wells which were ordered individually and built at people's houses. Some private wells were built inside the houses while others were outside. The number of people who had private wells was increasing over the duration of the survey.

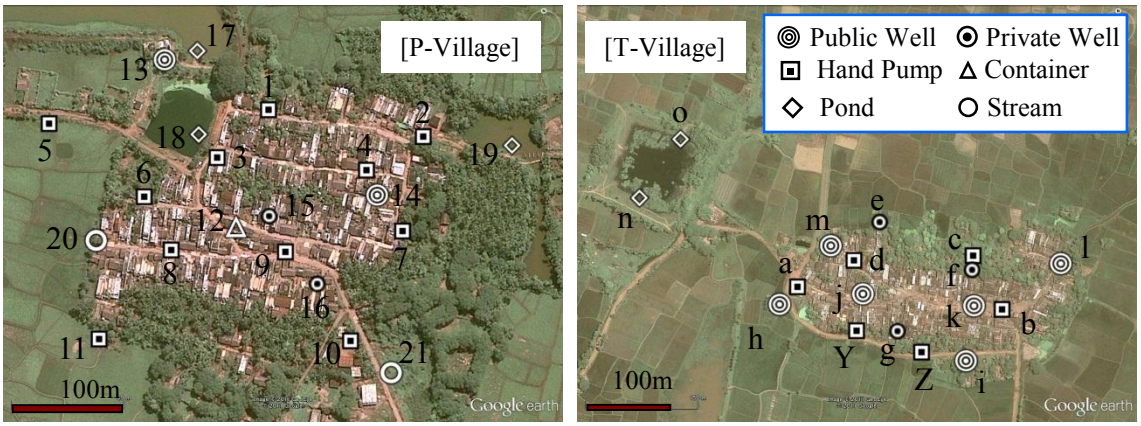

Fig. 2 Points of water quality survey in P-village (left) and T-village (right)

For measuring concentrations of coliforms and general bacteria, 1 mL of sampled water was dropped on a detection paper and put into a cultivator which was kept at 37℃ for about 24 hours

for cultivating coliforms and general bacteria. The detection paper was SUNCOLI produced by Sun Chemical Co. Ltd., and the cultivator was CB-101 produced by Sibata Science Technology Ltd. For measuring concentrations of iron, a test kit of WAK-Fe produced by Kyoritsu Chemical-Check Lab. Corp. was used. Furthermore, whether residents who lived near each water sources use it for drinking or not were checked through interviews.

Questionnaire and interview surveys were conducted at a public school in P-village. In this area, children from 1st grade (6 years old) to 5th grade (10 years old) go to a primary school, and children from 6th grade (11 years old) to 10th grade (15 years old) go to a high school. Compulsory education is conducted at primary and high school for ten years. Most children go to a public school in the village free of charge while others go to a private school in a nearby city. P-village has both a primary and a high school, but T-village has only a primary school. Children in T-village go to a high school in a neighboring village.

Questionnaire survey was applied to 13 years old 8th grade children, at a public school in P-village (n=31). Questions focused mainly on the use of drinking water sources and toilets, diarrhea frequency, etc. On the other hand, 10 years old 5th grade children were asked only one question: whether they have a toilet in their house or not (n=14). School teachers were interviewed about hygiene education at school.

RESULTS AND DISCUSSION

Use of water sources

Table 1 shows the number of water sources and whether they are used for drinking or not. In P-village, hand pumps, private wells and a public well at a temple are used for drinking purpose. Among these, the temple well was used frequently. However, other public wells, the container, and ponds are not currently used. On the other hand, most of people in T-village use the pond as drinking water source, and few people use pump or private wells. Public wells, except the temple well, are not used for drinking.

Table 1 Number of water sources and their use as drinking water

	P-Village		T-Village	
Water Source	Drink	Not Drink	Drink	Not Drink
Public Well	1	1	1	5
Private Well	2	0	3	0
Hand Pump	10	1	4	0
Container	0	1	0	0
Pond	0	3	1	0

Safety of drinking water sources

Fig. 3 shows the results of measuring concentrations of coliforms at P-village and T-village. Marks above numbers and alphabets show whether the water source was used for drinking or not. A circle means it was used for drinking and a cross means it was not. A triangle means few people drink it and a double circle means it was the most popular drinking water source. Only hand pump fulfilled WHO's guideline of drinking water quality that specifies coliforms should not be found in 1mL of sampled water. Nevertheless coliforms were detected in 4 pumps of 11 in P-village and in 3 pumps of 4 in T-village. Coliforms were also detected in all other water sources including well and pond which people used as drinking water sources.

Water from public and private wells are drawn from unconfined aquifers, thus it is easily affected by surface water. According to the results, surface water and well water of this area was contaminated by excreta. It was revealed that many people use ponds and well water for drinking, even though they are not safe.

On the other hand, water from hand pumps comes from confined aquifers that are difficult to be affected by surface water and can be defined as safe water which is not contaminated. However,

coliforms were detected in some pumps. This may be because some pipe parts of the pump were corroded and perforated and hence contaminated water mixed with pump water. Pump water was safer than other sources, but it was not completely safe and a risk of diarrhea exists.

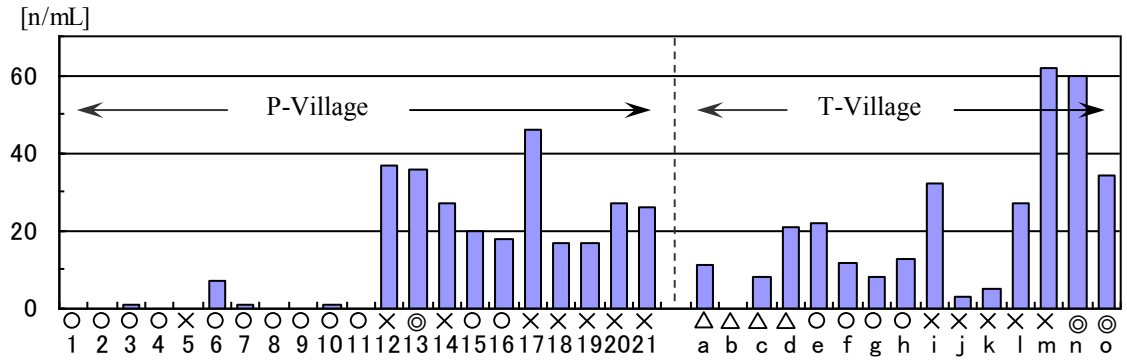

Fig. 3 Concentrations of coliforms on water sources

Possibilities of improving surface water from the point of view of hygiene education

Fig. 4 shows percentage of children whose houses were equipped with a toilet. More than 70% of children do not have a toilet at home, but most of them want one. As a reason, 76% selected "convenience". More than two out of three defecates in open spaces, and 42% in the class excrete near a pond. For the images of open defecation, 80% selected negative keywords like "dirty", "ugly", "inconvenient", and "shameful", but 13% selected positive keywords like "good feeling" and "cleanliness". Many children recognized open defecation as negative, and wanted a toilet for convenience.

There were two toilets at the public school in P-village, but children could not use them because they were broken and locked. According to the interview with the school teacher, children had used toilets properly in the beginning, but they gradually stopped using them properly, and toilets had become broken. This is because toilet users had to carry water from a hand pump, which was 50m away from toilets. When children feel the need to defecate at the school time, they have to endure or go outside.

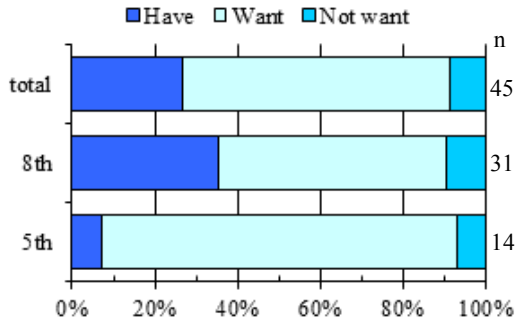

Fig. 4 Percentage of children whose houses are equipped with toilets

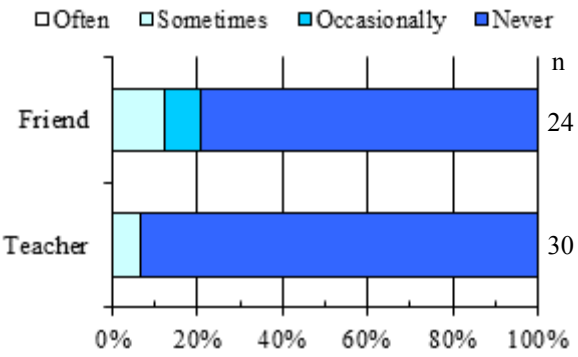

Fig. 5 Frequency of instruction to use toilet by friends or teachers

Teachers said that they taught children how to use a toilet when they taught hygiene. However, they also said that it was difficult to teach about toilet in daily life because they were broken. Fig. 5 showed frequency of instructions to use a toilet by friends or teachers. Most of the children did not realize that they were instructed about the usage of toilet at school. From the above reasons, it can be inferred that education about toilets was not conducted enough at school, and this is one of the factors that prevented the spread of toilets. Therefore, it is difficult and likely to take a long time to improve water quality of surface water.

Factors that influence people's choice of drinking water sources

According to the questionnaire survey at the public school of P-village, 52% of children used wells for drinking purpose and 32% of children used hand pumps. Fig. 6 shows the percentage of children who hesitate to drink water from wells and hand pumps. More than 40% of children hesitate to drink water from pumps. The most common reason was because of its "taste" and "smell". No one selected "location" as a reason. Less than 20% of children hesitate to drink water from wells. The most common reason was "family and friends do not use". "Safety/ dirtiness" and "location" were not selected.

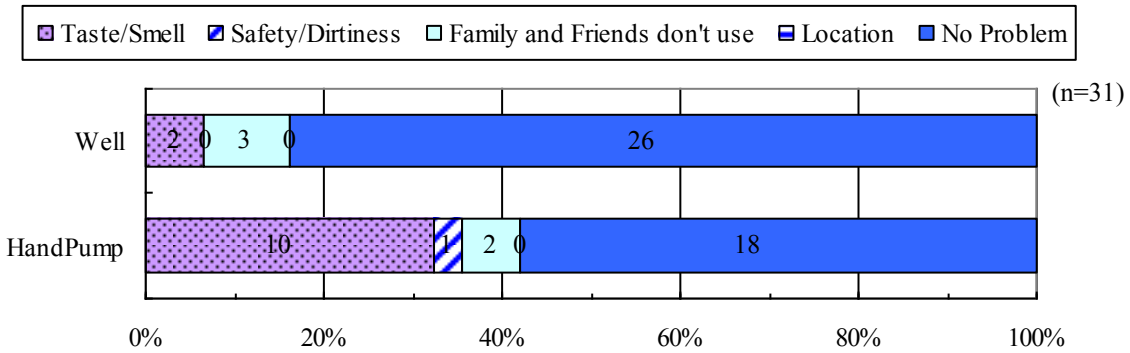

Fig. 6 Percentage of children who hesitate to drink water from wells and hand pumps

In T-village, most people used pond water for drinking purposes. They mentioned a better taste as the reason. They tended to dislike especially drinking water from pump because of its metallic taste. However, few people think pond was safe for drinking, and so they built and use private well or used pump for preserving their health.

Fig. 7 shows the results of measuring concentrations of iron at P-village and T-village. Marks above numbers and alphabets show whether the water source was used for drinking or not. For 'Ponds' and 'Wells', the average value was considered. In WHO's guideline of drinking water quality, there is a reference value about iron from a viewpoint of taste and coloring, though not from a viewpoint of safety. It specifies that concentrations of iron should be under 0.3mg/L. Higher levels of iron than the reference value were detected in some pumps. Two pumps of 11 in P-village and 3 pumps of 4 in T-village had higher levels. Particularly, values measured in pumps of T-village were very high; the highest being above three times the reference level. However, all other kinds of sources had a lower level than the reference value. Pump named '5' has been used for hand washing instead of drinking because it is located near a pond where many people practice open defecation.

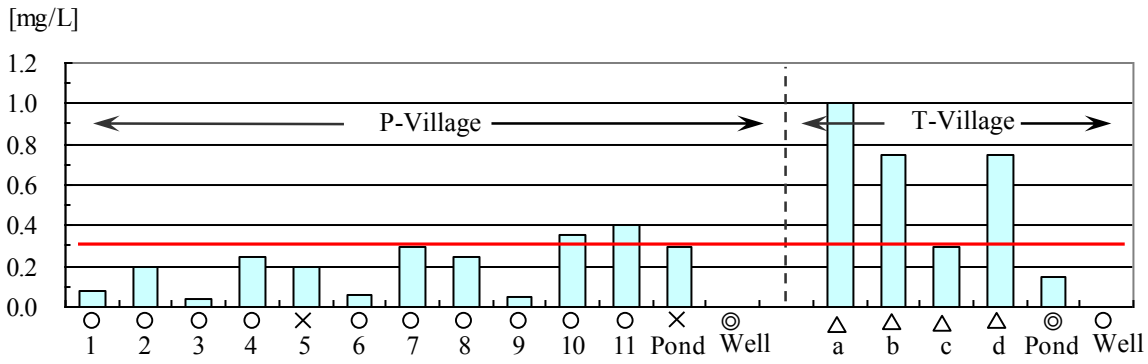

Fig. 7 Concentrations of iron in hand pumps, average of ponds and average of wells

People who did not have proper risk perception about each water source tended to choose by its taste and smell. Pump was the safest water source in this area, but many people hesitate to drink it. It was clear that this was caused by high concentrations of iron.

CONCLUSION

Water from ponds and wells used by many people for drinking contained many coliforms, and the risk of diarrhea by drinking water from ponds and wells is higher than that of hand pumps. It seems that it will take a lot of time to improve water quality of ponds and wells by spreading toilets because hygiene education was not conducted enough at school although most of children regarded open defecation negatively and wanted toilet in their homes.

Hand pumps are theoretically safer because the water comes from confined aquifers, which are difficult to be contaminated by surface water. However, coliforms were detected from some pumps on the actual site. In order to keep and use pumps as a safe drinking water source, regular inspection of water quality is needed.

However, people did not have proper risk perception about each drinking water source, and they chose and used source by other factors like taste. People especially hesitated to drink water from pumps, which was safer than others, because its concentration of iron tended to be high and its taste and smell got worse. Pump should be made of material which does not erode and affect the taste and smell of water. It is also important for people to have proper risk perception about each drinking water source in order to stop using unsafe water and then reduce the risk of diarrhea. Future studies should investigate ways to disseminate a proper risk perception among people to change their behavior.

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Research article

Fish Trade on Fishing Products in Tonle Sap Great Lake

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Abstract Looking to daily activities in Tonle Sap Great Lake and fish markets, the topic "Fish Trade on Fishing Products in Tonle Sap Great Lake" has been conducted to where fish products in Tonle Sap are exported, as well as of the way of fish processing. The study aims to (1) Identify the distribution of fish yields for domestic markets and fish species for processing; (2) Identify the distribution of fish yields for processing and different types of processing to domestic markets; (3) Evaluate the supply of the fresh fish yields in Tonle Sap to satisfy the demand of people in Cambodia; (4) Study market channels and values added by each transaction on fresh and processed fish products into domestic markets. Informally purposive sampling is selected for the research. The analysis shows the fish yields vary from each year in which the data has been recorded by the Fisheries Administration. However, during 2010, Tonle Sap Authority data shows the fish yield is about 537,000 tons, nearly triple of that of the Fisheries Administration of about 173,450 tons and equal to about 50% of Cambodian fish consumption. There are many fish species involved in the trade both domestic and international market such as bronze featherback, chevron snakehead, boeseman croaker, asian bonytongue, clown featherback, silver barb, giant snakehead, reddish sheatfish, frecklefin eel, blackspotted catfish, sickle fin barb, giant barb, peacock eel. The main actors of the supply chain of fisheries products are the fishing lot owners, fishers, fish collectors, wholesalers, trader-middleperson, and retailers. So, the fish market channel is from the first fishers until the final consumers. Fish market transaction is added from a transaction to another about 30% to over 80%, and the fish prices among domestic markets are not quite different from each other, just below 1,000 riel.

Keywords Tonle Sap Great Lake, fisheries product, fish trade, domestic fish products

INTRODUCTION

Currently, Tonle Sap Great Lake is a stock pool for many fish species and is one of the great lakes in South-East Asia, and is generally mentioned as the heart of Cambodia, which is illustrating the society, the economy, the environment, and the culture. In fact, this lake is not just a unique ecosystem of inundated flooded forest, fish habitats, and subsistence for agriculture; it is also a vital part of historical and cultural heritage of Cambodia's national identity (Campbell et al., 2006). It was a natural pool absorbing roughly 20% of the water flow from Mekong River and rich of the natural resources. Nearly half a million people are currently surviving and depending on the lake. Most people work as fisherman; some people plant crops, vegetables, rice, and other agricultural products. Various things to be considered were that fish supply would not be sufficient for current demands and for next generations. The main reason for the decline of all freshwater species was overexploitation and deforestation. The decrease of the natural resources and the rapid increases in the population had already resulted in the decrease of living standard throughout the lake area, as well as the entire country. Freshwater fish was further one of the most trading commodities in which the sellers sold them fresh in containers, fresh on ice, or in a wide variety of processing products. There were many steps and buying competitions involved in fish markets including the storage, handling, shipment, sale bargain, and product quality. Middlemen came and bought the fishing products from Tonle Sap Great Lake; then sold them by adding prices to the next buyers.

There were two main markets for fish products. Most of the exporters traded fish both fresh and processing products to the domestic markets in Phnom Penh, and also to foreign markets.

METHODOLOGY

The study collected the annual fish yield to estimate the fish products in 2009 only. Three main markets, Chong Koh, Kampong Luong, and Chong Kneas (Tonle Sap Great Lake) were chosen to study about fish market channels and fish prices. The study continued to ask for more information of fish prices from fishers, middlemen, retailers, and other key informants. Moreover, three more main domestic markets in Phnom Penh: Orussey Market, Chbar Ampov Market, and Doeumkor Market, were studied for the final fish prices. Three main methods were used to collect data from fishers and other key informants such as observation, semi-structure interview, and in-depth interview. The purposively selective sampling method was the main for accomplishing the study. The information was collected from the fishers about fish species and their prices. After that, the study continued to stock-wholesalers and retailers in domestic markets. Using prepared questionnaires, nearly 114 semi-structured interviews were carried out with fishers (60), traders or distributors (30), fish processors (21), and government officials (3) for three selected provinces in Tonle Sap Great Lake during the prohibited fishing season. There were three main markets in Phnom Penh and a fish distribution in Chrang Chamres Fish Distribution Center. The 91-prepared questionnaires were asked for the fresh and processed fish prices and fish species at Doeumkor market 20 out of 40 fresh fish retailers and 07 out of 15 processed fish sellers, at Orussey market 20 out of 25 fresh fish retailers and 07 out of 20 processed fish sellers, at Chbar Ampov market 20 out of 40 fresh fish retailers and 07 out of 20 processed fish sellers, and at Chrang Chamres Fish Distribution Center 10 out of 19 distributors.

RESULTS AND DISCUSSION

Identification of fish distribution

Tonle Sap Great Lake looks like the pool for many fish species. According to FiA (2009), freshwater fish exploitation in 2009 was 390,000 tons in total. The exploitation from fishing lots and middle-scale fishing was about 120,000 tons while the small-scale fishing was roughly 155,000 tons. The data of rice-field fishing around 115,000 tons was also included. However, the study was focused mostly on the 06-provinces adjoining to Tonle Sap Great Lake, so the total amount of industrial and middle-scale fishing products is 65,050 tons. TSA (2010) showed that the area in Tonle Sap Great Lake was around 1,500,000 hectares during the rainy season but in the drought period, it would recede to 250,000 hectares.

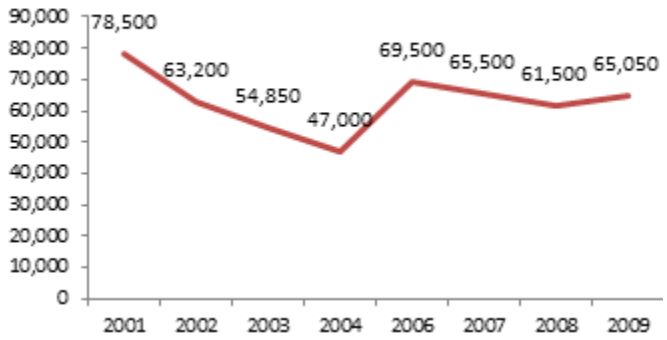

Fig. 1 Total catch of industrial and middle-scale fishing products (2001-2009)

In Table 1, the study focused on the catchment of fishing products in six provinces in cooperation with FiA (2009) and TSA (2009). There are three main parts to be considered: industrial and medium-scale fishing products (IFMSF), small scale fishing products (SSF), and small scale fishing in the rice field (SSFiR). The data of TSA (2009) was used for the study.

Table 1 Annual freshwater fish catch (Tons) in 6 provinces

No	IF-MSF	SSF	SSFiR	FiA	TSA
Kampong Chhnang	17,000	14,000	9,000		
Pursat	12,500	11,500	7,500		
Battambang	10,500	11,000	7,200		
Banteay	1,550	3,500	2,500	**173,450**	**537,000**
Siem Reap	11,500	13,200	8,500		
Kampong Thom	12,000	13,000	7,500		
Total	65,050	66,200	42,200		

Table 2 Fish distribution on the different uses in 2009

Fresh fish products		Domestic market	56,000
		Foreign market	14,000
Processed fish products	Dry and smoke fish products	Domestic market	12,800
		Foreign market	3,200
	Fermented fish paste called Brahoc	Domestic market	307,200
		Foreign market	76,800
Bait fish products		Domestic market	N/A
		Foreign market	67,000
Total (tons)			**537,000**

Table 3 Fish species of fresh and processing fish products for domestic market

No	Khmer name	Commerce name	Scientific name
1	Trey andaing	Walking catfish	*Clarias macrocephalus*
2	Trey chanteas phluk	Asiatic minnow	*Paralaubuca typus*
3	Trey chhkok	Giant barb	*Cyclocheilichthys enoplos*
4	Trey chhlonh	Peacock eel	*Macrognathus siamensis*
5	Trey chhlang	Blackspotted catfish	*Hemibagrus nemurus spp*
6	Trey chhpin	Goldfin tinfoil barb	*Hypsibarbus suvattii spp*
7	Trey chrorkaing	Sickle fin barb	*Puntioplites falcifer*
8	Trey diep/chdor	Giant Snake Head	*Channa micropeltes*
9	Trey damrey	Marble goby	*Oxyeleotris marmorata*
10	Trey kahè	Silver Barb	*Barbodes gonionotus*
11	Trey promah	Boeseman croaker	*Boesemania microlepis*
12	Trey slat	Bronze featherback	*Notopterus notopterus*
13	Trey sanday	Sheatfish	*Wallagonia attu*
14	Trey ta aun	Butter catfish	*Ompok hypophthalmus*
15	Trey riel top	Siamesae mud carp	*Henicorhynchus siamensis*

The data of FiA and TSA in 2009 are quite different from each other because the method to collect data was different. Because the study was under the department of Tonle Sap Authority, the study used data of TSA for reference. After collecting data of fishing products around the lake, the study separated it with various uses as in Table 2.

The study had asked for the fish species collected from Tonle Sap Great Lake. There were some usual sold-species from the lake into domestic markets as described in Table 3. However, there were about 10 fish species that were listed.

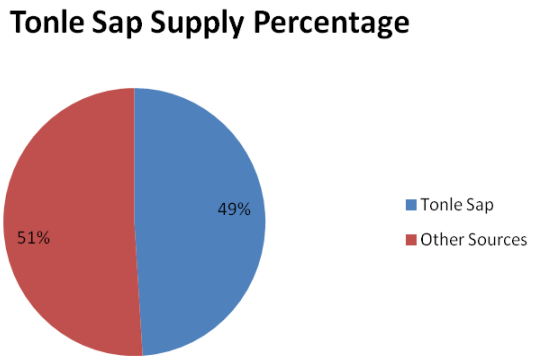

Fig. 2 Fresh fish products supplied in 2010 by Tonle Sap Great Lake

As shown in Fig. 2, the supply of fisheries products from Tonle Sap Great Lake is about 49% and the rest is from other sources while the demands of fish products reached about 1,102,500 tons a year for the current population, 2010.

Table 4 Type of fish processing in Tonle Sap Great Lake

Types	Fish Species, Khmer	Commerce name	Scientific name
Smoke fish	Trey riel top	Siamesae mud carp	*Henicorhynchus siamensis*
	Trey linh	Lesser bighead carp	*Thynnichthys thynnoides*
	Trey kesh	Reddiish sheatfish	*Wallago attu*
	Trey Phtong	Congaturi halfbeak	*Hyporhamphus limbatus*
Salt dried fish	Trey promah	Boeseman croaker	*Boesemania microlepis*
	Trey kanchos	Striped catfish	*Mystus atrifasciatus*
Sun dried fish	Trey kanchos	Striped catfish	*Mystus atrifasciatus*
	Trey phtuok	Chevron snakehead	*Channa striata*
	Trey promah	Boeseman croaker	*Boesemania microlepis*
Fermented fish paste called Brahoc	Trey riel top	Siamesae mud carp	*Henicorhynchus siamensis*
	Trey linh	Lesser bighead carp	*Thynnichthys thynnoides*
	Trey kawmphleanh	Three spot gourami	*Trichogaster microlepis*
Pasted fish called Pa Ork	Trey phtuok	Chevron snakehead	*Channa striata*
	Trey diep	Giant snakehead	*Channa micropeltes*
	Trey chhlonh	Peacock eel	*Macrognathus siamensis*
Frozen fish	Trey chhlang	Blackspotted catfish	*Hemibagrus nemurus spp*
	Trey chdor	Giant snakehead	*Channa micropeltes*
	Trey kesh	Reddish sheatfish	*Wallago attu*
	Trey slat	Bronze featherback	*Notopterus notopterus*

Identification of market channel and value added in domestic markets

The most alerting component of the fish marketing system in Cambodia was the supply chain and distribution channels before fish products reached consumers. There were many middlepersons essential for the fish trade. The fish market channel started from fishers/lot owners/cage/pond culture to collectors/middleman, to wholesalers/traders, to semi-wholesalers/second traders, to retailers, and to domestic consumers. Table 5 shows value added from each transaction regarding some fish species, which was estimated by the study..

Table 5 Value added of fresh fish products for domestic markets

Fresh fishing products		Fisher	Trader	Distributor	Consumer	Margin
Walking catfish	Price (r/kg)	3,500	4,500	6,000	7,000	3,500
	% of final price	50%	64%	86%	100%	50%
Striped catfish	Price (r/kg)	2,000	3,000	3,500	4,500	2,500
	% of final price	44%	67%	78%	100%	56%
Chevron snakehead	Price (r/kg)	4,500	7,500	9,000	14,200	9,700
	% of final price	32%	53%	63%	100%	68%
Giant snakehead	Price (r/kg)	6,000	13,000	14,000	16,300	10,300
	% of final price	37%	80%	86%	100%	63%

Marketing margins for the eight species study ranged from about 50 to 80 percent. Prices offered to fishers represent only about 25-45 percent of the final retail price. According to Yim and Mckenney (2003) the marketing margin of three species ranged from 65 to 75 percent of the consumer's prices. These showed there was not so much difference in the value added in 2003 and 2010, but the prices of fish products were higher in 2010 than those in 2009 because of the inflation and the higher demand.

Table 6 Value added of processed fish products

Marketing process			Fisher	Trader	Distributor	Consumer	Margin
Fermented Small fish paste	Three spot gourami	Price (r/kg)	2,500	6,000	7,100	8,300	5,800
		% of final	30%	72%	86%	100%	70%
Smoke Fish	Reddish sheatfish	Price (r/kg)	12,000	80,000	105,000	117,000	105,000
		% of final	10%	68%	90%	100%	90%
Sun Dried Fish	Giant snakehead	Price (r/kg)	7,000	30,000	35,000	40,000	33,000
		% of final	18%	75%	88%	100%	83%
Salt Dried Fish	Striped catfish	Price (r/kg)	3,500	10,000	13,000	15,600	12,100
		% of final	22%	64%	83%	100%	78%

Marketing margins for the four fish processing study ranged from about 65 to 90 percent. Prices offered to fishers represent only about 15-35 percent of the final retail prices but the consumers have to add about 50-90 percent of the final fish prices. The highest prices are generally added to the reddish sheatfish and giant snakehead. They are sold at the highest prices in the market. These are connected to the demand preferences and the human behavior at the fish marketing.

CONCLUSION

There were many fish species involved in the trade of both domestic market such as bronze featherback, chevron snakehead, boeseman croaker, asian bonytongue, clown featherback, silver barb, giant snakehead, reddish sheatfish, frecklefin eel, blackspotted catfish, sickle fin barb, giant barb, and peacock eel. Moreover, the price changed from each transaction. The main actors of the supply chain of fishery product markets were the fishing lot owners, fishers, fish collectors, wholesalers, trader/middleperson, and retailers. Therefore, the fish market channel was from fishing lot/pond/cage owners to the consumers. The existing infrastructure of marketing and trading of freshwater fisheries products was still poorly developed in terms of landing, storage, preserving, transportation, and retail facilities. The study described the market channel of the fish species in Tonle Sap Great Lake and showed mostly the fish market transaction in which the fish value was added from hand to hand.

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Research article

Resilience of Rice-field and Mountain-based Native Beef Cattle Raising: A Case Study in Nakhon Panom Province, Thailand

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Abstract Native beef cattle raising by small-scale farmers in the rural areas of Thailand is vulnerable to ecological, institutional and technological changes. Decrease of vulnerability can be achieved by increasing resilience. The study of the resilience of rice field and mountain based native beef cattle raising in Nakhon Panom province, Thailand was therefore conducted as a case study to assess the resiliency level of the system. A focus-group workshop and survey were used in this study. Animals were raised in harvested rice-fields and shifted to a free-grazing area in a forest-mountain area over the wet season. The results indicated that the system was resilient. For this reason, it is felt that native-beef cattle raising in these two ecologies are sustainable. The resilience of the system can be manifested into eight elements: 1) good governance among rural communities and national parks in terms of policy and cooperation; 2) socio-economic enhancement and a sound and sustainable livelihood; 3) well integrated natural food resources in the forest with abundant crop residues and natural grasses in the rice field; 4) adaptation of land-use and the less significant need to support the basic infrastructure; 5) sound orientation and awareness of risks in the system (therefore, risk reduction stems from the integration between indigenous technical knowledge (ITK) and proper technology for herd management); 6) farmers' awareness of early warning signs of identified risks that alert them to prepare, protect and prevent the loss of animals; 7) well preparedness and undertaking of procedures established for animal protection such as diseases outbreak, heavy rain and supporting networks; and 8) in-place plans of action for the recovery of food resources and a herd management plan. Improvement needed, farmers focus on value adding within integration to husbandry practices and increasing an adaptation capacity for changes in the future.

Keywords mountain, native beef cattle, resilience, rice-field

INTRODUCTION

The native beef cattle production system in the northeast of Thailand, has played an important role in the sustainable livelihood at household and community levels over the past century. The system is a natural synergism of agriculture and the forest ecosystem. Rice cultivation is a major crop in the region and is well integrated in the raising of native beef. Accordingly, changes in socio-economics and the ecosystem have greatly affected production of native beef cattle. As a result, the production system has a resilience level which reflects sustainability (Adger, 2000). Adopting the tools to assess the level of resilience will assist the understanding of the system, further improving and promoting production in the region. The aim of the study is then to assess the existing production system in the realm of ecosystems. Nakhon Panom province has been selected as the target ecosystem where native beef cattle are raised under natural conditions.

METHODOLOGY

Focus group is composed of group's leaders and members of native beef cattle raising, mixed gender with age of 40-70 years old. Discussions were held to assess the resilience of rice-field and mountain-forest beef cattle raising systems in the Nakae district of Nakhon Panom province. Data and information were collected by application of the Participatory Rural Appraisal (PRA) tool, integrating the modification guidelines from the Coastal Community Resilience (CCR) developed by the US Indian Ocean Tsunami Warning System (US-IOTWS, 2007). The eight basic elements of CCR represent the desired conditions necessary to support resilience of the system. Each element contains benchmarks that can help determine the extent to which the element is addressed or operating to enhance resilience. The eight elements are: 1) governance, 2) society and economy, 3) natural resource management, 4) land use and infrastructure, 5) risk knowledge, 6) early warning system, 7) emergency response, and 8) recovery. Interviewees were asked to rate the level of resilience for each element presented in the questionnaire. A rating score of 1-5 was provided, where 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high. A weighted average index (WAI) is then calculated for each element and illustrated in the spider diagram as shown in Fig.1.

RESULTS AND DISCUSSION

Characteristics of the ecosystem and overall resilience in the production system

The components of the studied ecosystem consist of a rice-field, which is adjacent to both a mountain and a settlement. The rice field serves as a habitat, with available feeding resources, such as straw, grass and drinking water in the dry season.

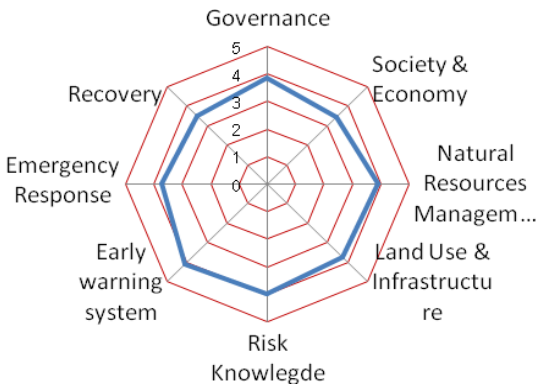

Fig. 1 The resilience diagram reflects resilience levels of native beef cattle raising in the rice-field and mountain forest-based system in Nakhon Panom province, Thailand (blue line)

Level of resilience: Low resilience (less than 3); resilience (equal to 3); and higher resilience (more than 3)

The mountain location provides natural grass, plant leaves, forest fruit, medicinal herbs, and drinking water. Resilience of the native beef cattle raising system in the component ecosystem is illustrated in Fig.1. Every element has a WAI score greater than three. It clearly indicates that the overall dimension of the production system is highly resilient. This reflects a system of sustainability over the past century. The details of each element are described in the following sections.

Governance of community-based, native beef cattle raising management

Good governance facilitates the consensus on development, responsibility, accountability and successfulness. The main focus is on institutional context, as the study is initiated formally via farming groups. The aim is to coordinate and strengthen the production system. The group has cooperated within and has been linked closely to policies from the Provincial Department of Livestock Development (DLD). The DLD supports technical services, including the development of in-place production plans and guidelines. Management and implementation of procedures were closely monitored by the committee. The group exhibited great cooperation with national parks regarding conservation and utilization of forest resources. Forest use purposes were for either native beef raising or sustainable household living. The community attempted to make significant contributions to protect, conserve and rehabilitate the forest ecosystem.

Community-based socio-economics of native beef cattle rising

Socio-economics reflects the production system's resilience and is well integrated to the livelihood of the community. Native beef cattle production is highly resilient in term of socio-economics and is adapted to both society and culture. The agricultural system of the study area, dominated with native beef cattle, rice cultivation and non-timber forest production, has provided a sustainable livelihood for more than a century. Regarding beef cattle farming today, it is said that "native beef cattle raises the farmer" rather than the cattle being raised by farmers. It is ranked second in importance after the paddy field. It provides security as the community's food source, either directly or indirectly; and a significant annual cash income. Additionally, cattle manure used as fertilizer to sustain soil fertility (Pholsen, 2005) is an equally important by-product. Normally, native beef cattle are ready to be sold when they return from the mountain-forest. One to two head of cattle per farmer are expected to be sold, at either a community event or outside market. Due to low production costs, farmers may decide not to sell their cattle if the price is too low or experience a high demand to sell, when prices are high. They normally decide to keep the herd though maintaining the herd size is not cost effective.

Community-based natural resources management for native beef cattle

Overall community-based forest resource management reflects the high resiliency for sustainability of the beef raising system. In the study area, farmers allow the native beef cattle to graze for six months in the mountain-forest during the rainy season, and six months in the post harvest rice-fields surrounding the village in the dry season. This is the normal practice for the typical combination of two ecosystems. As previously reported (Duanyai, 2009), the switching of the two ecosystems was due to insufficient feeding resources in the mountains and unavailable grazing land during rice cultivation. Natural resources in the ecosystem are considered to be most important for beef cattle raising. In general, natural resources are well protected and monitored by communities, local government and national parks. These communities demonstrate strong leadership in terms of conservation and forest resource management, with national parks and other stakeholders. The greatest reduction in beef cattle capacity is due to the prohibition of the use of rice fields surrounding the village and/or national parks. The number of cattle may be reduced to only one from ten in proportion. This reflects the importance of the rice-field ecosystem for the production system. The sensitivity of habitats, ecosystems and natural resources are protected and maintained to reduce risks from hazards such as forest fire, logging, hunting, collecting and other

encroachments. Communities are actively engaged in planning and implementing forest management activities, which are well integrated to their livelihoods.

Community-based land use and infrastructure for raising native beef cattle

Communities expressed a high resilience for the land use system. They have established measures that reduce the risks from forest fires and other hazards that negatively impact their livelihood and beef cattle raising in the long term. In general, communities have incorporated a better infrastructure in raising native beef cattle, such as creating a reservoir or canal to supply water to the rice fields. This serves agricultural activity in the dry season, enhances household income, and increases the security of beef cattle raising. Other infrastructures in the community are maintained such as a tap-water supply pipe, road accessibility, a broadcasting system, and effective mobile-phone communications. Therefore, marketing systems for beef cattle are well established between merchants and farmers regarding both the exchange of information and the sale of cattle. An equally important infrastructure is the servicing network of animal production from the DLD. The establishment of livestock volunteers in the community link villages for the purpose of disease prevention and other services.

Risk knowledge and mitigation measures on native beef cattle raising

Communities are aware of the risks and hazards that affect beef cattle raising, as seen in Table 1. The table shows all possible risk factors affecting the different levels of the native beef production system in the study's two combination ecosystems. The highest risk factors (scoring 7-10) show the unavailability of food resources in the mountains, rice straw in the rice fields, capital for first investment, and prohibition from national parks. Most risk factors are reduced via proper mitigation measures. This knowledge has been integrated into the community's livelihoods by means of both formally and informally exchanging information related to activities learned from the past. Other minor hazards are fever, injury, and lesions and/or wounds due to scratching in the forest. Disease outbreaks are a major hazard risk that can heavily affect the loss of cattle nationwide. However, mitigation measures provided regular vaccinations for cattle prior to placing them in mountain-forest areas. And, while forest fires in the dry season damage natural mountain grasses, fires in successive seasons may permanently damage natural grass, affecting native beef cattle raising in the rainy seasons as well. The measure to protect forest fires in the dry season has been taken with the cooperation of national parks., conducting preparedness to protect forest-fires in the dry season. In the rainy season, the hazard risk is at low level. Therefore, market price fluctuation is generally less affected, due to the existence of more marketing channels and seasonal summer events; such as marriages and festivals. Improving the quality of native beef meat by fattening is unfavorable among Thai farmers, as the return from the fattened beef is not significantly higher than from natural raising. It therefore leads to higher risk from increased investment.

Community-based early warning system for native beef raising

Effective warning mechanisms and understanding early warning messages helps to reduce the loss of beef cattle. Since farmers' awareness of hazards and information of risks, including their accessible capacity of cattle, provide a better herd management and advance preparedness in reducing the loss of animals. For enhancing a faster recovery of the production system, the community has established a communication network within the community, DLD, national parks, and beef cattle merchants. These networks facilitate a better flow of information for vulnerable beef cattle rising activities, such as any unidentified causes of death, diseases outbreaks, and government policies related to the DLD, agriculture and national parks, as well as market price and supply and demand within the local area. The community has various teams to monitor the native beef cattle activity in the mountain-forest area. Any cause for alarm will reach the cattle owner within a few hours so that they can respond swiftly.

Table 1 Risk factors affecting native beef cattle raising, from 1 (lowest) to 10 (highest)

Risk Factors	Rank of Impact	Description and Mitigation Measures
1. No community person for treatment of traditional disease	5	Number of farmers will be decreased about 50% as they are unsure of the survival of cattle in the forest-mountains due to lack of services for sick or injured cattle
2. Impact due to sudden change of season	1	No effect on native beef cattle, as they have a high capacity for adapting to the change of weather
3. Less food resources in the forest-mountain	8	Without food resources in the forest-mountain, it is of no use to raise native beef cattle in the forest-mountain
4. Onset of disease outbreak	4	Available volunteers service at the right time of disease outbreak
5. Risk from lack of skill in new farmers	2	Anyone can start raising 1-2 head of cattle without knowledge background, due to husbandry techniques based on indigenous technical knowledge, transferred from generation to generation
6. Fluctuation on price of beef cattle	2	Low production costs and low risks. Farmers can continue raising them until the price is better
7. Unavailability of native beef market	1	It can be sold at farm-gate by local merchants or thru the community's consumers mostly through local events and festivals.
8. Unavailability of concentrated feed	1	It is unnecessary for native beef cattle. It is needed for the skinny beef. Fattening is unnecessary
9. Unavailability of rice straw	10	It is the major feed resource. Farmers reserves rice-straw at home sufficiently throughout the dry season and partly in wet season
10. Unavailability of capital	10	Necessary for starting the business. But it is not considered as a risk
11. Risk from type of current breed of cattle	1	The native breed is the most suitable to the natural resources and environment. It has high tolerance to weather, insects, parasites and diseases, therefore adapting to the low quality of feed resources
12. Fattening program for native beef cattle	6	Fattening programs are a risk, considered unnecessary because prices are insignificant to normal raising beef cattle
13. Hybrid Brahman beef cattle.	4	Low adaptation capacity and low reproductive performance.
14. Prohibition from national parks	7	A high effect, especially in the rainy season, when insufficient rice straw may reduce the numbers of beef cattle around 70%
15. Unavailability of rice fields surrounding the community	9	Significantly affect the long term, as rice fields provide year round resources, which may be reduced around 90% of the current total
16. Accidents causing death.	< 1	Less effect to the number of cattle, as it is rarely happens
17. Onset of forest fire	9	Complete damage to the natural grass in the forest, for 1-2 years.
18. Unavailability of village livestock volunteers	3	Important in providing services, but has little effect to the herd size.
19. Unavailability of groups	5	For better coordination among members and other organizations
20. Unavailable DLD Officers	6	Lack of support for disease prevention and for emergency care

Mitigation, preparedness and emergency response for native beef cattle raising

Proper actions taken to reduce the loss of animals, enhance the resilience of the production system. Farmers are experienced in emergency response procedures to prevent the loss of animal life in the production system. Many emergency cases such as cattle fever, injury and wound require special treatment. In addition to the groups and beef cattle owners, village volunteers are key people in

emergency response to such cases, as well as right-time artificial insemination, and search and rescue of missing cattle. This includes accessibility to Provincial DLD for all emergency cases. In the area of risk management, and in the case of cattle evacuation or relocation; the shorter-route will be taken. That is to say, that the owner would decide to slaughter the animal rather than move it. Well preparedness and mitigation measures provide shelter from changing weather, and safeguard the welfare of the beef cattle; including guarding and monitoring the herd and population of cattle in forest-mountain areas.

Community-based native beef cattle raising recovery

The collapse of raising systems may be caused by various risk factors. The advance collaboration of related organizations would reduce risks from policy changing. However, this rarely takes place, due to the current policies of the DLD and national parks as well as community-based participation and co-management for forest protection, conservation, and utilization. Therefore, government policies are in place for damage compensation due to the loss of an animal from disasters, drought, flood, storm, and thunderstorms. The subsidies have been undertaken by local authorities, and provincial disaster prevention and mitigation through the Ministry of Interior. Thus, groups of native beef cattle raising farmers were formed to support the recovery function, especially in the loaning of feed resources and coordination support. Hence, social cohesion and strong leadership among groups have encouraged adaptation to change and facilitated a rapid product system recovery.

Challenge and sustainable development

The results of this study of the native beef raising system in a dual combination ecosystem reflect a synergism between man, native beef cattle and the ecosystems. It is agreed that ecosystems are the most vital component of the production system. A change in the ecosystem due to policies, technology, and damage caused by man-made or natural disasters, have a severe effect on animal husbandry. This has been clearly realized by stakeholders in the area. Native beef cattle adapt in nature with the abundance of natural resources in the ecosystem. Management adapts the Indigenous Technical Knowledge (ITK) integrated with new technology. This approach facilitates unsophisticated adoption and enhances the resilience of the production system. Sustainability of production systems is strengthened through concrete plans for conservation and rehabilitation of the two ecosystems, with a proper utilization of natural resources and proper land-use planning. Establishments of beef cattle raising group can promote self reliance. Strengthening the capacities is crucial via training courses, technical advisement, encouraging the development of planned, assistance in implementing, following-up, and evaluating the successfulness of the program.

CONCLUSION

Native beef cattle raising in the two ecosystems is a highly resilient system. Vulnerability of the production system is reduced from various mitigation measures undertaken to sustain the production system. It is recommended that the sustainability of native beef cattle can be enhanced via maintaining the ecosystems and increasing the capacity of stakeholders in conservation practice and proper utilization of natural resources and land-use planning.

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Research article

Estimated Maximum Daily Intake of Streptomycin Residue in Pork Consumed by Age and Gender Groups in the Philippines

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Abstract Dietary intake of significant amounts of residues can lead to adverse health effects and the development of antimicrobial resistance in the population. This study was conducted to determine dietary intake of antibiotic drug residues in pork consumed in the Philippines. The specific aim was to estimate maximum daily intake of streptomycin residue ($EMDI_{STC}$) by age and gender groups. Parameters such as maximum residue limits (MRL), 90^{th} percentile food consumption, body weight, age and gender groups were gathered from local and international institutions. A mathematical equation was used to calculate $EMDI_{STC}$ from MRL multiplied by the 90^{th} percentile food consumption and adjusted by body weight. In the present study, the $EMDI_{STC}$ for infants from birth to less than 12 months of age had the highest intake ratio of streptomycin residue followed by children, adolescents and adults where males were significantly higher than females ($p<0.05$). Based on the findings of the present study, it is concluded that streptomycin detected in pork affects infants from birth to less than 12 months that are more likely to consume it and more vulnerable due to physical activity. This is the first attempt to estimate dietary intake of antibiotic residues in the Philippines. Improvement of mathematical models used in this study is proposed to prioritize better models for veterinary drug residues to ensure the safety of food produced from farm to table.

Keywords: dietary intake, pork, antibiotic residue, age-gender group, Philippines

INTRODUCTION

Food needs to be consumed for maintenance of human functions. Food has to be safe for human consumption. Food safety is imperative for the development and maintenance of a healthy population (Titus, 2007). Consequently, health effects and safety aspects of food are important issues for today's consumers. There are increasing public health concerns that drug residues and their metabolites could be found in meat and other foods of animal origin may and cause adverse effects on consumers' health (EFSA, 2007).

Through time livestock production has evolved from small scale to large scale integrative farming (NMIS, 2006). This required the increased use of veterinary drugs. These are used to cure or prevent diseases in animals, to increase feed efficiency or growth rate, and to sedate animals in order to minimize the effect of stress (Botsoglou and Flatouris, 2001; Doyle, 2006). With the

widespread use of veterinary drugs in animal production, there is global concern about the consumption of foods of animal origin that may contain residues and their possible adverse effects on human health (Huss et al., 2004). For instance, with the use of antimicrobials in animal production, there is a possibility for the creation of antibiotic-resistant pathogens in animals that may be transferred to man (FSIS, 2000; Doyle, 2006). Boden (2005) cited that drug residues in food are regarded as very important from the public health's point of view. Moreover, there has been concern about carryover of veterinary drug residues in meat, eggs, and milk to people consuming these foods (Botsoglou and Flatouris, 2001; Doyle, 2006). Potential hazards associated with the presence of veterinary drug residues in edible tissues have been reported to cause toxic or allergic reactions, anaphylactic reactions, headache, and severe aplastic anaemia (WHO, 1999; Kelly, 2005).

Thorough literature search revealed no available study on estimated antibiotic drug residues in pork consumed using mathematical equations in the Philippines. With the increase in reports of occurrence of risk of veterinary drug residues in foods of animal origin in the last two decades (Health Canada, 2003a, Sumner et al., 2004), there is a strong need to study dietary intake of veterinary drug residues. To date, there is no local study conducted on the prediction for residual antibiotics in the Philippines. Thus, this study aims to derive an estimated maximum daily intake of streptomycin residues in pork consumed by age and gender groups in the Philippines.

The overall objective of the study is to determine dietary intake of antibiotic drug residues in pork consumed in the Philippines. The specific aim is to estimate maximum daily intake of streptomycin residue by age and gender groups.

METHODOLOGY

The study was conducted using secondary data collected from local and international institutions for estimating EMDI (estimated maximum daily intake). For instance, local data like the report on veterinary drug residue (2003-2008) from National Meat Inspection Service (NMIS), recommendation on Maximum Residue Limit (MRL) published by the Bureau of Aquaculture Fisheries and Product Standard (BAFPS), the report of Food Consumption Survey in 2003 and Recommended Energy and Nutrient Intake in 2002 published by Food and Nutrition Research Institute (FNRI), and the development of antimicrobial resistance from Research Institute for Tropical Medicine (RITM). International data came from Codex Alimentarius Commission (CAC) on amount of antibiotic drug residues, the procedural guidelines on residues of veterinary drugs in food from JECFA, and from an updated report of the 32nd session of the Codex Veterinary Drug Residues in Food 2009.

EMDI modelling combines MRL data with 90th percentile food consumption data and body weight factor to estimate EMDI. The basic EMDI model is of the form:

EMDI = [MRL X 90th percentile food consumption] ÷ weight factor

where EMDI is an estimate of drug residue intake expressed in µg/kg BW/day.

RESULTS

Streptomycin is active against a wide range of gram-negative organisms and some gram-positive pathogens in pigs, cattle and sheep. Streptomycin was evaluated by the Codex Committee at its 12th meeting in 1969, 43rd meeting in November 1994, 48th meeting in 1998, report of the 11th session of the Codex Committee on residues of veterinary drugs in food in September 1998 and updated as of the 32nd session of the Codex Alimentarius Commission in July 2009. The committee proposed a temporary MRL's for streptomycin at 600 µg/kg (muscle, liver, fat).

The reference weight for adults, 59 kg for males and 51 kg for females, and the average weight in the Philippines, 55 kg (FNRI, 2003) as well as the 90th percentile food consumption per capita in the Philippines and three islands are shown in Table 1.

Table 1 Mean one-day per capita pork consumption (gram, raw, as purchased) 2003 food consumption survey

	Philippines	Luzon	Visayas	Mindanao
Fresh Meat				
Pork				
Mean	31.80	39.89	23.07	18.24
95% Cl	31.76, 31.83	39.84, 39.93	23.01, 23.14	18.19, 18.30
P90	108.21	127.31	88.50	57.29

Source: FNRI, 2003

However, the weight difference between age groups: infants, adolescents, adults and older; the 90th percentile food consumption per capita; and average weights in the Philippines were calculated using Eq. (1) below.

The 90th percentile food consumption difference age groups = [average weight difference age groups × the 90th percentile food consumption per capita in the Philippines] ÷ average weights in the Philippines (1)

Using Eq. (1), the 90th percentile food consumption different age groups was calculated separately by ages (infants, children, adolescents, and adults), gender, average weights in different age groups, and average weight in the Philippines. A summary for computation of the 90th percentile food consumption in the Philippines is shown in Table 2.

Table 2 Summary of 90th percentile pork consumption per capita by age group and average weight in the Philippines, Luzon, Visayas and Mindanao

Age Groups		Weight (kg)	Philippines (g)	Luzon (g)	Visayas (g)	Mindanao (g)
1. Infants, mo						
	Birth- <6 (3)	6	12	14	10	6
	6-<12 (9)	9	18	21	15	9
2. Children, y						
	1-3 (2.5)	1	26	30	21	13
	4-6 (5.5)	19	37	44	31	20
	7-9 (8.5)	24	47	55	39	25
3. Adolescents, males, y						
	10-12 (11.5)	34	67	79	55	35
	13-15 (14.5)	50	98	115	81	52
	16-18 (17.5)	58	114	134	94	60
4. Adolescents, females, y						
	10-12 (11.5)	35	69	81	57	36
	13-15 (14.5)	49	96	113	79	51
	16-18 (17.5)	50	98	115	81	52
5. Adults, males, y						
	19-49	59	116	136	95	61
	50-64	59	116	136	95	61
	65 and over	59	116	136	95	61
6. Adults, females, y						
	19-49	51	100	118	83	53
	50-64	51	100	118	83	53
	65 and over	51	100	118	83	53

Eq. (2) was used to calculate the EMDI of streptomycin residues by adaptation from the value of Eq. (1) then multipled by MRL muscle tissue and adjusted by weight factor as recommended by

Codex committee and Philippines National Standard. Then comparison of estimates of streptomycin residues intake was computed.

$EMDI_{STC}$= [MRL × the 90th percentile food consumption difference age groups] ÷ average weights differences age groups (2)

Table 3 summarizes the EMDI of streptomycin residue for all locations. Particulars for the computation of EMDI of streptomycin residue in the Philippines, Luzon, Visayas and Mindanao are shown in Appendix B Tables 2 to 5 (Venn et al., 2010).

Table 3 Summary of EMDI of streptomycin residue intake of fresh pork in the Philippines, Luzon, Visayas and Mindanao

Age Groups	Philippines (µg/kg BW/day)	Luzon (µg/kg BW/day)	Visayas (µg/kg BW/day)	Mindanao (µg/kg BW/day)
Infants, mo				
Birth- <6 (3)	1.2000	1.4000	1.0000	0.6000
6-<12 (9)	1.2000	1.4000	1.0000	0.6000
Average	*1.2000*	*1.4000*	*1.0000*	*0.6000*
Children, y				
1-3 (2.5)	1.2000	1.3846	0.9692	0.6000
4-6 (5.5)	1.1684	1.3894	0.9789	0.6315
7-9 (8.5)	1.1750	1.3750	0.9750	0.6250
Average	*1.1811*	*1.3830*	*0.9743*	*0.6188*
Adolescents, Males, y				
10-12 (11.5)	1.1823	1.3941	0.9705	0.6176
13-15 (14.5)	1.1760	1.3800	0.9720	0.6240
16-18 (17.5)	1.1793	1.3862	0.9724	0.6206
Adolescents, Females, y				
10-12 (11.5)	1.1828	1.3885	0.9771	0.6171
13-15 (14.5)	1.1755	1.3836	0.9673	0.6244
16-18 (17.5)	1.1760	1.3800	0.9720	0.6240
Average	*1.1786*	*1.1854*	*0.9718*	*0.6212*
Adults, males, y				
19-49				
50-64	1.1796	1.3830	0.9661	0.6203
65 and over	1.1796	1.3830	0.9661	0.6203
	1.1796	1.3830	0.9661	0.6203
Adults, females, y				
19-49	1.1764	1.3882	0.9764	0.6235
50-64	1.1764	1.3882	0.9764	0.6235
65 and over	1.1764	1.3882	0.9764	0.6235
Average	*1.1780*	*1.1856*	*0.9712*	*0.6219*

Fig. 1 shows that EMDI of streptomycin residues for infants is 1.2 µg/kg BW/day from birth to less than 12 months of age. 1.2 µg/kg BW/day was calculated as 600 µg/kg of MRL multiplied by 90th percentile food consumption infant of 0.012 kg divided by the average weight of infant at 6 kg. It is equivalent to children from one to three years of age. In general, infants had consumed more streptomycin residues than children (1.1811 µg/kg BW/day) followed by adolescents (1.1786 µg/kg BW/day) and adults (1.1780µg/kg BW/day). Moreover, EMDI for males was significantly higher than that for females ($p<0.05$).

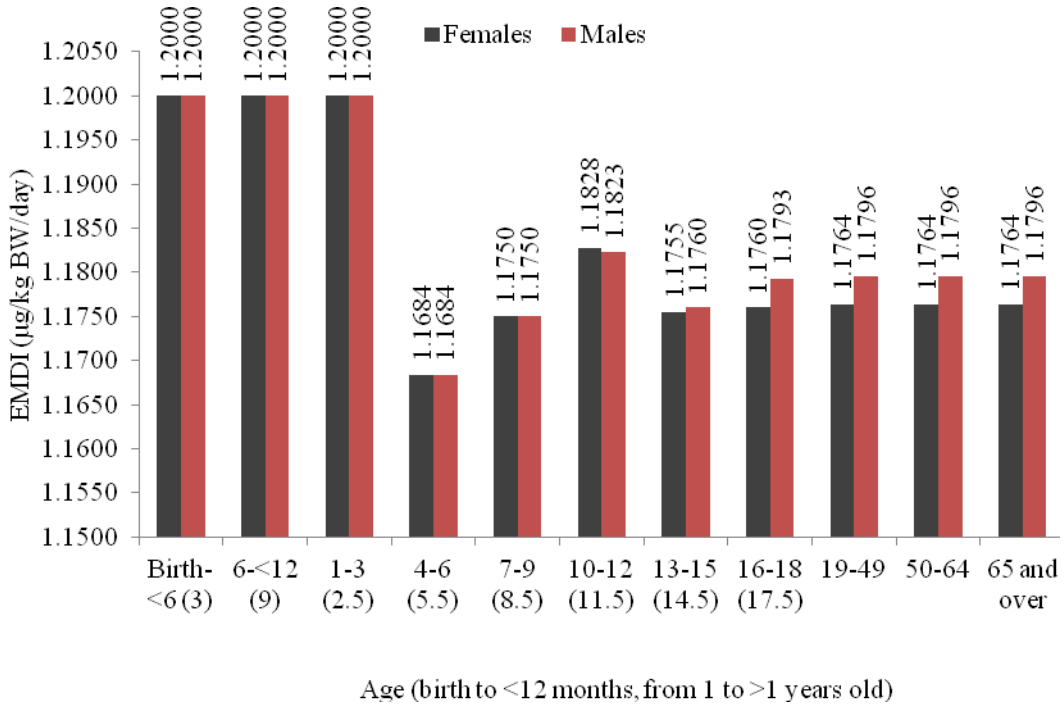

Fig. 1 Estimated maximum daily intake of streptomycin residue for females and males from different age and weight groups in the Philippines

DISCUSSION

Prediction of EMDI of streptomycin residues from dietary intake of pork using a stepwise approach is a step forward to provide an estimate potential exposure of the population. Hence, analysis of EMDI found that infants from birth to less than 12 months of age had the highest intake of streptomycin residue in the Philippines, followed by children, adolescents and adults.

A similar study on the exposure assessment of chemical from packaging materials in food by Pocas and Hogg (2007) mentioned that food consumption by infants and small children is much higher, based on the body weight, than by conventional adult model of 1 kg_{food}/60 kg BW. In addition, infants and children, because of their higher food consumption rates per kg BW, were generally expected to have a higher dietary daily intake of substances (Kroes et al., 2002). However, the assessment on dietary Melamine exposure, Xu et al. (2009) reported that infants of three months old had the highest intake estimate of melamine and with the increase in age, the intake decreased. Another example was conducted on dietary exposure to copper in the European Union. Steve (2008) reported that in most studies in EU member states, age and sex differences were more apparent than regional differences. Young and middle-aged adults have higher mean intake than elderly or very elderly.

CONCLUSION

Based on findings of the present study, streptomycin residue have been detected in pork which infants from birth to less than 12 months are more exposed to and more at risk, because of their higher food consumption rates per kg of body weight, and they are generally expected to have a higher exposure level due to physical activity.

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Research article

Diversity and Community Structure of Terrestrial Invertebrates in an Irrigated Rice Ecosystem

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Abstract Diversity and community structure of terrestrial invertebrates in rice ecosystems were studied in rice fields under irrigated condition from January to April 2011. The research revealed that terrestrial invertebrate fauna comprised 84 species of insects in 72 families and 10 orders. Arachnids are the most abundant with 18 species in 10 families, amounting to a total of 102 terrestrial invertebrate species from irrigated rice ecosystem in Khon Kaen. The majority of insects belonged to Order Hymenoptera (29 species) followed by Homoptera (15 species), Coleoptera (11 species) and Diptera (9 species). The community structure of terrestrial invertebrates consisted of natural enemies (70 species) followed by insect pest (26 species), insect visitor (5 species) and scavenger (2 species).

Keywords terrestrial invertebrate, irrigated rice ecosystem, community structure

INTRODUCTION

Irrigated rice fields are managed as wetland ecosystems that operate on a short temporal scale and provide a rich diversity of organisms (Heckman, 1979). The system is dominated by micro, meso and macro invertebrates (especially arthropods) inhabiting the soil, water and vegetation sub-habitats of the rice fields. The terrestrial arthropod community in rice fields mainly consists of insects and spiders. The occurrence of terrestrial arthropods in a rice ecosystem is mainly influenced by the rice plants. The different communities of terrestrial arthropods in the rice field include rice pests, their natural enemies (predators and parasitoids) and other non-rice pest insects that inhabit or visit the vegetation. The composition of the arthropod communities is known to change with the growth of the rice crop (Heong et al., 1991). Dale (1994) stated on over 800 species of insects damaging the rice plant. There are only a few studies that examine the overall terrestrial arthropod community in rice fields. Heong et al., (1991) and Schoenly et al., (1995) studies carried out in the Philippines provide an insight into the arthropod communities and their guild structure in irrigated rice fields. In Thailand, studies on terrestrial arthropods in rice fields are confined to surveys documenting the distribution of major rice insect pests and their natural enemies (Ruay-aree, 1994) while no attempts have been made to document the structure and diversity of terrestrial arthropod communities in rice fields. Such a study carried out over successive rice cultivation cycles would provide useful information for the development of effective and safe integrated rice pest management strategies.

The objective of this study was to determine the contribution of the terrestrial arthropod community to the irrigated rice field ecosystem.

METHODOLOGY

The study was conducted at conventional irrigated rice fields in Khon Kaen province, Muang district, located in the northeastern region of Thailand. Photoperiod-insensitive variety Pitsanulok2 was used**.** Sampling of the terrestrial arthropod community was conducted to determine species composition using standard sweeping net. This was done at fortnightly intervals after planting, from January to April of 2011. Specimens were collected from 20 sweeps per replication and were sorted and counted later in the laboratory. They were divided into different insect and spider taxa and counted.

The insects and spiders collected from the rice fields were identified and classified into the smallest possible taxa using available keys and guides for the different taxa. Barrion and Litsinger (1994) study was used as a reference for rice pests, their predators and parasitoids. The Araneae were identified using Barrion and Litsinger (1995). Following the identification of the terrestrial arthropods collected from the rice habitats, they were assigned to guilds according to Moran and Southwood (1982) and Heong et al., (1991). These guilds were based on feeding habits and included phytophages (rice pests and non-rice pest visitors), predators, parasitoids and scavengers decomposers.

RESULTS AND DISCUSSION

A total of 102 arthropod species were recorded from the irrigated rice field during the study. A terrestrial arthropod fauna comprising 84 species of insects that belongs to 72 families and 10 orders, and 18 species of arachnids in 10 families. The majority of the insect species documented from the studied rice field belonged to the order Hymenoptera (29 species in 18 families), dominated by the family Braconidae and Ichneumonidae (Fig.1). The second largest insect order recorded was Homoptera, consisted of 19 species, in 5 families, dominated by the family Cicadellidae (14 spp.). Coleoptera was the third largest insect order, with 13 species in 11 families. Coccinellidae and Bruchidae were dominant among the Coleoptera. In order Diptera, 9 species were identified in 20 families. Order Hemiptera included 9 species in 7 families. The hemipterans were dominated by family Reduviidae (2 species) and Miridae (2 species). The Odonata included 2 species in 2 families. The Orthoptera included 3 species identified in 4 families. The Lepidoptera included 3 species in 3 families. The remaining 2 insect orders (Neuroptera and Thysanura) included one specy each. The Arachnids consisted of 18 species of Araneae (spiders) in 10 families. Amongst the spiders, family Araneidae had the highest number of species (4 spp.) followed by the family Theridiidae (3 spp.).

Terrestrial arthropods recorded from the rice ecosystem were assigned to guilds based on food habits of the species. Accordingly, five arthropod guilds were identified. The majority of these arthropods were predators (36 spp.) (Table 1), where spiders were the dominant predatory group with 18 species followed by Hemiptera with 5 species, Coleoptera and Diptera with 4 species each. From the 5 species identified, all of them were visitors and non rice pest insects that were associated with weeds in the rice field. The visitor guild was dominated by Coleoptera (3 spp.) followed by Diptera and Lepidoptera with 2 species each. The phytophagous insects comprised 26 species of rice pests represented by sap feeders, leaf feeders, stem feeders and root feeders (Table 1). Homopterans (15 spp.) were the dominant phytophagous pest group, closely followed by hemipterans pests (2 spp.). The parasitoid guild comprised 32 species of insects being dominated by hymenopterans (30 spp.). The scavenger/decomposer guild contained the fewest number of species, dominated by the order Diptera and Coleoptera with one species each. The overall species composition reflects a high richness of arthropod natural enemies (predators and parasitoids) in relation to the rice insect pests, where the natural enemy to pest ratio is 2.8:1. A majority of the parasitoids recorded attack rice insect pests.

This study highlights the richness of the terrestrial arthropod fauna associated with an irrigated rice field ecosystem in Khon Kaen province. The terrestrial arthropod fauna comprising 102 species was recorded during the present study. The study also reflects the importance and the role

of one single group of insects; the Order Hymenoptera with the largest number of species represented almost entirely by beneficial insects including natural enemies of paddy pest insects and pollinators. The richness of the predatory spider fauna inhabiting the rice fields is evident from their species composition, abundance and distribution within the rice ecosystem.

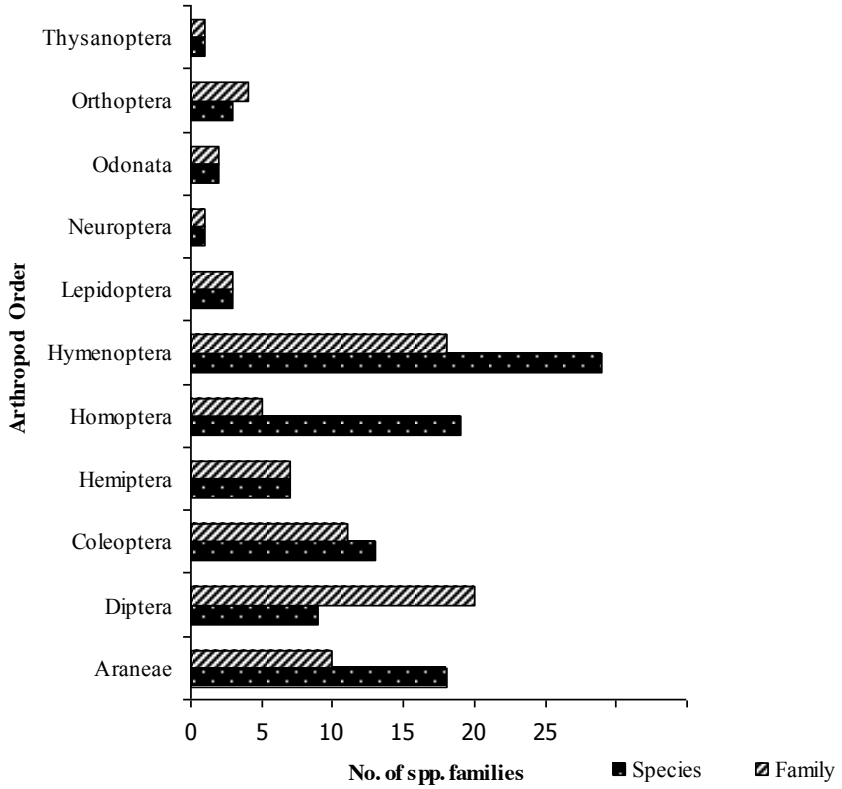

Fig. 1 Species composition and taxonomy of arthropods in irrigated rice ecosystem, at Khon Kaen province documented from January to April of 2011.

Table 1 Number of terrestrial arthropod in difference guilds in the rice habitat based on sweep net collection

Guild	Phytophagous					Predators	Parasitoids	Scavengers/ decomposers
	Rice Pests				Visitors (non-rice pests)			
Order	SF	DFM	SB	RF				
Araneae	-	-	-	-	-	18	-	-
Coleoptera	-	1	-	2	3	4		1
Diptera	-	1	1	-	2	3	1	2
Hemiptera	2	-	-	-	-	5	-	-
Homoptera	15	-	-	-	-	-	-	-
Hymenoptera	-	-	-	-	5	-	29	-
Lepidoptera	-	2	-	-	2	-	-	-
Neuroptera	-	-	-	-	-	1	-	-
Odonata	-	-	-	-	-	2	-	-
Orthoptera	-	2	-	-	1	2	-	-
Thysanoptera	1	-	-	-	-	-	-	-
Total	18	5	1	2	5	45	30	3

Note: Pests: SF – Sap feeders; DFM – Defoliators/miners; SB – Stem borers; RF – Root feeders

The guild structure of the arthropod fauna further emphasizes the importance of the predators (36 spp.) and parasitoids (32 spp.) that outnumbered the phytophagous rice pests (26 spp.). Thus,

the natural enemies accounted for 70.8 % of all the terrestrial arthropod taxa collected. The composition of the rice field arthropod fauna, while highlighting the high biodiversity in a monoculture crop, confirms the long term stability of the rice agroecosystem in respect to pests and natural enemies. As is evident from the present study, the significant positive relationships between the pest insects and their natural enemies (predators and parasitoids) exhibit the natural balance that exists among arthropod guilds in the rice field ecosystem. A high species richness among arthropod natural enemies in rice ecosystems has been observed by previous researchers as well (Heong et al., 1991).

CONCLUSION

In conclusion, the composition and structure of the arthropod communities in an irrigated rice ecosystem in Khon Kaen was classified, which order Hymenoptera (29 species) was dominant followed by Homoptera (15 spp), Coleoptera (11 spp), and Diptera (9 spp). The community structure of terrestrial invertebrates consisted of natural enemies (70 spp) followed by insect pests (26 spp), insect visitors (5 spp) and scavengers (2 spp). The findings highlight the existence of stable relationships between the rice insect pests and their arthropod natural enemies, under minimal biocide application. The population of arthropod natural enemies in rice fields could be conserved and enhanced through the maintenance of a rich weed flora during the fallow period, management of weed communities on the bunds through partial slashing and by minimal use of biocides when needed, to avoid economic damage by specific insect pests.

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Research article

Assessment of Farmer's Satisfaction and Preference Using Improved Rice Varieties in the Southern Lao PDR

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Abstract Since 1993, more than 21 improved rice varieties have been released to Lao farmers. However, there is no study conducted yet on farmer's satisfaction on the use of improved rice varieties. Hence, the purposes of this study were to 1) evaluate the level of farmer's satisfaction on using improved rice varieties; and 2) farmer's preferences on rice characteristics. Purposive and simple random samplings were used to select the samples. Intervals mean score was used to measure the level of farmer's satisfaction. The target population was farmers who have grown rice under irrigated and rainfed conditions in the lowland areas. A total of 118 farming households in the rice producing areas of Savannakhet and Champasak provinces were surveyed through structured questionnaires from March to April 2011. The study found that all rice grown under irrigation were improved varieties. In rain-fed condition, about 96% were improved varieties and about 4% were traditional varieties. The average rice yield in irrigated areas was higher than in rainfed conditions. Popular improved rice varieties grown in the study areas were Phonengam 3 (PNG3), followed by Thasano 3 (TSN3) and Thadokkham 1 (TDK1). The level of farmer's satisfaction on using improved rice varieties ranged from high to highest level. However, the aroma characteristic was at a medium level. High yielding characteristic was the most preferred by farmers, followed by the grain size, early maturity, tolerance to drought, and resistance to pest and diseases.

Keywords: improved rice variety, satisfaction, preference, southern Lao PDR

INTRODUCTION

Agriculture is one of the most important sectors in Lao People's Democratic Republic (Lao PDR). The share of agriculture in economy accounted for 34.4 % of the Gross Domestic Product (GDP) and provided around three-quarters of the total workforce (Department of International Corporation, 2011). Rice is the main staple food of the Lao people and accounted for more than 903,501 ha (80%) of the total cropped areas with a total production of 3,102,368 tons, the average rice yield was 3.44 t ha^{-1} (Department of Planning, 2009). The rice production systems in Lao PDR can be classified into three broad ecosystems: irrigated lowland, rain-fed lowland and upland. Irrigated and rain-fed lowland are mainly located in central and southern regions. Savannakhet and Champasak provinces are the main rice growing areas in southern region. In 1990, about 95 % of rice grown in the lowland were traditional varieties with average yield of 2.32 t ha^{-1} (Linquist et al., 2006). To achieve self sufficiency at the national level the Lao-International Rice Research Institute (Lao-IRRI) project was set up in 1990 to increase rice production in the country (Shrestha et al., 2006). The main purposes of this project were the following: 1) to develop improved rice varieties or modern rice varieties (MVs) for lowland areas in the Mekong River Valley; and 2) to supply Lao farmers with varieties with high yield potential, resistance to the major pests and diseases, and broad adaptability to Lao condition (Schiller et al., 2000). Since 1993, more than 21 MVs were released such as Thadokkham (TDK1 to TDK11), Phonengam (PNG1 to PNG6),

Thasano (TSN1 to TSN5) and Namtanne (NTN1) (Inthapanya et al., 2006; Bounphanousay, 2010). Most of these varieties were glutinous rice varieties, photoperiod non-sensitive, high yielding and fertilizer-N responsive, resistant to plant diseases such as brown plant hopper (BPH), good milling and eating quality. Since the release of MVs to farmers in 1993, no study was conducted so far to assess farmer's satisfaction level with improved rice varieties in the country. This information is vital to guide rice breeders and extension workers to facilitate wider acceptance of further released varieties. Furthermore, the information on farmer's preference to rice characteristics is also essential for the rice breeders to know the characteristics farmers need. This study aimed to evaluate the level of farmer's satisfaction on using MVs and farmer's preferences to rice characteristics.

METHODOLOGY

A purposive sampling technique was used to select the representative areas. In consultation with the National Rice Research Program (NRRP), the study areas were selected from the two largest rice growing provinces (Savannakhet and Champasak) in the southern parts of Lao PDR. District with both irrigated and rain-fed rice production where the farmers had experiences in growing MVs were selected. Face to face interviews with household heads were conducted using structured questionnaires in 4 villages: Kor and Phaleng in Champhone district, Savannakhet province, and Nakham and Tomoh in Pathoumpone district, Champasak province. Sample size was calculated using the Taro Yamane formula (Yamane, 1960). Out of 191 households, 118 were randomly selected using simple random sampling technique. The questionnaire was pre-tested before the actual survey.

Farmer's satisfaction level was evaluated using a rating scale from 1-5, with 5 for the highest satisfaction level, and 1 for the lowest satisfaction level (Table 1). Farmers were asked to select the improved rice variety most planted in their rice fields. Farmers were then invited to express their satisfaction level base on seed, agronomic, postharvest, cooking and eating quality characteristics of the their selected varieties (Table 3). To determine what rice characteristics were most preferred, a set of photographs were shown to farmers, and allowed them to select the image they most preferred, and asked the reasons of their choice.

Statistical Package for Social Science (SPSS) software program was used for data analysis. The analysis included frequency, mean, percentages and t-test. Farmer's satisfaction levels were determined using interval mean scores, dividing into five interval levels (Chantrasouvan, 2002). The intervals mean score (Table 1) was calculated using Eq. (1) below. For example, using highest score of 5, lowest score of 1, and number of interval levels of 5, the resulting interval mean score was 0.08. Using Eq. (2), the highest point of the first level was 1.79.

$$\text{The highest point of the first level} = \text{The lowest score} + \text{interval score} - 0.01 \quad (1)$$

$$\text{Interval score} = \frac{\text{Highest score} - \text{Lowest score}}{\text{Number of interval level}} \quad (2)$$

The calculation of interval mean scores shown as follows:

$$\text{Interval score} = \frac{5-1}{5} = 0.08 \quad (3)$$

Table 1 Measurement of the satisfaction levels

Description	Rating score	Range
Highest satisfaction	5	4.20 – 5.00
High satisfaction	4	3.40 – 4.19
Medium satisfaction	3	2.60 – 3.39
Low satisfaction	2	1.80 – 2.59
Lowest satisfaction	1	1.00 – 1.79

Source: Chantrasouvan (2002)

RESULTS AND DISCUSSION

Rice varieties used in Southern Lao PDR

Results of the household survey showed that 100% of the rice varieties grown in dry season (irrigated) were MVs. About 96.0% of the varieties grown in wet season (rainfed) were MVs while only 4.0% were TVs. PNG3 was the variety most grown in the study areas which accounted for 21.6% in dry season and 15.9% in the wet season (Table 2). Other MVs widely grown in the study areas were TSN3 and PNG6. PNG3, a high yielding and photoperiod non-sensitive glutinous rice variety, has good eating and milling qualities and suitable to drought prone areas such as in central and southern regions of Lao PDR. However, this variety is susceptible to low temperature, and to some pests and diseases such as bacterial leaf blight, gall midge and brown phanthopper. The MVs commonly grown by farmers included TDK4, TDK5, TDK6, TDK7, TDK11, PNG5, PNG6, TSN1, TSN2, TSN4, TSN5, TSN7, RD6, and RD10, while TVs grown were Khao-teay, E-pa, E-teay, La-nard, E-dengnoi and Damdane. About 95% of the rice varieties grown were glutinous rice, and only 5% were non-glutinous rice (i.e Homsavan, KDML 105 and CR 103).

Table 2 Popular rice varieties and percent of each variety planted in the study area during dry and wet season

Name of Rice varieties	% of rice varieties planted under irrigated condition	% of rice varieties planted under rain-fed condition
Phonengam 3 (PNG3)	21.6	15.9
Thasano 3 (TSN3)	19.7	7.0
Thadokkham 1 (TDK1)	12.7	11.4
Phonengam 6 (PNG6)	11.9	10.0
RD10	8.2	5.5
Thadokkham 7 (TDK7)	6.0	5.0
Thadokkham 4 (TDK4)	0.0	9.5
Phonengam 5 (PNG5)	4.5	4.0
Thadokkham 5 (TDK5)	3.7	2.2
Other rice varieties	11.7	29.5
Total	100.0	100.0

The average yield of MVs in dry season (irrigated) was 3.08 t ha^{-1} and about 2.74 t ha^{-1} in wet season (rain-fed). The average yield of TVs was about 2.26 t ha^{-1} (only in wet season). TDK8 had the highest yield (3.63 t ha^{-1}) under irrigated condition (dry season), while TSN3 was the highest yield (3.39 t ha^{-1}) under rainfed condition (wet season). Average rice yield under irrigated condition was higher than that under rainfed condition. This is mainly attributed by good solar radiation during dry season which is essential for good photosynthetic activities of the rice plant. Farmers under irrigated areas (dry season) generally used higher chemical fertilizer input than in rainfed areas. Moreover, farmers with access to irrigation water also had better control and thus less risk to droughts and weed problem. In the wet season, flooding is a common problem of rice farmers. Based from the survey, farmers also indicated the importance of avoiding prolong use of same varieties in the same field. According to them, changing varieties regularly would increase rice yield and avoid incidence of pests and diseases. Sources of MVs seed were the following: 1) rice research center (Thasano Rice Research Center in Savannakhet province, and Phonengam Rice Research Station in Champasak), 2) exchange with neighboring farmers, 3) support from District Agriculture and Forestry Office (DAFO) and 4) Rice Productivity Improvement Project or RPIP.

Farmer's satisfaction using improved rice varieties

This study measured the farmer's satisfaction level on MVs based on: seed, agronomic, post-harvest characteristic, and eating and cooking quality. Results found that farmer's satisfaction was generally high and the highest level based on the characteristics evaluated by farmers (Table 3). With respect to seed characteristics, seed germination ability of MVs was at the highest satisfaction

level. According to farmers, the time needed to germinate seeds was shorter (soaking period of MVs took only 24 hours while the TVs took 48 hours), and percentage germination was higher compared to TVs. In terms of agronomic characteristics, the seedling growth rate of MVs was at the highest satisfaction level, MVs seedlings can be transplanted at a younger age (about 20 days old) compared to TVs (about 30 days old).

Farmers were also extremely satisfied (highest satisfaction level) with harvesting, yield and milling qualities of MVs. Farmers perceived that yields of MVs were higher than TVs because of their superior number of panicles per hill and grains per panicle. Due to their uniform plant height, the harvesting operations of MVs were easier than TVs. MVs was also perceived as lodging resistant especially during wet season when lodging can cause severe loss of production. In term of milling quality, farmers reported that polished grains from MVs were more appealing to them because they were whiter and lower percentage broken rice. Cooking (softness) and eating qualities of MVs were also mainly at highest level. However, the aroma of cooked rice was at a moderate satisfaction level only. TVs have better aroma than MVs. Since most rice produced by farmers is mostly for home consumption, softness (when cooked), whiteness and aroma were very important for farmers. Cooking and eating qualities are affected by grain amylase content (Shiller et al., 2006). Sall et al. (2000) indicated that amylose content is the most important chemical characteristic and determines the hardness of cooked rice. After cooking, rice grain with intermediate amylase content will produce "soft" cooked rice, while those with high amylase content will produce "hard" cooked rice. The majority of respondents were satisfied in PNG3 rice variety due to its agronomic characteristics (high yield, long panicles, uniform plant height), good for eating (soft and tasty) and milling quality (less broken rice and white polished grain).

Table 3 Percent frequency distribution of farmers according to satisfaction levels, and mean value of satisfaction levels with improved rice varieties

Characteristics of improved rice variety	Satisfaction level					Mean (n=118)	S.D (±)	Meaning
	Highest (5)	High (4)	Medium (3)	Low (2)	Lowest (1)			
I.Seed characteristic								
Grain shape and size	36.5	40.7	18.6	4.2	0.0	4.09	0.84	High
Seed germination	50.0	39.8	10.2	0.0	0.0	4.40	0.66	Highest
II.Agronomic characteristic								
Growing	33.9	52.5	12.7	0.8	0.0	4.19	0.68	High
Seedling growing	39.8	50.8	8.5	0.8	0.0	4.30	0.65	Highest
Tillering ability	37.3	44.9	16.9	0.8	0.0	4.19	0.74	High
Leaf structure	16.1	57.6	22.0	4.2	0.0	3.86	0.73	High
Panicle	30.5	46.6	19.5	3.4	0.0	4.04	0.80	High
Plant height	20.3	55.1	22.9	1.7	0.0	3.94	0.70	High
Pest resistance	14.4	48.3	28.8	7.6	0.8	3.68	0.84	High
Disease resistance	10.2	46.6	35.6	7.6	0.0	3.59	0.77	High
Lodging resistance	25.6	53.0	18.8	1.7	0.9	4.01	0.77	High
Maturity	25.4	54.2	20.3	0.0	0.0	4.05	0.67	High
III. Post harvest								
Harvesting	67.8	24.6	6.8	0.8	0.0	4.59	0.65	Highest
Grain weight	39.0	44.9	11.9	2.5	1.7	4.17	0.86	High
Yield	44.1	39.8	11.0	5.1	0.0	4.23	0.84	Highest
Milled rice	45.8	43.2	9.3	1.7	0.0	4.33	0.71	Highest
IV. Cooking and eating quality								
Softness	50.8	39.8	9.3	0.0	0.0	4.42	0.65	Highest
Eating quality	50.0	40.7	6.8	2.5	0.0	4.38	0.7	Highest
Aroma	14.4	27.1	42.5	14.4	2.5	3.36	0.98	Moderate
Overall Satisfaction	34.3	44.75	17.49	3.15	0.31	4.10	0.75	High

Satisfaction levels of male and female farmers on using MVs were also compared. Among the characteristics considered, only those in harvesting were significantly different. Based on the mean score of harvesting difference, the satisfaction level of the female group was higher than the male group because the harvesting activities were carried out mainly by the female group. According to female interviewees, MVs had uniform plant height, thus facilitating harvesting. The p-value of satisfaction between male and female farmers on MVs in term of seed characteristic, agronomic characteristic, grain weight, milled rice, cooking and eating quality are statistically not significant. The mean score between the two groups were also not significantly different.

Farmers' preference on rice characteristics for future improvement

The results of farmer's preference are presented in Table 4. Varieties with high yielding characteristics were the most preferred by farmers for they assure an abundant harvest for family consumption, and extra income to support household expenditure. Big and long grains were also preferred as farmers perceived that these were indicators of good grain quality. The third preference was early maturity characteristic of the variety. Some farmers grew more than one rice variety in their rice field, but the lack of manual labor at peak of harvesting season was one of the predicaments of the farmers in the study areas. So, planting a number of early maturing varieties would facilitate better scheduling of labor during harvesting season. Farmers could harvest first the short duration (early maturity) varieties, then medium and late duration varieties. In addition, some households usually used up their rice stock in the storages before the peak of harvesting season, so the short duration varieties were very important for them. The fourth preference was the drought resistant characteristic of the variety. As farmers are also facing global warming effects, which have caused uneven and uncertain distribution of rainfall, planting drought resistant varieties were needed especially in rainfed conditions. The fifth preference was on resistance to pests and disease. According to farmers, a number of MVs are susceptible to pests and diseases, and therefore MVs to be introduced in their areas should be resistant. The preferences and perceptions expressed by farmers were similar to that of Manzanilla et al. (2011).

The study found that lack of water was the main problem for irrigated condition. Farmers indicated that the water from irrigation system was not enough after transplanting due to inefficient water delivery and unmaintained irrigation facilities and thus caused significant yield loss. In the wet season, pests and diseases problems such as rice bug, thrip, stem borer, gall midge, and grasshopper were the main concerns.

Table 4 Farmer's preference on rice characteristics

Characteristic of rice varieties	Score of farmers' preference *					Total score	Rank
	First	Second	Third	Fourth	Fifth		
High yielding	345	96	30	12	7	490	**1**
Good quality of grain	65	120	69	30	14	298	**2**
Softness	15	48	45	16	16	140	6
Need less fertilizer	25	12	24	24	6	91	8
Early maturity	30	52	66	22	9	179	**3**
Resistance to drought	45	44	42	30	11	172	**4**
Tolerant to flood	15	4	0	8	6	33	10
Resistance to pests and diseases	20	56	30	36	16	158	**5**
Resistance to lodging	15	24	27	42	21	129	7
High price	15	16	12	12	7	62	9
Can grow in DS and WS	0	0	9	4	5	18	11

*Note: * Score for each preference: for first preference multiply total frequency by 5; for second multiply by 4; for third multiply by 3; for fourth multiply by 2, and for fifth multiply by 1*

CONCLUSION AND RECOMMENDATION

This study concluded that the majority of farmers in southern region of Lao PDR have adopted improved rice varieties. The most popular rice varieties were namely PNG3, followed by TSN3, TDK1 and PNG6. The average rice yield in irrigated area (dry season) was higher than rainfed area (wet season). The farmer's satisfaction levels using MVs were mainly high and the highest levels. Characteristics with the highest satisfaction levels included seed germination, seedling growing, harvesting, yield, milled rice characteristics, and eating quality. The level of farmer's satisfaction for aroma characteristic was at moderate level as traditional varieties have better aroma compared to improved varieties. This means that rice breeders should enhance the aromatic smell of the improved varieties to facilitate higher satisfaction level from farmers. The farmer's preference on rice characteristic indicated that high yielding potential was most preferred by farmers, followed by size and shape of rice grain, early maturity, resistance to biotic (pests and diseases) and abiotic (drought, flooding, lodging) stresses. Rice breeders need to consider these characteristics in their rice breeding program to facilitate wider acceptance of improved varieties.

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Research article

Preliminary Social and Environmental Assessment of Zulfikarabad: a New Coastal Mega City Project in Pakistan

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Abstract This article presents the preliminary social and environmental assessment of Zulfikarabad Mega City Project that is underway in the coastal region of Sindh Province in Pakistan. Four parameters comprising the existing land use, hazard profile at the site, occupational structure of the local communities and existing land property rights are examined. Data sources included remote sensing imagery, questionnaire survey, rapid appraisals, literature survey and official records. Findings of the land use analysis reveal that most parts of the City would be built by clearing the mangrove areas which have been declared protected forests since 1950s. Besides, the location is prone to the modest frequency of earthquakes and cyclones which in some cases were not only devastating for the lives and properties of local people but also had brought significant economic losses to the regional economy. Numerous villages of varying sizes are located on the proposed site where the majority of the population ekes out their living from agricultural and fishing activities. There is a clear indication that the Government's prime attraction towards this location is the 'availability' of so-called 'wastelands'. This standpoint is contested in the light of land use analysis. Considering that the City is still in its planning stage, the finding of this study will serve as a useful guide for more in-depth studies on some of the emerging concerns over the megacity project.

Keywords coastal mega cities, city and regional planning, Indus delta, mangroves clearance, Zulfikarabad

INTRODUCTION

Megacities, on one hand are recognized as global junctions, engines of economic growth, agglomerations for cost-effective provision of facilities to civilians, and markets of surplus rural labor; while on the other hand, these geographies are portrayed as unmanageable, subjects of poverty and disparities, and polluted environs impressing heavy footprint on local environments (Haiqing, 2003; Juha I, 1998). Over the last few decades, rapid urbanization has resulted in the proliferation of megacities in hazardous regions of the developing countries and has left billions of people exposed to natural disasters (Juha I, 1998; Wenzel, Bendimerad and Sinha, 2007). A natural disaster can be conceptualized as a function of natural hazard, exposure or propinquity of humans or their properties to a hazard, and vulnerability or propensity to suffer a loss (Juha I, 1998). Occurrence of a natural hazard is almost always beyond the control of humankind and little can be done in this regard at least in the short run. Ideally, however, exposure to a hazard can be minimized for existing megacities but various practicalities limit the prospect to relocate these huge masses in safer zones. The only front where humans can intervene is the vulnerability; where entities exposed to hazards can be made resilient and prepared through improved construction techniques, early warning systems and specific disaster preparedness measures. Although various practicalities limit the prospect of reducing the exposure of existing coastal megacities to natural hazards, any new urban development should be allowed only in safer zones so as to preempt future disasters. Nevertheless, in some regions such as the Arabian Gulf, countries like UAE, Qatar, Saudi

Arabia, Dubai and Bahrain has developed various new townships without considering their exposure to natural hazards (Kumar, 2009).

Pakistan is busy with its second planned city after independence following the conventional justification of reducing pressure from the unmanageable Karachi megalopolis (Government of Sindh, 2011). After considering the 'availability' of one million ha of land, the location of Zulfikarabad is finalized at four coastal sub-districts of Thatta district in Sindh Province (District Government Thatta, 2010). This paper presents the preliminary social and environmental assessment of Zulfikarabad Mega City site based on four parameters comprising the existing land use, hazard profile, the occupational structure of local communities and existing land property rights. The next section describes the methodology and is followed by a section on the results of four analyses as mentioned above. The last section makes discussion and draws important policy implications and recommendations. The study highlights some of the emerging concerns about the safety of future inhabitants of the new coastal city and livelihoods of the communities currently living in the area.

METHODOLOGY

Required information was collected using primary and secondary sources. For land use analysis, five classes namely: Mangrove vegetation, Agriculture and non-mangrove vegetation, Deltaic land/wet mudflats, Inland residential and uncultivated agricultural areas, and Water, were determined. Classification was performed on satellite image LT51520432011058KHC00 from LANDSAT TM dated: 27th February, 2011 using a hybrid classification approach that combined unsupervised and supervised classification techniques. At first, the selected image was classified into 100 classes using Iterative Self-Organizing Data Analysis Technique Algorithm (ISODATA) of unsupervised classification method. Signatures obtained through ISODATA classifier were identified and labeled based on the maps given in Memon (2011) and high resolution satellite imagery of Google Earth. Merging of signatures was conducted in accordance with the predetermined classes. Since the histograms of all bands were normally distributed, the final classification was performed through Maximum Likelihood method. The classification accuracy was assessed based on 256 randomly selected Ground Control Points which indicated the overall accuracy of 85.16 percent and Kappa Coefficient of 0.80 suggesting the acceptability of classification results.

Information on the occurrence of two kinds of hazards, earthquakes and tsunamis, was gathered from various secondary sources as indicated in Table 3 and elsewhere in the text. Records on different categories of land rights were obtained from the District Revenue Office, Thatta. Information on the occupations of the local communities was obtained from two sources. Out of total 343 households (Table 4), the occupational affiliation of 107 households representing the communities which live on the fringes of the active delta was extracted from the raw dataset compiled for a study on mangroves conducted by Memon (2011) in 2009. The occupational affiliation of the remaining 236 households was obtained through rapid appraisals in four randomly selected inland villages where the village heads, in consultation with their advisers, reported the occupations of each household in their village registers. Since, only one parameter, namely the occupational engagement of local communities was to be assessed, this method was deemed appropriate all in terms of time, human and financial resources.

RESULTS

Existing land cover of Zulfikarabad site

Zulfikarabad is planned in the Indus Delta located along the southeastern coast of Pakistan (Fig. 1). The site is under the administrative jurisdiction of District Thatta. A little more than two-thirds of the site area falls in the intertidal zone (Fig. 1), which comprises mangroves on 7.2 percent, wet mudflats on 40.2 percent and water in major and minor creeks on about 20 percent (Table 2).

Mangrove vegetation is dominated by *Avicennia marina* species (locally called *Timir*) while small stands of planted *Rhizophora mucronata* species could also be found. The deltaic mudflats remain empty for most part of the year, until monsoon and subsequent freshwater regimes in the Indus River facilitate the natural growth of *Porterasia coarctata* species (locally called *Sohan*) in the northern part of the site (Fig. 1). The remaining one third of the site is located further inland and is a part of abandoned delta that comprises agriculture and inland vegetation on about 09 percent and uncultivated agricultural and residential areas on 24 percent (Table 2). The major crops cultivated in the area include sugarcane, vegetables, banana and sunflower while the wild vegetation comprises shrubby stands of *Prosopis juliflora* (locally called *Devi* or *Kekar*).

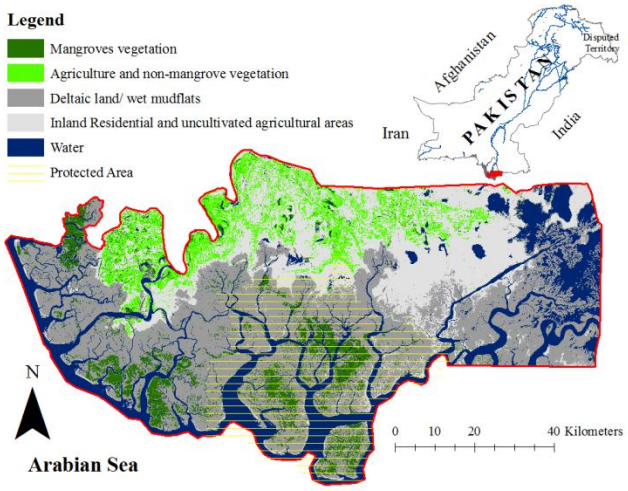

Fig. 1 Location of Zulfikarabad, its existing land use and the demarcation of protected areas

Almost half of the mangroves cover, significantly higher than one third of wet mudflats and about one third of the water bodies constituting Zulfikarabad site are declared protected areas since 1956 (Table 2) and are managed by Shah-Bandar Subdivision of Sindh Forest Department (Memon, 2011).

Table 2 Existing land use of Zulfikarabad site and land under 'Protected Area' category

Major Land Cover/Land Use	Entire Site		Protected	
	Area (ha)	% [a]	Area (ha)	% [b]
Mangroves vegetation	54,708	7.20	26,726	48.85
Agriculture and non-mangrove vegetation	66,688	8.77	1,088	1.63
Deltaic land/ wet mudflats	305,870	40.25	114,987	37.59
Inland Residential and uncultivated agricultural areas	182,675	24.04	14,355	7.86
Water	150,053	19.74	47,426	31.61
Total	759,995	100	204,581	26.92 [a]

a. Percentage of the total
b. Percentage of relavant land cover class

Hazard profile of the region

Zulfikarabad site is exposed to extreme geological and atmospheric disturbances and has witnessed various cyclones, tsunamis and earthquakes in the Past. Although the locations and magnitudes of some ancient earthquakes are doubtful (Ambraseys, 2004; Bilham et al., 2007), various others are well documented. For example, in 1819, Allah Bund Fault (ABF) generated an earthquake of 7.7 Mw that formed a 90 km long dam across Kori Creek (Jordan, 2008; Khan, Abbasi, Hadi, Laghari and Bilham, 2002) – flowing 10 km south of Zulfikarabad site. Furthermore, the ABF earthquake caused a crustal displacement of 7-9 meters that generated a large tsunami submerging Sindri town in India (Jordan, 2008). The ABF created another earthquake in 1896, causing extensive damage in Shah Bandar town (Pararas-Carayannis, 2006) that is the headquarters of one of the constituting sub-districts of Zulfikarabad. In the northwest of Zulfikarabad, the Makran Subduction Zone

(MSZ) is also seismically very active. On 28 November 1945, MSZ generated an earthquake of 8.1 Mw with its epicenter at the distance of about 450 km from Zulfikarabad. The quake and Tsunami killed more than 4,000 people along the Makran Coast and a few in Kachchh and Mumbai (Jordan, 2008; Pararas-Carayannis, 2006). The Tsunami generated by the MSZ earthquake swept 12 fishermen (Pararas-Carayannis, 2006) and destroyed various fishing villages near Dabo Creek of Keti Bandar that is another sub-district constituting Zulfikarabad (Jordan, 2008; Pararas-Carayannis, 2006). Some recent disasters, for which statistics are considerably reliable, are more indicative of the nature and magnitude of natural hazard exposure and vulnerability of the site (Table 3). The Tropical Cyclone 02A of 1999 and the Bhuj earthquake of 2001 created disasters which went unparallel in the 20th Century (Table 3).

Table 3 Some recent natural hazards and disasters in the coastal region

Hazard	Disaster
Cyclone TC – 02A, May 19, 1999 Category 3 hurricane	– The cyclone had landfall near Keti Bandar and caused widespread and destruction in 160 km coastline of Sindh Province. It caused 56 breaches in the tidal link, wiped away 73 settlements[1], collapsed 75,000 houses and partially damaged 59,000 houses[2]. At least 168 people and 10,000 livestock died[1, 2]. It inundated 0.16 million ha of farmlands[2], destroyed 1,800 boats and partially damaged 642 boats[1]. The loss to infrastructure and fishing assets of the local communities exceeded PKR 1,000 million[1]
Bhuj Earthquake, January 26, 2001 (7.9 Mw on the Richter scale) in India	– Negligible human loss along Sindh Coast but the quake devastated almost everything within 300 km radius of the epicenter[3] in India. The aerial distance between epicenter[4] and Zulfikarabad was less than 150 km. Reportedly[5] 20,000 persons died, about 166,000 injured of whom 20,700 sustained serious injuries and 247 persons were missing. Livestock deaths also exceed 20,000[5]. In India, it affected 21 districts, destroyed about 187,000 houses and partially damaged 500,000 houses[5] in 800 villages. Together with these losses, severe damages to thousands of schools, about 750 km of the Indian National Highway and telecommunication networks suffered an estimated loss of INR 214,620 million[5].
Cyclone Yemyin, June 21-26, 2007 causing severe flood	– The cyclone caused 460 deaths in Baluchistan, 89 deaths in Karachi and 38 deaths in Thatta and Badin[6]. Reportedly in Keti Bandar[7], it killed three persons, injured a dozen more, collapsed 750 houses totally and 1,050 houses partially. Besides, it destroyed 26 boats completely and 174 boats partially[7]. An estimated population of 22,424 living in 2,822 households[7] in the northern part of Zulfikarabad site was affected.

Sources: (NDMA, 2007b)[1], (Khan and Nomani, 2002)[2], (Khan, M.A. et al., 2002)[3], (Indian Metrological Department in Malik, Nakata and Sato, 2001)[4], (Ministry of Agriculture, Government of India in CESNED, 2001)[5], (NDMA, 2007a)[6] (WWF-Pakistan, undated)[7]

Occupational structure of the local communities

Zulfikarabad site is sparsely inhabited with a population density of not exceeding 40 persons per km^2. Nevertheless, about 275,888 persons are living in 277 villages in four sub-districts identified as the site of Zulfikarabad (District Government Thatta, 2011). Furthermore, various small settlements may also exist on the site as the village list prepared for Sindh Rural Development Project (SRDP) in 2005 indicates 709 settlements in the four sub-districts ranging between two and four hundred households. The majority of the local people earn their livings from surrounding natural resources comprising sea, mangroves and land. Marine fishery is a major primary and secondary occupation followed by crop cultivation and livestock herding as the second and third important occupations, respectively (Table 4). Besides these major occupations, some people were also formally employed as non-fishing laborers or were engaged in other occupations such as venders and village artisans (Table 4). It was gathered that almost half of them had a secondary occupation that was almost always the marine fishery, crop cultivation or livestock herding (Table 4). The majority of marine fishers and livestock herders (specialized in camel herding) were settled on the fringes of the delta while those engaged in agriculture were settled further inland.

Table 4 Occupations of the local communities residing on Zulfikarabad site

Occupation	Dependent households (N=343)	
	Primary	Secondary
Marine fishery	54.23	26.53
Livestock herding	12.24	7.87
Boat driving	4.08	–
Crop cultivation	16.91	12.24
Formal jobs (Govt, NGO and Private sectors)	6.12	–
Daily wage labor (other than marine fishing)	3.21	–
Other occupations	3.21	2.62
No Occupation	–	50.73
Total	100	100

Land property right on the proposed site

The State is the major landholder owning more than three-fourths of the land in the four coastal sub districts constituting Zulfikarabad (Table 5). Two other categories of land which can have significant influence of the state are Running Grants and the land for Public Purposes. Running grants are the lands which the government has allotted to any individual but the actual transfer of rights to the allotted party remains pending till they complete installments payable against the allotment. Meanwhile, the allotted party can take the possession of land and cultivate it. The land for 'Public Purpose' is the one that is utilized for villages, schools, hospitals, roads and similar purposes and was reserve for the welfare of local inhabitants. Thus the remaining one fourth of the land which comprises the land for Public Purpose (3.02 percent), Private Land (7.44 percent), Private land for which Transfer Orders (TO) has been issued (6.94 percent) and Running Grants (5.38 percent), is the land where local communities has a direct stake (Table 5). Besides, it is also noteworthy that 204,581 ha or roughly 35 percent of the state owned land that is considered as 'available' for Zulfikarabad City is the area declared as 'Protected' mangrove areas since 1950s (Fig. 1 and Table 2).

Table 5 Land property rights in four coastal sub districts of Thatta district

Name of sub district	Total area of sub district in hectares[1]	Major categories in Land Register – area in hectares (%)					
		Public purpose	Private land	Private land T.O issued	Running grants	State Land	Other Land
Keti Bandar	61,885	2,969 (4.80)	14,952 (24.16)	2,340 (3.78)	4,967 (8.03)	37,253 (60.20)	162 (0.26)
Kharo Chan	92,366	2,834 (3.07)	5,766 (6.24)	1,643 (1.78)	3,876 (4.20)	79,154 (85.70)	–
Shah Bandar	295,453	3,583 (1.21)	20,205 (6.84)	17,208 (5.82)	11,987 (4.06)	239,605 (81.10)	5,547 (1.88)
Jati	266,880	12,268 (4.60)	12,457 (4.67)	28,571 (10.71)	17,749 (6.65)	190,325 (71.31)	–
Total[2]	716,584	21,654 (3.02)	53,380 (7.44)	49,762 (6.94)	38,579 (5.38)	546,337 (76.24)	5,709 (0.80)

Source: (ZDA, 2011)

1. *Area as per the land register which is different from the total geographical area of the sub district*
2. *A small difference of 1,165 ha bringing about a difference of 0.16% is due to typographical errors in the official records*

DISCUSSIONS AND POLICY IMPLICATIONS

In the wake of climate change, hazard exposure and disaster vulnerabilities of existing coastal megacities are already a major concern for researchers and policy makers. Nevertheless, some countries such as those located in the Arabian Gulf and the Indian Ocean are establishing new coastal townships and cities in the regions which had experienced a number of severe atmospheric

and geological hazards in the recent past (Kumar, 2009). Surprisingly, the location of Zulfikarabad Mega City Project in Pakistan is also guided by the 'availability' of the land. Government's tendency to build new cities in hazardous zones seems unabated and ignorant of the past experiences. For example, Islamabad – the first planned city and capital of Pakistan – was also built in a high seismic zone that experienced an unprecedented earthquake in 2005 causing 87,000 deaths and destroyed about 32,335 buildings in various towns and cities including the collapse of Margalla Towers in Islamabad (USGS, 2011). Even the argument that "the land required for Zulfikarabad City is available in the Indus Delta" also cannot be justified since the major proportion of the said government land is 'Protected Mangrove Areas' while the remaining land is under some form of private or communal property (Table 2). Drawing on the mangrove cover statistics provided by Memon (2011), this study gathers that Zulfikarabad will cost the clearance of about 50 percent of the mangrove cover of Pakistan, half of which are already declared as protected forests by the government (Table 2). Furthermore, the City is going to be constructed in a region that is more exposed to the oceanic disturbances and seismic activities of Kachchh than the coastlines of the Arabian Gulf.

Loss of mangroves coupled with the large scale 'development' on account of Zulfikarabad City may further aggravate the ferocity of meteorological and geological hazards and pose a threat to the lives and properties of future inhabitants of the proposed city. These findings of the site's exposure to meteorological and geological hazards are consistent with Bilham et al. (2007) and Pararas-Carayannis (2006) who suspected that the seismic disturbances originated in Kachchh region of India could endanger Karachi megalopolis (located 300 km Northwest of Kachchh) and thus are valid threats for Zulfikarabad site that is juxtaposed to the source of various past quakes.

Regardless of the disaster vulnerability of Zulfikarabad site, the local livelihoods primarily are linked with the surrounding natural resources including mangroves, marine fishery and agriculture. Memon (2011) reported that upstream diversion of the Indus River has already resulted in loss of livelihoods of erstwhile paddy farmers and camel herder who coped with the situation by shifting their occupation to marine fishery. Certainly Zulfikarabad will make it impossible for them to continue their fishing activities and thus push back them in a similar position where they were left few decades ago following the construction of dams and barrages. Considering that the development work of the city is still in its planning stage, it is recommended that more in-depth studies on the above mentioned aspects need to be carried out before starting the onsite development of Zulfikarabad Mega City.

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Research article

Hydrogen Peroxide and Peroxidase Activity as Potential Indicators on Adaptability of Plants to Salinity Stress Condition

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Abstract The purpose of this study is to investigate whether hydrogen peroxide content as well as peroxidase enzyme activity in the leaves of the cultivars can be used asindicators of the adaptability of plants to salinity stress conditions. For this purpose, leaves of 6 cultivated plant species: *Cassaia siamea*, *Acacia auriculiformis*, *Acacia magium*, *Pithecellobium dulce*, *Combretum quadrangulare* and *Albizia lebbeck* were collected from previously high salinity areas where the salinity of soil have been improved by plant cultivation, and the relationships between soil characteristics, plant species and the content of hydrogen peroxide and peroxidase enzyme activity were examined. The results show that *C. quadrangulare* has low hydrogen peroxide content and high peroxidase enzyme activity compared to other plants at the same electrical conductivity (0.16 dS m^{-1}), suggesting that this plant has less stress than the others. In other words, *C. quadrangulare* can adapt to high salinity stress conditions better than the others. *A.magium* and *A.auriculiformi* are the second best. Based on the present results, *C. quadrangulare* is the best promising species for growing on high salinity areas.

Keywords salt affected area, hydrogen peroxide, peroxidase enzyme activity

INTRODUCTION

Soil salinity is one of the most significant abiotic stress factors that decrease productivity. High salt concentration in soil or in water affects plant growth, nutrient uptake and metabolism through the decrease in the amount of water available for plants, through ion imbalance or disturbances in ion homeostasis by disturbance of essential intracellular ion concentrations, and through ion toxicity due to excessive Na^+ or Cl^- uptake (Greenway and Munns, 1980; Gossett et al., 1994; Zhu, 2001; Parida et al., 2004). An excess of exchangeable Na ion is harmful to plants, principally because it induces undesirable physical and chemical conditions of the soil. In addition, Na influences soil structure, resulting in a decrease of water infiltration and gas exchangeability. Salinity affects the growth of plants by decreasing the availability of water to the roots due to the osmotic effect of external salt and by toxic effects of excessive salt accumulation within the plant. Drastic changes in

ion and water homeostasis lead to molecular damage, growth arrest and even death (Munns, 1993; Munns et al., 1995).

There is now conclusive evidence that production of reactive oxygen species (ROS) is enhanced in plants in response to different environmental stress conditions such as salinity, drought, water logging, temperature extremes, high light intensity, herbicide treatment and mineral nutrient deficiency. The most stable ROS is hydrogen peroxide (H_2O_2), which is highly reactive and can cause serious oxidative damages to membrane lipids leading to loss of membrane integrity and increase in electrolyte leakage and cell death. ROS were considered to be toxic by-products of aerobic metabolism (Wise and Naylor, 1987; Mittova et al., 2000; Zhu, 2001; Mittova et al., 2002; Slesak et al., 2008).

Salt tolerant plants maintain their growth and have many mechanisms to maintain ionic homeostasis, osmotic homeostasis and detoxification pathways (Dubey, 1994; Zhu, 2001; Parida and Das, 2004). It is known that plants containing high concentration of antioxidants show considerable resistance to the oxidative damage caused by free radicals (Ashraf and Harris, 2004; Parida and Das, 2004; Slesak et al., 2008).

Several authors have discussed the effect of salt stress on the amount of H_2O_2. One mechanism that underlies the tolerance of plants to salt stresses is the ability of plants to detoxify ROS and scavenging systems by antioxidative pathways. The salt-tolerant plant presented lower increase in the amounts of ROS and antioxidant enzymes than the salt-sensitive plants. Therefore, the increment in ROS such as H_2O_2 content and antioxidant enzymes activity in leaves depended upon the levels of salt tolerance (Dubey, 1994; Zhu, 2001; Parida and Das, 2004; Slesak et al., 2007). Chen et al. (1993) and Duand (1997) proposed that peroxidase and catalase are two major systems for the enzymatic removal of H_2O_2 in plants. Until now, the information about the biochemical parameters of each plant that can grow on high salinity soil is insufficient. Therefore, in this study, we use H_2O_2 and peroxidase enzyme as potential indicators to detect the ability of plants to grow on high salinity areas.

METHODOLOGY

Soil and plant samples were collected in May, 2010 at the area near Akkrasathsoonthorn Reservoir, Somsanuk Village, Borabue District, Mahasarakam Province, where the high salinity of soil has been improved by tree plantation during the past 2 years. The study area at the beginning was classified into high salinity (6.23 dS m^{-1}) and very high salinity (18.9 dS m^{-1}) areas. After 2 years of tree plantation, the salinity of both areas decreased to slight salinity (< 1 dS m^{-1}).

Electrical conductivity and pH of soil were measured by using a conductivity meter and a pH meter, respectively, based on a soil-water ratio of 1:5 by weighing10 g of soil in a beaker. The soil sample was left for 30 minutes to measure the electrical conductivity and for an hour to measure pH value.

Hydrogen peroxide content in the leaves was determined according to the method 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. Crude extract 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, and mixed by vortexing briefly. The absorbance of mixture was read at 390 nm. A mixture without the supernatant served as a blank. The content of H_2O_2 was calculated from a standard curve and the concentration was expressed as μmole g^{-1} fresh weight.

Peroxidase 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 30 s (linear phase) after H_2O_2 was added. One unit of peroxidase activity was expressed as ΔA470 min^{-1} mg $protein^{-1}$.

Soluble protein content of the crude extract was determined according to the method of Bradford (1976) using the Bio-Rad assay kit (Bio-Rad Laboratories, USA) with bovine serum albumin (BSA) as a calibration standard.

RESULTS AND DISCUSSION

In the present study, the H_2O_2 content and the peroxidase activity in the leaves of 6 plant species harvested from various salinity areas were measured. With increasing EC value in soil**,** salinity had a significant effect onthe amounts of H_2O_2 and peroxidase enzyme activity in all 6 cultivated plant species. The data show that the leaf H_2O_2 contents in 6 cultivated plant species were increased and different (Fig. 1).

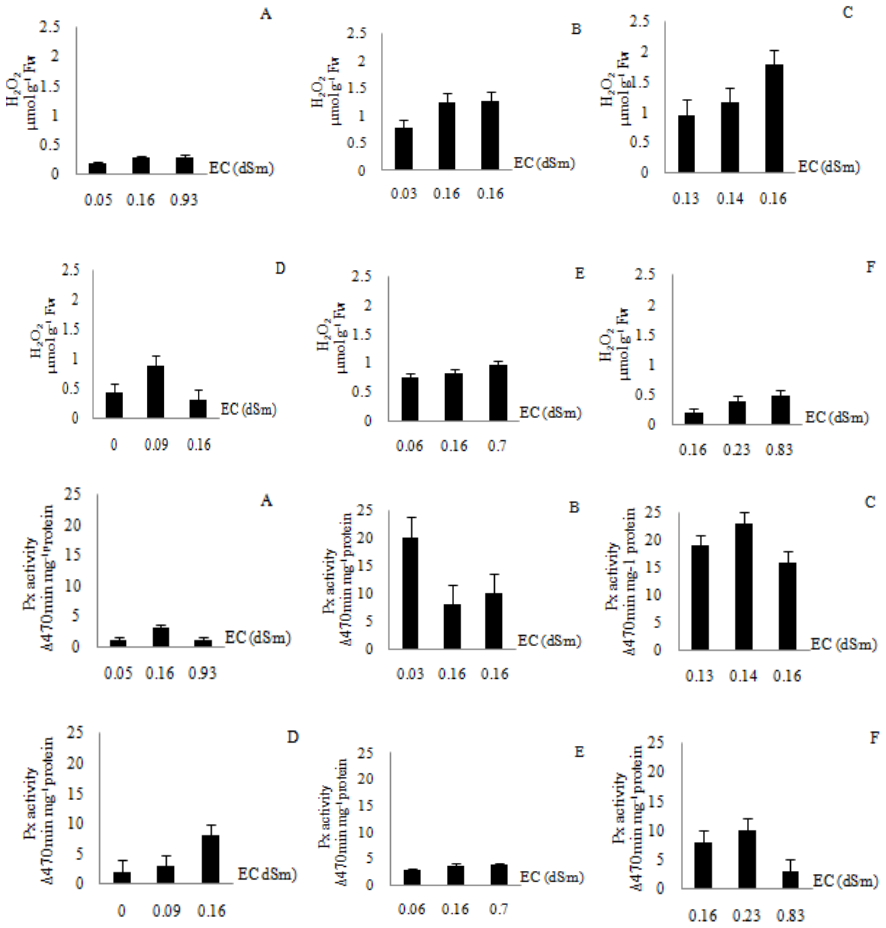

Fig. 1 The effects of salinity of the soil on hydrogen peroxide content and peroxidase activity in leaves of 6 plants.
Combretum quadrangulare (A), *Pithecellobium dulce*(B), *Albizia lebbeck* (C), *Acacia auriculiformis* (D), *Cassaia siamea* (E), *Acacia magium* (F)

With the increase of EC value in soil, the relation between salt tolerant plants and the amount of H_2O_2 and peroxidase enzyme activity under salt stress can be classified into 2 groups: group I (less responsive to salt stress than group II) consisting of 4 plant species: *C. quadrangulare*, *A. auriculiformis*, *C. siamea*, and *A. magium*, that showed a slight increase in both the amount of H_2O_2 and the peroxidase activity; and group II (more responsive to salt stress than group I) consisting of *P. dulce* and *Albizia lebbeck*, that showed increase in both H_2O_2 content and peroxidase activity in leaves. The result indicated that *C. quadrangulare* is the most tolerant plant based on its ability to

maintain the lowest H_2O_2 content value (ranging from 0.2 - 0.3 μmol/g FW) when compared the others. Besides, it showed the lowest peroxidase enzyme activity (ranging from 1-3 units min^{-1} mg^{-1} protein). Thus, the ability of salt tolerance in *C. quadrangulare* did not depend on the peroxidase activity. This means it may be equipped with some mechanisms which help protect it from H_2O_2.

These results support previous reports such as Fadzilla et al. (1997) that described an increase of H_2O_2 production, occurred gradually in response to salt stress in rice plants. In addition, Uchida et al. (2002) reported that the most tolerant cultivar (Pokkali) had a lower level of H_2O_2 than the salt-sensitive Pusa Basmati 1. Also, Vaidyanathan et al. (2003), 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.

Moreover, in the group I, *C. siamea* also showed a slight increase in both the amount of H_2O_2 (ranging from 0.2 - 0.5 μmol/g FW) and the peroxidase activity (ranging from 2 - 4 units min^{-1} mg^{-1} protein) with increasing EC value in soil. In contrast, in *A. magium*, the H_2O_2 content and the peroxidase activity increased with salinity levels, but the peroxidase activity decreased at 0.16 dS m^{-1} and 0.93 dS m^{-1}values. The result indicated that it has low efficiency to produce peroxidase activity when it grows on high salinity areas. While, in *A. auriculiformis*, though the H_2O_2 content and the peroxidase activity increased with salinity levels, the H_2O_2 content decreased at 0.16 dS m^{-1}. This means that *A. auriculiformis* has high efficiency to produce antioxidant enzyme to detoxify H_2O_2. Also, when comparing to the others in group I, *A. auriculiformis* is the best species for growing on high salinity areas.

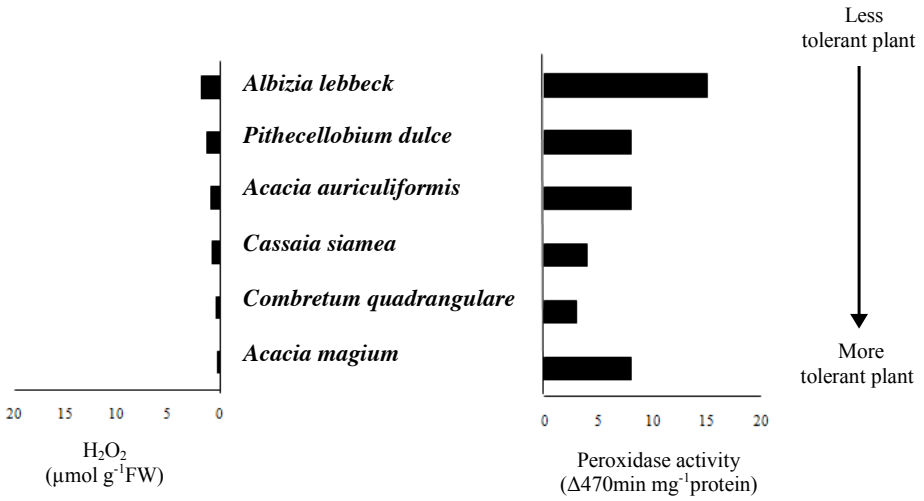

Fig. 2 The effects of salinity of the soil (0.16 dS m^{-1}) on hydrogen peroxide content and peroxidase activity in leaves of 6 plants

When comparing the amount of both parameters at the same electrical conductivity (0.16 dS m^{-1}) in the leaves of 6 plant species (as shown in Fig.2), the amount of H_2O_2 and peroxidase enzyme activity may be depending upon the levels of salinity in soil and also depending on the plant species.

CONCLUSION

The results presented here revealed that salt affected both the content of hydrogen peroxide and the activity of peroxidase in the cultivated plant species. This study confirms that with increasing of EC value in soil, halophytes do not accumulate H_2O_2 uniformly. Both biochemical parameters may be used as potential indicators to detect the ability of plants to survive and grow in their respective areas. This study also indicated that hydrogen peroxide content and peroxidase activity were clearly related to the ability of survival in each plant and the ability to detoxify H_2O_2, respectively. In summary, the accumulation of both important substances in plants could be used as an index to

indicate the salt tolerance of plant and the best promising species to improve saline soil and to serve as plant energy was *C. quadrangulare*.

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Research article

Suitable Timing of Compost Application and Its Effectiveness on Mung Bean in the Crop Station of Royal University of Agriculture

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Abstract Agriculture is one of the main sectors for Cambodian economy since 85% of citizens live in the countryside, and among which 75% are farmers. They use the same soil every year for farming, which causes the soil to become infertile. To solve this problem, adding organic fertilizer is the best method to improve the stability of soil fertility. Compost is one type of organic fertilizers which can be applied to improve soil properties such as the soil's physical, chemical and biological properties. Because of these reasons, an experiment on suitable timing of compost application and its effectiveness on mung bean was conducted. The experiment aimed to determine which kind of organic fertilizers is appropriate for mung bean growth and yield, and to identify the suitable timing of compost application for the mung bean crop. There were 4 kinds of compost for conducting the experiment: conventional compost, pellet compost, neem conventional compost and neem pellet compost, and two different timings of compost application (one week before seeding and during seeding of mung bean). Plots were designed as randomized complete blocks design (RCBD) with three blocks. In each block there were nine treatments including the control. As a result, there was no significant difference between different timings of compost application (one week before seeding, and while seeding). We had the highest yield by application of neem compost one week before seeding, which was 2.056 t/ha. The next was neem compost during seeding=1.850 t/ha, and the lowest yield was found in the control treatment=1.341 t/ha. According to the results above, application of neem compost one week before seeding is suitable to get higher yield of mung bean though there was not a significant difference between timings of compost application.

Keywords conventional compost, pellet compost, neem conventional compost, neem pellet compost, timing of application

INTRODUCTION

To produce rice and other crops from year to year, it is necessary to apply nutrients continually. So, organic fertilizers have been applied into the soil in order to keep the soil fertility and ensure sustainable agriculture. Compost is one type of organic fertilizer which is made from plant residues, that can offer nutrients to soil, decrease the level of compacted soil, and improve chemical and physical properties of soil (soil quality) (Mihara and Fujimoto, 2009; Aero Sun Time, 1990). According to the experiment of Ungsa (1990-1991) about the effectiveness of fertilizer and spacing on quality and mung bean yield, it was concluded that the application of chemical fertilizer did not improve the quality of mung bean significantly, but the applied compost increased mung bean yield significantly.

Pellet compost or granular compost was developed by Institute of Environment Rehabilitation and Conservation (ERECON) and Tokyo University of Agriculture (TUA) (Mihara and Fujimoto, 2007). Pellet compost is made of conventional compost, clayey soil, and molasses in the proportion of 10:1:0.01 (Mihara and Fujimoto, 2007). 0.01 units of molasses is the most suitable proportion for making pellet compost (Mihara, et al, 2005). Between conventional compost and pellet compost, conventional compost is more likely to be prone to erosion than pellet compost, as the molasses plays roles as connectors for compost aggregate. It means that nutrient losses of farm land applied with pellet compost can be reduced compared to the conventional compost (Mihara and Fujimoto, 2007). Siriwattananon and Mihara (2008) concluded that pellet compost application is an effective way for reducing soil fertility loss which is one way to contribute to the practice of sustainable agriculture.

Neem compost is a type of compost made from neem leaves and other materials. Neem compost is used to increase soil quality, soil fertility, and it also provides more nutrients to soil and crops. Neem compost is being used by many farmers and agronomists because of the discovery of its benefits such as the increase of pest resistance for plants, which can be applied to all kinds of plants and crops, improvement of soil condition, and the prevention of some kind of root diseases (Oil seeds shop, 2010).

Harvesting age of mung bean is 70-90 days depending on the variety (Sokha, 1997), and nutrient releasing rate of compost is slower than chemical fertilizer (Mihara and Fujimoto, 2007). Hence, different timings of compost application should be studied.

Based on good features of these organic fertilizers and the above-mentioned factors, an experiment was conducted about the suitable timing of compost application and its effectiveness on mung bean in the crop station of Royal University of Agriculture. The objectives of this experiment aimed to determine which kind of organic fertilizers is appropriate for mung bean growth and yield, and to identify the suitable timing of compost application for the mung bean crop.

MATERIALS AND METHODS

Conventional compost, pellet compost, neem conventional compost, and neem pellet compost were made at ERECON CaM-branch (Institute of Environment Rehabilitation and Conservation, Cambodia Branch). The field experiment was conducted in the crop station of Royal University of Agriculture.

Materials such as cow manure, water hyacinth, siam weed, morning glory, grass, chaff ash, rice husk, vegetables, tree leaves, neem leaves, and fertile soil were collected to make compost (Kinal, et al., 2007). After putting materials into the compost box, water was used to moisturize the solution. Then compost was turned regularly until it became mature. After that, conventional compost, and neen conventional compost were sieved with 1.5 millimeter diameter sieve to get powdered compost for making pellet compost by mixing it with clayey soil, and palm sugar in the ratio of 10:1:0.01.

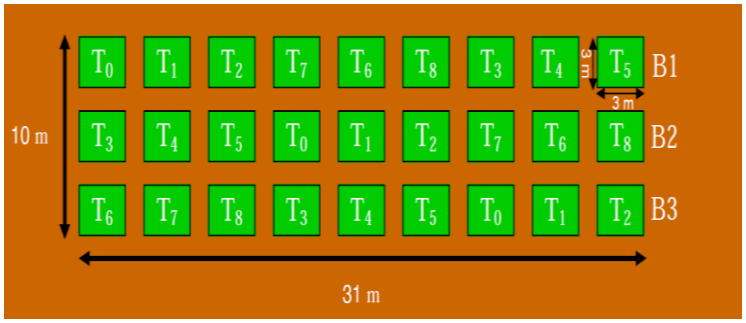

Fig. 1 Experimental plots design

After getting organic fertilizers, conventional compost, pellet compost, neem conventional compost, and neem pellet compost, they were applied at the time set at the rate 18t/ha (Mihara and Fujimoto, 2007) by using CARDI CHEY variety—mung bean variety released by Cambodian Agricultural Research and Development Institute (CARDI) in 2001.

Total experimental site was 310 square meters (31m x 10m). Plots were designed through randomized complete block design (RCBD) consisting of 3 replications with 9 treatments for each block. The space between blocks and treatments was 0.5m. The size of treatment was 3m x 3m, and mung bean was seeded with 30cm spacing in row and 40cm spacing in column.

Data collection

To measure the effectiveness of those fertilizers, indicators such as plant height (cm), total number of pods per plant (number), weight of 1000 seeds (g), and mung bean yield (t/ha) were collected from 15 random plants of each treatment.

Data analysis

Collected data was calculated and determined the significant difference of each treatment by testing analysis of variance (ANOVA) and least significant difference (LSD) by using Microsoft Excel and SPSS software.

Table 1 Result of N P C, and OM analysis of compost

Type of compost	Total N ($x10^{-5}$ kg/kg)	Total P ($x10^{-5}$ kg/kg)	Total OM ($x10^{-2}$ kg/kg (=%))	Total C ($x10^{-2}$ kg/kg (=%))
Conventional compost	263.5	60.2	13.0348	7.2994
Pellet compost	234.3	98.7	11.4161	6.3939
Neem conventional compost	241.3	187.3	20.2767	11.3549
Neem pellet compost	367.2	120.9	13.3969	7.5022

Source: Compost analysis at laboratory of Tokyo University of Agriculture, Japan, 2010

RESULTS AND DISCUSSION

The results of the experiment were summarized in Table 2. There was not a significant difference of plant height ($P>0.05$) among different treatments. Similar to the result of Sithradeth (2008), the experiment on effect of cow manure and N P K application on the same mung bean variety (CARDI CHEY variety), demonstrated that plant height was not significantly different between treatments. Anyway, Table 2 showed that the average plant height of all treatments in which compost was applied were higher than the control, which was the same result of Ungsa (1990-1991), where compost treatments improved agronomic characteristics of mung bean.

Table 2 Results of the experiment

Treatments applied	Plant height (cm)	Total pods per plant (number)	Weight of 1000 seeds (g)	Yield (t/ha)
T_0: Control	64.326	36.42^{c}	75.91^{b}	1.341^{c}
T_1: Conventional compost one week before seeding	65.111	38.85^{bc}	81.21^{abc}	1.598^{bc}
T_2: Pellet compost one week before seeding	64.488	39.62^{bc}	79.62^{bc}	1.703^{b}
T_3: Neem conventional compost one week before seeding	64.400	42.5^{a}	81.04^{ab}	2.056^{a}
T_4: Neem pellet compost one week before seeding	65.133	41.73^{ab}	78.99^{bc}	1.764^{ab}
T_5: Conventional compost while seeding	65.488	40.68^{ab}	83.26^{a}	1.660^{bc}
T_6: Pellet compost while seeding	64.644	38.05^{bc}	78.90^{cd}	1.757^{bc}
T_7: Neem conventional compost while seeding	64.888	40.11^{b}	81.98^{ab}	1.850^{ab}
T_8: Neem pellet compost while seeding	65.911	38.88^{bc}	80.81^{abc}	1.686^{b}
significant difference between treatment	Ns	*	**	*
Coeficient of Variance(C.V=%)	5.94	4.49	2.11	11.94

**= significant difference at P< 0.05, **= significant difference at P< 0.01, ns= Non significant difference*

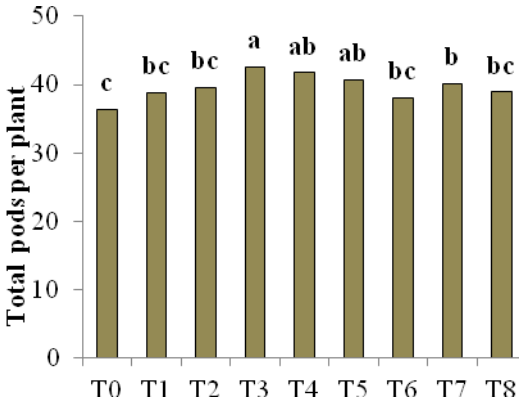

Fig. 2 Total pods per plant of different treatments

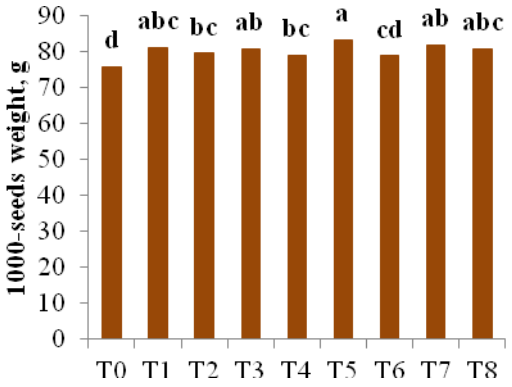

Fig. 3 Weight of 1000 seeds of different treatments

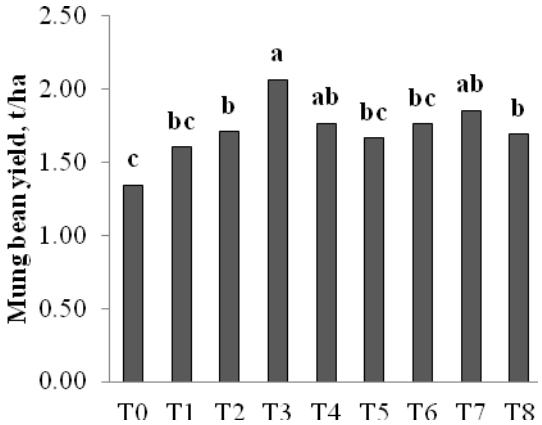

Fig. 4 Mung bean yield of different treatments

Total pods per plant of each treatment was significantly different ($P<0.05$). Treatment applied with neem conventional compost one week before seeding (42.50 pods) had more total pods per plant than the treatment applied with neem pellet compost one week before seeding (41.73 pods). These two treatments applied neem compost; according to the result of N P C and OM analysis of compost (Table 1), neem conventional compost ($P=187.3 \times 10^{-5}$ kg/kg) and neem pellet compost ($P=127.9 \times 10^{-5}$ kg/kg) contained more phosphorus (P) than other composts. Sokha (1997) found that phosphorus was very important for mung bean to improve root growth, and especially phosphorus was very active to make mung bean's flower and pods good. The treatment that had the least pods per plant was the control (36.42 pods) (Fig. 2) and (Table 2). Ungsa (1990-1991) pointed out that compost application could improve the total pods per plant more than control and chemical fertilizer application.

Among all treatments, the highest weight of 1000 seeds was the treatment applied with conventional compost while seeding (83.26 g), then neem conventional compost while seeding (81.98 g), conventional compost one week before seeding (81.21 g), neem conventional compost one week before seeding (81.04 g), neem pellet compost while seeding (80.81 g), pellet compost one week before seeding (79.62 g), neem pellet compost one week before seeding (78.99 g), and the lowest weight of 1000 seeds was the control (75.91 g). There was a significant difference between treatments ($P<0.01$) (Table 2 and Fig. 3).

The treatment that applied neem conventional compost one week before seeding got the highest yield (2.05 t/ha), followed by the neem conventional compost while seeding (1.85 t/ha), neem pellet compost one week before seeding (1.764 t/ha), pellet compost while seeding (1.757 t/ha), pellet compost one week before seeding (1.703 t/ha), neem pellet compost while seeding (1.686 t/ha), and conventional compost one week before seeding (1.598 t/ha). The lowest yield was observed in control (1.34 t/ha). Treatments were significantly different ($P<0.05$) (Table 2 and Fig. 4). Similarly, Ungsa (1990-1991) determined that application of compost increased yield significantly.

CONCLUSION

Based on the above results, applying compost one week before seeding or during seeding had no significant difference. In the case of mung bean yield between treatments of the same organic fertilizers at different timings: conventional compost (T_1) and (T_5), pellet compost (T_2) and (T_6), neem conventional compost (T_3) and (T_7), and neem pellet compost (T_4) and (T_8), had no significant difference in yields. However, the most suitable timing of compost application was one week before seeding due to the higher yield of mung bean than that of mung bean yield with composts applied while seeding. The most suitable compost for mung bean to get higher yield was neem conventional compost (based on comparision of yield got from each treatment).

ACKNOWLEDGEMENTS

Thanks to ERECON for supporting me to learn and practice how to make compost, pellet compost, and other technical knowledge to successfully conduct this experiment. Also, special thanks to Royal University of Agriculture and faculty of Agronomy for supporting and providing many agricultural courses and field experiments.

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Research article

Study on Suitable Moisture for Pellet Compost Making and Machanical Mixing Technique

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Abstract Pellet compost contributes to sustainable agriculture systems in Cambodia. It also inspires Cambodian farmers to use organic fertilizers instead of chemical fertilizers in agricultural practices. According to the sustainable agriculture program for environment conservation of the Institute of Environment Rehabilitation and Conservation (ERECON), one topic for study concerns machine and mixing techniques with suitable moisture for making pellet compost. The purposes of the experiment are to study about the process of making pellet compost with two kinds of machines (diskpelleters and mincing machines), and to identify appropriate moisture for practical use of each machine. There are some parameters for studying the process of making pellet compost of those machines, such as potential of each machine, percentage of good pellet compost, length of the granule, and characteristics of the granule. In identifying moisture, five treatments and three replications were selected, each of which was added with different amounts of water: T1= 750 ml, T2= 900 ml, T3= 1050 ml, T4= 1200 ml, and T5= 1350 ml into 5.505 kg of compost mixture compound with 23.36% of water content, which consists of conventional compost, termite-mound soil and palm sugar with a ratio of 5:0.5:0.005. As a result, for the diskpelleter machine experiment, we got the best result for treatment T2 which was added with 900 ml of water and had 45.42% of water content. The producing capacity of this machine was 139.75 kg/h in dry mass. For mincing machine, treatment T3, added with 1050 ml of water and having 48.69% of water content, got the best result, with a producing capacity of 64.39 kg/h in dry mass. Therefore, 45.42% of water content in compost mixture was the best moisture for making pellet compost with the diskpelleter machine and 48.69% of water content in compost mixture was the best moisture for making pellet compost with the mincing machine.

Keywords: conventional compost, termite-mound soil, pellet compost, water content.

INTRODUCTION

Pellet compost making is an activity that contributes to the sustainable agriculture system in all agricultural countries, especially in developing countries like Cambodia. Currently, soil degradation has been widespread around the world due to agricultural practices depending on chemical fertilizer only. Therefore, it should be improved from the viewpoint of soil nutrient substance. Pellet compost combined with conventional compost, soil, and molasses at the ratio of 10:1:0.01 by adding some amount of water has been used for sustainable agriculture (Mihara, M. and Akimi, F., 2007). According to Mihara et al., (2005) adding 0.01 unit of molasses with moisture is suitable for crop growing, but if molasses is added in higher amount, the crop growth is reduced and has a shorter life than when normal fertilizer is applied. The compost pellet size produced by mincing machine was 0.5 cm in diameter and 1 cm in length with the same ratio above mentioned (Siriwattananon, L. and Mihara, M., 2008). There are many kinds of plant residues for making conventional compost such as rice straws, sugar cane leaves, corn trees, grasses or leaves, bean residues, saw dust, bean trees and animal manure that can be used as raw materials (Mihara, M. and Akimi F., 2007). According to CEDAC (2008) there are several composting materials such as liquid bio-fertilizer, chicken manure, bat manure, palm sugar, hill soil, surface soil, ash, and bean residues at the ratio of 50:50:5:3:100:100:50:5, respectively. Moisture determination of compost mixture was very important for Extruder machines and Diskpelleter machines. Moisture of compost mixture has a strong effect on compost cohesion and on the speed of pellet compost process. The suitable moisture for Extruder machine was from 35% to 45% and from 25% to 35% for diskpelleter machine (Hara, 2001). Furthermore, conventional compost is very important for making pellet compost, so we should make sure that it does not contain hard waste and stones that can damage the machine, thus requiring more spending on machine repair. Pellet compost is used as an organic fertilizer and its production is expensive because it should be produced with high quality standards, and nutrient substances (Hara, 2001). Advantages of pellet compost include the ompost's bulk density, being for conventional compost 1.9g/cm^3, that is, less than soil bulk density which is 2.7g/cm^3, so whenever rainfall or surface runoff water occurred, conventional compost could be washed out easily. On the other hand, pellet compost stays in the soil and prevents soil nutrient erosion, is very effective and it is easy for transporting (Mihara, M. and Akimi, F., 2009). Pellet compost can be used on any kind of crops that will grow well and produce high yield. Moreover, it does not have an impact on human health and it is economical, and so farmers can earn money from selling pellet compost (CEDAC, 2008). Therefore, the objectives of the research are to study the process of making pellet compost with two kinds of machines (diskpelleter and mincing machines), and to identify an appropriate moisture for practical purposes with each machine.

MATERIALS AND METHODS

The research was carried out at the Royal University of Agriculture and it is focused on two purposes: the processes of making pellet compost with two kinds of machines, and the suitable moisture of compost mixture for each machine. The materials for this research are: mixture machine, two pellet compost machines, oven machine, conventional compost, termite-mound soil, palm sugar and water. According to Hara (2001), the process of making pellet compost has eight steps, which are: composting, mixture agitator, mechanized sieve, molding machine, dryer, mechanized packaging in bags, distribution and storage, and this method was used in the present research. Diskpelleter machine and mincing machine were used for making pellet compost combined with conventional compost, termite-mound soil, and palm sugar in the ratio of 5:0.5:0.005. In order to determine the suitable moisture of compost mixture, 5 treatments were defined and each treatment contained 5.505kg of compost mixture compound added with 5 different levels of water; T1: 750 mm, T2: 900 mm, T3: 1050 mm, T4: 1200 mm, and T5: 1350 mm. Moreover, replications for producing pellet compost of each treatment were completed three times, as R1, R2, and R3. Data of experiment were collected, such as moisture of compost mixture

by selecting sample and putting it in oven machine, potential of each machine by weighing total compost pellet product with timing during making, compost pellet length by measuring in meters and good pellet compost by separating good and broken compost pellet. Furthermore, according to Chrun Rithy (2009), the water content of compost mixture in dry mass was calculated by the Eq.(1) (Norman, 1987).

$$Md = Ww / Wd \times 100 \quad (1)$$

where, Md is the moisture content, d.b. (%), Ww is the weight of water (g) and Wd is the weight of dry sample (g).

Several software programs were used to analyze all data, based on objectives of the present study. Those programs were Microsoft Excel and SPSS 15 used to compare the significant difference of 5% for the treatments by analyzing a variance of one-way ANOVA and LSD.

RESULTS AND DISCUSSION

The pellet compost making processes

The pellet composting process was considered, each stage being done in order and all materials prepared for pellet composting. There are seven stages of making pellet compost by using diskpelleter machine and mancing machine, as shown in Fig. 1

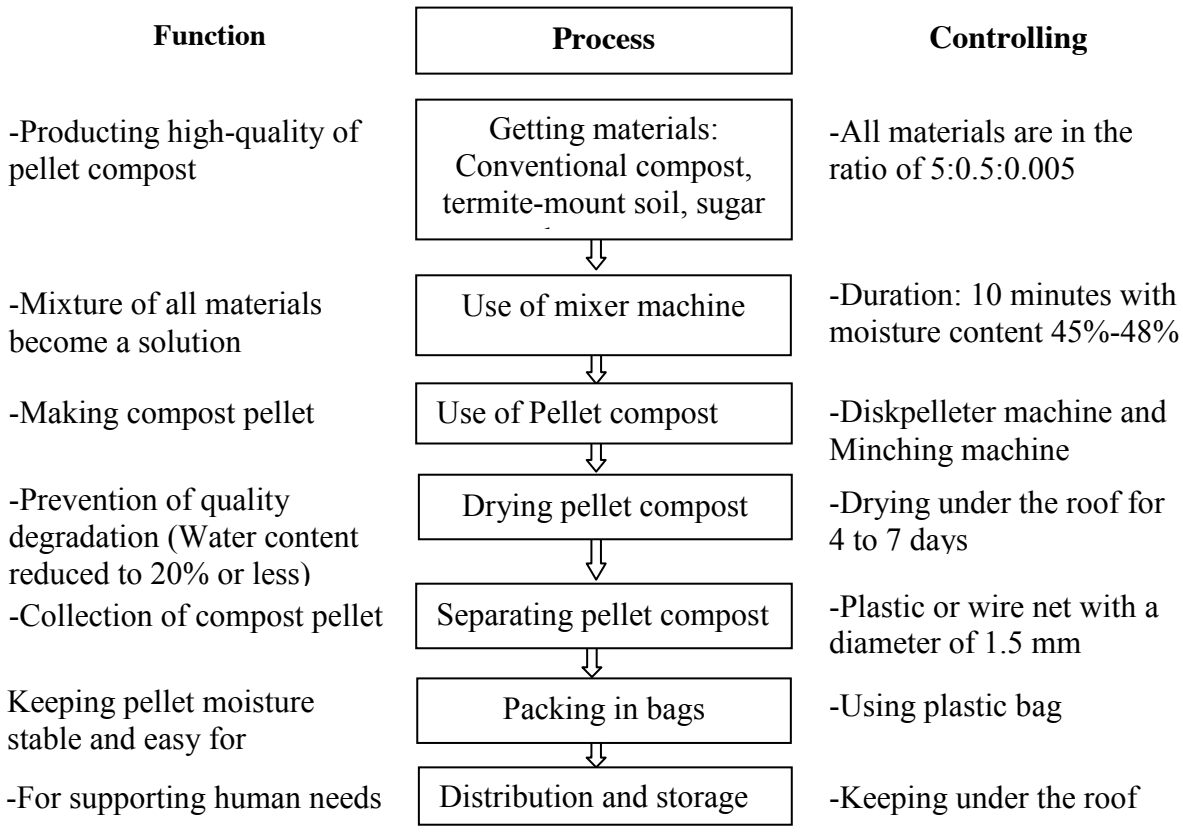

Fig. 1 Process for making pellet compost

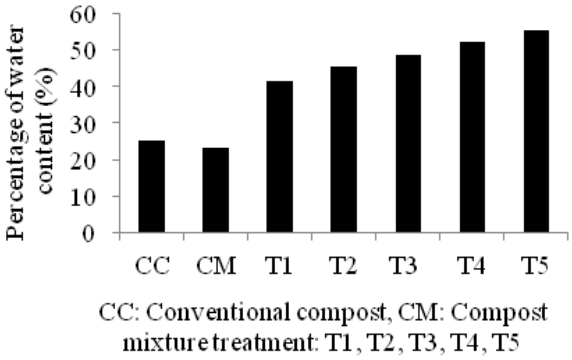

Fig. 2 Moisture of compost mixture (%)

Firstly, materials for making pellet compost include conventional compost, termite-mound soil, and sugar were mixed at the ratio of 5:0.5:0.005 by adding a suitable water amount. We had to make sure that the conventional compost and termite-mound were in good condition. Secondly, all materials were mixed by mixer machine until it became a fine mixture, for about 10 minutes. Thirdly, the compost pellet was produced by the diskpelleter machine and the mincing machine. In this stage, compost mixture with suitable moisture was put into the machines, resulting in the production of pellet compost. Fourthly, after producing pellet compost, this was dried under the roof around 4 to 7 days so its water content could be reduced to 20% or less, being this a suitable moisture for storage (Hara, 2001). When drying pellets, some of them were cracked, and so it was necessary to separate them by sacking with a plastic net. Then, pellet compost was packed in plastic bags in order to keep stable moisture. Finally, pellet compost was distributed and stored under a roof or cool place. The results of the moisture of compost mixture (Fig. 2) showed that water content of conventional compost (CC) was 25.34%. After being mixed with termite-mound soil and sugar, the water content of compost mixture (CM) was reduced to 23.36%. The treatment T1 was to add 750 ml of water on 5.505 kg of compost mixture compound, and its water content increased to 41.65%. 150 ml of water was added, increasing from one treatment to another: T2, T3, T4, and T5 and water content increased to 45.42%, 48.69%, 52.28%, and 55.49% respectively.

The potential of diskpellet machine for producing pellet compost

According to the results in Fig. 3, the potential of treatments using the diskpelleter machine decreased while water content increased in T1, T2, T3, T4, and T5. The highest potential of this machine was T1: 49.96 g/s or 180 kg/h in dry mass, that had a higher significant difference than the other treatments ($P<0.05$). The lowest potential was T5: 25.01 g/s or 90 kg/h in dry mass. In contrast, even though the treatment T1 had the highest potential value, the compost pellet was a little bit dry, and so it was easy to be cracked. Furthermore, the good compost pellet after sacking it is not different to those of T2 and T3 with a significant difference level of $P>0.05$ (Fig.4). The results of the experiment in Fig. 5 show that the length of compost pellet is not significant among treatments ($P>0.05$). The longest compost pellet length from diskpelleter machine was in treatment T5: 11.24 mm and the shortest was in treatment T1: 8.93 mm; these compost pellets were 5 mm in diameter.

A survey was applied to 20 people to evaluate moisture and length of pellet compost for each treatment. Scores ranged from one to five, with one being very bad to five being very good. Fig. 6 shows that the most popular treatment was T2: 3.65 marks for pellet moisture and 3.7 marks for pellet length. Therefore, the best treatment was T2: 45.42% of moisture and 9.43 mm of compost pellet length using the diskpelleter machine

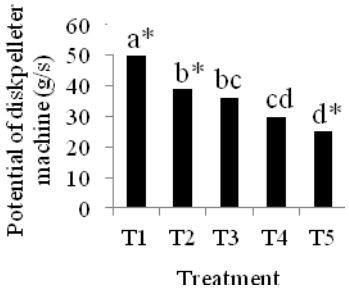

Fig. 3 Potential of diskpelleter machine (g/s)

** Significant difference at P<0.05*

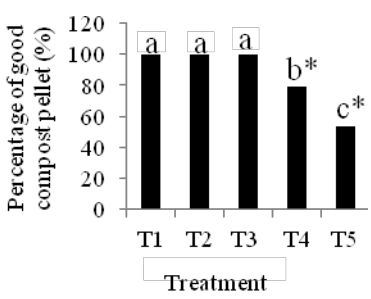

Fig. 4 Percentage of good compost pellet (%)

** P<0.05*

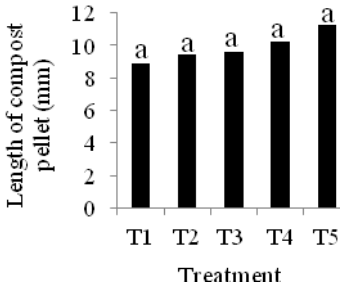

Fig. 5 Length of compost from diskpelleter machine (mm)

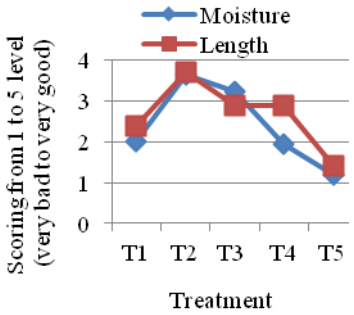

Fig. 6 Suitable characteristic of compost pellet

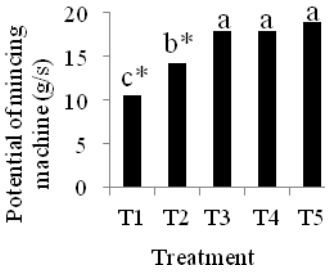

Fig. 7 Potential of mincing machine (g/s)

** Significant difference at P<0.05*

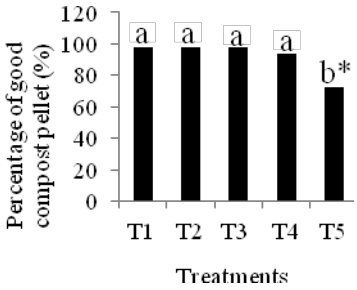

Fig. 8 Percentage of good compost pellets (%)

** P<0.05*

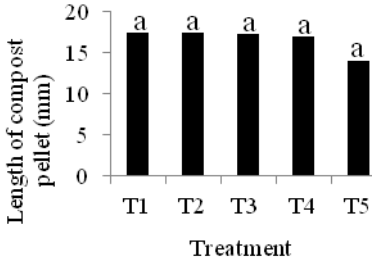

Fig. 9 Length of compost pellet from Mincing machine (mm)

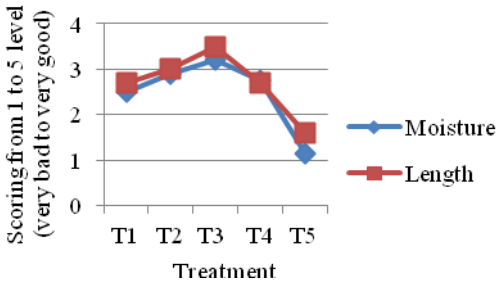

Fig. 10 Suitable characteristic of compost pellet

The potential of the mincing machine for making pellet compost

According to the results in Fig. 7, the potential of treatments using the mincing machine increased, when water content increased in T1, T2, T3, T4, and T5. The highest potential of this machine was in T5: 18.88 g/s or 68 kg/h in dry mass and it was not significantly different to treatments T3 and T4 (P>0.05). The lowest potential was T1: 10.5 g/s or 37.8 kg/h in dry mass. In contrast, even though the treatment T5 presented the highest value, the compost pellet was too wet, and so it stuck together and became a big aggregate. The good compost pellet after being separated had a significant difference to other treatments with a significant level of P<0.05 (Fig. 8). The results of the experiment in. Fig. 9 show that the length of compost pellets was non-significant among treatments (P>0.05). The longest compost pellet length was in treatment T1: 17.52 mm and the shortest was in treatment T5: 14.07 mm. Those compost pellets were 5 mm in diameter. A survey

was applied to 20 people to evaluate moisture and length of compost pellets for each treatment. Scores ranged from one to five, with one being very bad to five being very good. Fig. 10 shows that the most popular treatment was T3: 3.2 marks for pellet moisture and 3.5 marks for pellet length. Therefore, the best treatment was T3: 48.69% of moisture and 17.33 mm of compost pellet length with the mincing machine.

Discussion

According to Hara (2001), the most suitable moisture of compost mixture was 35% to 45% for the Extruder machine and 25%-35% for the Diskpelleter machine. However, the most suitable moisture of compost mixture in this research was 48.69% of water content for the mincing machine. In addition, the water content of compost mixture from 45.42% to 52.28% could be applied with this machine, while 45.42% of water content of compost mixture was the most suitable for making compost pellet by the diskpelleter machine. Moreover, the water content of compost mixture from 41.65% to 48.69% could be applied with this machine, too.

CONCLUSION

Based on the results of this research, it can be concluded that the diskpelleter pellet compost machine has potential to produce pellet compost from 90 kg to 180 kg per hour, while the mincing machine can produce from 37 kg to 68 kg per hour. According to the results of LSD analysis and survey on 20 people about compost pellet characteristics (moisture and length) the optimal choice when using the diskpelleter machine is treatment T2 added with 900 ml of water on 5.505 kg of compost mixture with 23.36%, being the water content of compost mixture after adding water 45.42%. For the mincing machine treatment T3 was the most suitable, which was added with 1050 mm of water on 5.505 kg of compost mixture, and the water content of compost mixture after adding water was 47.69%.

ACKNOWLEDGEMENTS

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Research article

Aspects of the Aging Farming Population and Food Security in Agriculture for Thailand and Japan

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Abstract This paper highlights the aging farmer population and food security in agriculture, an issue for both Thailand and Japan. The increase of elderly population in both countries is particularly marked in the agricultural labor force as the number of agriculture labor force has continually decreased due to the exodus of young farmers from agriculture. This has significantly impacted food security. The 152 Thai and 10 Japanese respondents, consisting of farmers aged over 55 years were sampled using a purposive sampling technique that was based on the interviewing survey carried out on August-December 2011. For techniques of data analysis, the descriptive statistics and cohort method were used. The results present an increasing trend of aged farming population and aging farmers mainly engaged in farming aging 65 and over in both countries. In case of the increase in Japan, it can be explained by the number of post-retirement farmers. It is interesting to note that the aging trend increases in number partly due to a slower rate of exiting from farming. The disadvantage is that older farmers would be much less efficient in agriculture, especially rice cultivation. However, the role of maintaining a farm land can be entrusted to the aging famers. From the survey, it was found that food insecurity is a risk due to a reduction of the farm labor force and the aging society. Yet, most farmers in both countries believed that a shortage of farm labor force has probably not given rise to a problem of food insecurity because in modern agriculture less labour is needed and the use of machinery is increasing. Thus, the government should improve access to modern technology and machinery to increase efficiency for coping with the above situations.

Keywords older farmer**,** post-retirement farmer, population mainly engaged in farming, cohort method, part-time farmer, full-time farmer

INTRODUCTION

In most countries, population aging tends to be greater in rural areas than in cities (Gerardo, 2005). This is because rural-to-urban migration is usually highly age-selective, involving mostly young adults who migrate to cities to seek urban employment (Gustavo, 2008). As a result, the population left behind in the countryside typically have higher proportions of older people (Gerardo, 2005). According to National Statistical Office (2011), in Thailand the agricultural population, over 65 year old occupied nearly 10% of the population. For Japan, over the 50-year period, from 1960 to 2010, an annual rate of decrease of roughly 1.16% for farm household has brought the agricultural population down to 6.50 million in 2010 (Ministry of Agriculture, Forestry and Fisheries(MAFF), 2011). As the younger population has moved out of agriculture, the aging farming population has become more prominent. Consequently, the agriculture sector will increase the reliance on the elderly population for labour. The aging of producers in the low capital-intensive agricultural sectors of many developing countries could imply lowering of the productivity of labor (Philippe,

2011). Probably labour productivity is one of the greatest stress areas that the rural exodus exercises on the food stability of these countries.

To date, there has been little research into the aging farm labor force in Thailand and Japan. This issue is a major problem for rural development, so there is a need for more research to quantify the current situation. Thus, this study has focused on the change in population demographics as its impact on food security in both Thailand and Japan and the prospective role of the aging population as a farm labor force for agricultural development.

METHODOLOGY

The research used secondary data to analyze the expected rural population and numbers predicted to be engaged in farming for the next 25 years in both Thailand and Japan. It also used primary data from a survey carried out in Khon Kaen, Thailand in 4 villages; Nonkaow village, Wangto village, Nontoon village and Tarae village; and in Tottori prefecture, Japan. A total of 162 respondents made up of farmers aged over 55 years in Thailand and Japan were sampled using a purposive sampling technique. 10 respondents from Japan also were members of Inaba Japan Agricultural Cooperative (JA). This research was based on an interviewing survey that was carried out during August-December 2011. For techniques of data analysis, the descriptive statistics and cohort method were used. With a differentiation of data collection period, Japan began in 2005 (Uchida, 1998) but Thailand since 2003 (National Statistical Office, 2011). For prediction, in Japan it can be calculated at provincial level as Tottori prefecture; but in Thailand, it must be forecasted on a national level due to a lack of data at provincial level. In case of the total number of agricultural population, less than 14 years has been estimated according to Uchida's method and the group aged over 75 years was compared with the general population aged over 75 years in Tottori province for Japan and in national level for Thailand (Uchida, 1998). This study also collected data from a discussion with Japanese scholars and professors in Tottori University.

RESULTS

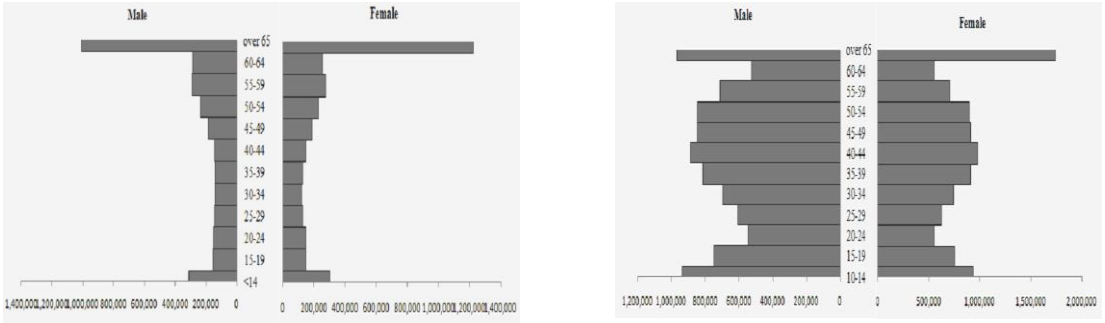
Current Situation and Tendency of Aging Population in Agriculture

According to the 2010 Census of Agriculture and Forestry (MAFF, 2011), in Japan, the number of farmers has fallen by half since the 1980s. The number of Japanese working in agriculture and forestry declined to 2.6 million in 2010, down from 5.43 million in 1985. The average age of Japanese working in agriculture and forestry was 65.8 in 2010 (Figure 1-a). The rate of aging population aged over 65 years increased by 34.3 % in 2010 compared to 8.2 % in 1960.

Thus, the total number of farm household members will have steeply fallen, as the number of aging farmer household members will be rising. In Thailand, on the other hand, the aging farmers have shown an increasing number of agricultural workforces from 4.5 % in 1980 to 16.7% in 2008 while agricultural workforce aged 15-39 represented the fallen proportion to 37.2 % in 2008. In contrast to this group, the agricultural workforce aged 40-59 increase by 36.1 % in 2008 compared to 27.4% in 1985 (Fig. 1-b). From this analysis, it can be concluded that the reduction in the young farming labor force has had effects of rapidly aging of the agricultural workforce. Table 1 showed that the rising portion of older farmers is due to an absolute increase in their numbers as well as a steady decrease in the number of farmers aged under 65 in both Japan and Thailand.

For Tottori prefecture, Japan, in the next 25 years the agricultural population aged over 65 is expected to be reduced from 34,656 persons in 2005 to 33,743 persons in 2030; and from 74,468 persons in 2005 to 12,725 persons in 2030 for the population aged under 65. In contrast, for Thailand, the total number of farming population aging under 65 is expected to decline from 18.07 million in 2003 to 16.64 million in 2028 or around 19% in 2003-2028. But the total agricultural population and population mainly engaged in farming aging 65 and over has a greater number than other age groups similar to Japan (Table 1). From this viewpoint, the aging trend is partly due to a slower rate of quitting from farming. Regarding Japan, the number of farmers aging 65 and over

shows an increasing figure. This increase may indicate the number of post-retirement farmers[1]. The post-retirement farmers can be classified into 3 categories based on pension income as follows: First, post-retirement farmer at early retirement age who are aged 50-54 years; Second, post-retirement farmer at first period retirement age who are aged 55-59 years and Third, post-retirement farmer at second period retirement age who are aged 60-69 years (Sawada, 2003; Supaporn and Tsuneo, 2005). The number of post-retirement farmers began rising from the 1990s; especially, in 2005-2010 period. This increase was due to the number of those who were born at the peak period of births; the post war "baby boom" of 1945-1949.



a) Japan, 2010 **b) Thailand, 2008**

Fig. 1 Farming population by age group

Table 1 Prediction of the number of farming population and population mainly engaged in farming for the next 25 years for Tottori province of Japan and for national level of Thailand

Tottori Province, Japan (person)												
Age group	farming population						population mainly engaged in farming					
	2005	2010	2015	2020	2025	2030	2005	2010	2015	2020	2025	2030
Under 30	29735	17454	11469	7836	5714	4246	2551	1044	619	438	332	251
30-54	30481	20378	13624	9584	7107	5064	4439	2681	1794	1360	1166	979
55-64	14252	16309	14169	9400	5259	3415	7050	6743	5281	3088	1833	1283
Over 65	34656	32528	35023	38312	37266	33743	27031	22965	22081	22451	21253	19955
Total	**109124**	**86669**	**74285**	**65132**	**55346**	**46468**	**40171**	**33433**	**29775**	**27337**	**24584**	**22468**
Thailand (1000 persons)												
	2003	2008	2013	2018	2023	2028	2003	2008	2013	2018	2023	2028
Under 30	7482	5711	6496	5940	6144	5992	1077	616	1057	679	1081	1029
30-54	8697	8538	10482	8037	11053	8663	2947	2653	3412	2442	3780	2193
55-64	1894	2496	1936	2154	2082	1986	574	609	548	550	573	502
Over 65	1560	2050	2775	3587	3867	4454	320	255	291	349	393	449
Total	**19633**	**18795**	**21689**	**19718**	**23146**	**21095**	**4918**	**4133**	**5308**	**4020**	**5827**	**4173**

Source: author's calculation

Older farmers in agriculture of Japan

From the survey applied to 10 respondents, the majority of the farmers were averagely 66.7 years old. Seven were high school graduates and only three farmers were college graduates. The average number of family members who reside together was 2 but most households involved in farming are elderly couples that can receive some assistance from the children who live in the cities and return home on holidays like Golden Week. The type of farming work for households can be divided into

[1] The post-retirement farmer is defined as farm household members who mainly engage in a non-farming job and change to only a farming job after retiring from a non-farming job.

2 categories as follows: (1) part time farmers; that is, farmers who regularly do non-farm jobs but help farming on weekends (Saturday and Sunday). They do farming part time before retiring from their regular jobs; and then, after retiring they work as full time farmers. These farmers generate income from not only their pension but also their farming job. The share of pension amounts to more than 50% of total income. (2) Full time farmers; that is, farmers who work in farming job before and after 60 years as full time farmers. Of the 10 farmers, most have changed from part time farmers to full time farmers. They are post-retirement farmers at second period retirement age who have been working as farmers for around 6-7 years after retirement and will expect to do farming activities for around 10 years more. Only 3 farmers have always been full time farmers, and have farming experience of 45 years. They intend to continue farming for next 10-15 years. The motivation of this farmer type is to protect their land because they have no successor to continue farming. Moreover, most landholdings are small in size of 2.53 ha for rice paddies and of 2 ha for upland fields (Table 2). There are four types of agricultural cultivation; that is, rice-vegetable, rice-vegetable-flower, vegetable-flowers and vegetable that are operated by four, one, two and one farmers respectively. The fruits grown are persimmon, plum and lemon and the vegetables grown are tomato, Japanese radish, kidney bean and goya etc. Only two farmers grow flowers for sale such as pansy and lily. They grew rice once a year due to a very cold winter, and they worked 6.5 hours/day in planting period and 8 hours/day in harvesting period. They also cultivate crops in urban areas around houses, making vegetable plots and then bringing their small amount of products to sell through Japan Agricultural Cooperative (JA). As above mentioned, the farm size of rice paddy is small leading to be much less efficiency in agriculture. However, the older farmers have been conservative on rice cultivation leading to slow down in the number of farm households growing rice. They expand the area of their farm land through the use of rental lands.

Table 2 Farm size of landholding and cultivated area in Japan

Farm size (ha)	Landholding (No, %)		Cultivated Area (ha, %)			
	Paddy field	Upland field	Rice	Vegetable	Flower	Fruit
0.1-0.3	-	-	-	2 (20)	-	-
0.4-0.6	-	1(10)	-	1 (10)	-	-
0.6-0.9	-	2 (20)	1 (10)	2 (20)	1 (10)	1 (10)
1.0-3.0	4 (40)	4 (40)	4 (40)	3 (30)	1 (10)	1 (10)
3.0-6.0	3 (30)	3 (30)	2 (20)	-	2 (20)	1 (10)

Older farmers in agriculture in Thailand

For over 90% of farm households, farming is the main occupation. The remainders have non-farm jobs as main jobs. The average age of farmers is 63.5 years. 5.3% (8 households), four farmers previously worked in non-farm jobs as government workers and after retirement entered into farming. These farmers moved from part time farmers to full time farmers. Three farmers worked in factories and after reaching the age of 55 and over, changed to farming. Formerly, they helped farming activities such as rice harvesting. Just one farmer has had a small private business while doing a farming job until now. The motivation of continuing farming activities is being successors (42.8%), generating income (3.2%), occupying a farm land (38.2%), and no successor (15.8%). Regarding the size of landholding, most farmers have 1.0-2.99 ha and only five households have a bigger size of land. Just two households do not own land. Most farmers grow rice with less than 1.0 ha, while a small number grows either cassava or sugarcane in areas less than 1.0 ha and 1.0-2.99 ha respectively (Table 3). Although they do farming with small size lands, they can protect farm lands from other sectors same as Japan and also support farm activities especially rice cultivation, leading to be conservative rice cultivation farmers like Japan. With most of the farmers growing rice in a single crop, this research has focused on the number of working days and hours as shown in Table 4. It was found that they mostly used working days and hours in transplanting, applying fertilizer and harvesting. The main farm labor force is the farming couple but their children help transplanting and harvesting. Also, some households have hired labor and used machinery in transplanting and harvesting.

Table 3 Farm size of landholding and cultivated area in Thailand

Farm size (ha)	Landholding (No, %)	Cultivated Area (No, %)		
		Rice	Cassava	Sugarcane
<1.0	34 (22.4)	72 (47.3)	9 (5.9)	10 (6.6)
1.0-2.99	84 (55.3)	68 (44.7)	5 (3.3)	12 (7.9)
3.0-5.99	27 (17.8)	6 (3.9)	2 (1.3)	5 (3.3)
6.0-9.0	5 (3.3)	-	-	-

Table 4 Average number of working days and working hours for a single crop

Activities	Number (day)	Number (hour/day)
Soil preparation	3.89	1.61
Transplanting	5.31	5.56
Applying fertilizer	5.45	2.06
Weed control	3.93	1.83
Harvesting	6.43	5.61

Older farmers and food security for Japan and Thailand

The opinion of aging farmers in both countries regarding the food security issue was that food security is an issue caused by the reduction of farm labor force and the aging society. However, most believed that the shortage of farm labor has not actually given rise to a problem of food security as modern agriculture needs smaller labor force and the shortage of labor can be covered by the use of modern machinery. In addition, the impact of high oil prices has partly led to food insecurity because food prices are increasingly corresponding to the price of oil. This is also because of a rise in production costs, such as fertilizers. Another factor is the increasing demand due to the increase of population and income (Table 5). In the same table it was found that no significant difference in opinion of food security in agriculture could be detected between Japan and Thailand. As above mentioned, Thai farmers have recommended that the production pattern should be diversified by growing crops other than main crops such as perennials while Japanese farmers thought that they should change commercial production to sustainable production; that is, increasing crop diversification to increase self-reliance leading to be a source of food support for consumers.

Table 5 Opinion of food security in agriculture for Japan and Thailand

Items	Japan		Thailand		Test of Difference*
	Frequency	Percentage (%)	Frequency	Percentage (%)	
Increasing aging farmer	3	40	49	32.24	
Impact of high oil prices	1	10	27	17.76	2.047^{ns}
Shortage of farm labor	5	30	68	44.74	
Increasing demand	1	10	8	5.26	
Total	**10**	**100**	**152**	**100**	

**Difference was compared using chi-square test; ns = non-significant*

DISCUSSION

With an increasing trend of aging farming population, agriculture and rural development will be increasingly encouraged by older persons (Gustavo, 2008). Older farmers have expansive knowledge and experience of agricultural production that are conservative traditional agricultural practices and they can transfer their experience to young farmers in spite of that older farmers are less incentive for investment and innovation in agriculture (Stloukal, 2000) and are slower to adapt to the change in agriculture (Siamwalla, 2004). In other words, the aging of producers in the low capital-intensive agricultural sectors could imply a lowering of the productivity of labor (Philippe,

2011). However, the role of maintaining farm land can be entrusted to the aging famers with support from outside and use of mechanization. Thus, governments should improve the technological and crop seed development as well as machinery availability to increase production efficiency to offset production decreasing.

CONCLUSION

Population aging 65 and over has an upward trend in both counties. Older farmers in both countries have played a key role of farm land maintenance involving rice cultivation. In order to maintain food security both Thai and Japanese farmers should increase crop diversification other than main crops.

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Research article

Influences of Agricultural Irrigation on Regional Salinity Balance in Arid Areas of Northwestern China

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Abstract It is widely recognized that saline transfer and distribution are important considerations in arid areas, where salinization is prevalent, not only for sustainable agricultural production but also for regional environmental conservation. This study discusses the saline balance of the irrigation area in the Tarim River basin of northwestern China. Water quality was investigated at irrigation and drainage channels from 2007 to 2011. The regional water balance was calculated using the water supply and drainage volume data owned by the Xayar Water Management Office and its branches. Comparing the quality of irrigation and drainage water, the concentration of cations (except K^+) in drainage water was found to be 15 times more than that in irrigation water. Based on the estimation of water balance, it was confirmed that only approximately 5% of the irrigation water flowed out as drainage water. The remaining supplied water is used for evapotranspiration, and groundwater recharge was considered. In addition, the output load of K^+, Ca^{2+}, and Mg^{2+} was lower than the input load. However, the output load of Na^+ increased by approximately 20% of the input load. This indicates that continuous irrigation does not necessarily promote saline transfer and that salinity is retained in groundwater or soil in this region. Finally, because of the substantial exhaustion of Na^+, it is necessary to consider the influence of increased levels of Na^+ in downstream drainage areas.

Keywords salinization, saline movement, irrigation and drainage, water balance, water quality

INTRODUCTION

In arid areas where salinization is prevalent, an important question to consider is where the salinity moves. If saline simply moves downstream through drainage, then water containing saline nourishes irrigated areas and natural vegetation in the downstream areas. If saline does not move downstream through drainage, it may accumulate in the groundwater or soil and lead to problems in future groundwater use. Thus, it is widely recognized that saline transfer and distribution are important considerations in arid areas, where salinization is prevalent, not only for sustainable agricultural production but also for regional environmental conservation.

While many studies have described soil salinization and prevention of salinization in the field (Chen, 2010, Barrett-Lennard, 2002), research concerning saline movement and saline balance over

wide areas, particularly in arid areas such as the Tarim River basin, is lacking. In the Tarim River basin, soil salinization has occurred in approximately 80% of the irrigated area (Yamamoto et al., 2006). Consequently, it is necessary to examine saline movement and saline balance not only at the field level but also over wide areas in this region.

METHODOLOGY

The study was conducted at the Xayar County in Xinjiang, northwest China (Fig. 1). Xayar County is located in the Ugen River basin. Ugen River is a branch on the upper stream of the Tarim River. The county population is approximately 180,000 and its area is 31.97×10^3 km^2. The main local crop is cotton and other crops such as wheat and corn. The cultivated area is 0.632×10^3 km^2, where cotton plants cover approximately 50% of the total cultivated area. Irrigation relies mainly on surface water from the Ugen River and ground water is used mainly in cotton and fruit fields for drip irrigation. Annual rainfall is 47.3 mm, potential evapotranspiration is 2000.7 mm and the annual mean temperature is 10.7°C (maximum temperature, 41.6°C and minimum temperature, −28.7°C) (Xayar Government HP).

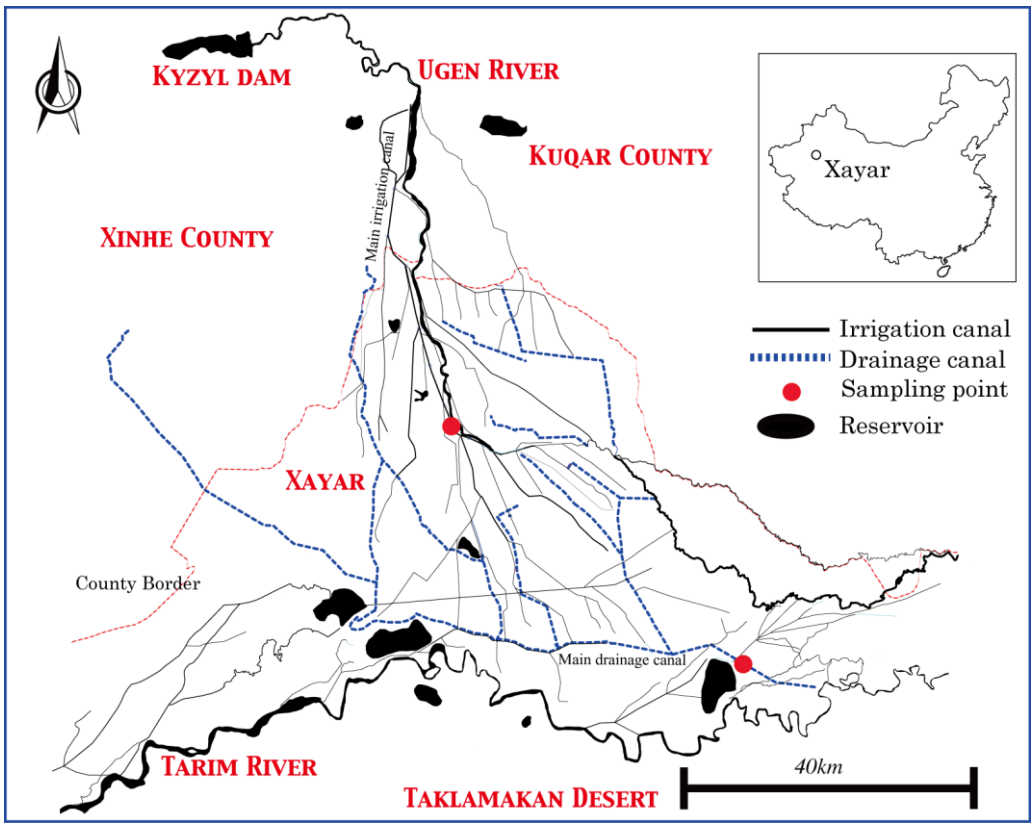

Fig. 1 Outline of Investigation Area

The regional water balance was calculated by using the 2007 - 2009 data of daily water supply and drainage discharge owned by the Xayar Water Management Office. Each discharge was calculated several times a day by flow measurement. Evapotranspiration data was derived from Ge Gao et al. (2007) because it was not available for this site. Water was collected at irrigation and drainage canals several times in 2007-2011 only during which water flowed, and then these samples were analyzed in the laboratory. Electric conductivity (EC) was measured by EC meter (HANNA Instruments) and sodium (Na^+), calcium (Ca^{2+}), potassium (K^+) and magnesium (Mg^{2+}) were analyzed by ion chromatography (SHIMADZU Corp).

RESULTS AND DISCUSSION

Discharge of irrigation and drainage and water balance

To estimate the water balance in Xayar County, the irrigation and drainage discharge data supplied by water management office were used. In addition, the drainage volume flowing through Xayar and Xinhe counties was estimated by multiplying the irrigation distribution rate by the total drainage volume. Irrigation water from Ugen River is distributed to these counties at a constant rate (Xayar, 32.5%; Xinhe, 28.0%; Kuqar, 39.5%) at Longkou headwork located at the upper point of these counties (Abdisalam Jalaldin, 2005) and the drainage discharge was assumed to depend on the irrigation requirement as rainfall runoff has little influence. To estimate evapotranspiration in Xayar County, we multiplied potential evapotranspiration by the constant 0.1. This constant is the ratio of annual actual evapotranspiration to annual potential evapotranspiration during 1971 - 2000 (Ge Gao et al., 2007). Fig. 2 shows the monthly change in irrigation and drainage discharge and Fig. 3 shows the annual water balance in 2007 - 2009.

The largest discharge of irrigation water occurs in March and in summer season because water demand rises during the sowing and growing periods. In addition, irrigation water is required in November for sowing wheat in autumn. The largest discharge of drainage occurs in March and April, decreasing in summer. Drainage discharge is believed to increase when shallow groundwater outflows by thawing of the frozen soil layer. In contrast, drainage discharge is believed to decrease when outflow from shallow groundwater is restricted by soil drying that is a result of increasing evapotranspiration potential in summer.

The water balance in 2007 and 2008 showed the same tendency. However, the supplied water volume decreased in 2009. This reduction is believed to have been caused by decreasing water intake from the river resulting from improved water-conserving irrigation techniques, such techniques being introduced widely to farmers at the beginning of 2007 (T. Yamamoto et al., 2010). Water balance data suggest that approximately 800-1000 mm y^{-1} of supplied water seeps into the ground. Water management office data suggest that water-conserving irrigation techniques have been implemented in 10% - 20% of the total cultivated area. The net water requirement of cotton is 540 mm y^{-1} in this area. If this volume is pumped up from groundwater in the water-conserving irrigation area, we can estimate that 5% - 13% of seepage water was utilized, which is equal to the reduction in water supplied during this period.

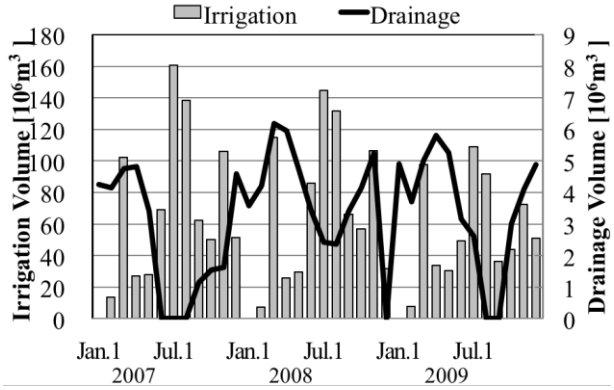

Fig. 2 Irrigation and drainage discharge (2007-2009)

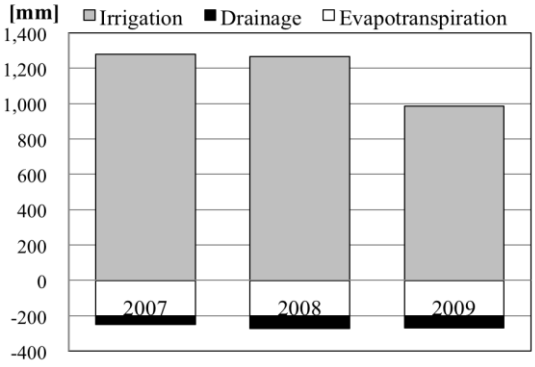

Fig. 3 Water balance (2007-2009)

Water quality of irrigation and drainage water

Table 1 shows water quality of irrigation and drainage water on each sampling day. Changes in EC values were small in irrigation water except for August 2007. Concentration of Na^+ varied considerably, but concentrations of other cations exhibited only small changes. In particular, Na^+ concentrations tended to decrease during summer and increase during winter. EC values of

drainage water were stably higher. Changes in cation concentrations in drainage water were lower according to the variation coefficient, but the concentration of each cation measured was higher than that in irrigation water. In addition, the seasonal changes in cation concentrations were not confirmed. When the average quality of irrigation and drainage water was compared, the concentrations of Ca^{2+} and Mg^{2+} in drainage water were found to be 15 times higher than those in irrigation water. Na^{+} concentration in drainage water was also 20 times higher than that in irrigation water. This indicates that the soil in this region is naturally saline or has turned saline because of irrigation with water that became concentrated with salts before running off. In contrast, K^{+} concentration in drainage water was only 4 times higher than that in irrigation water. This is likely because the concentration of K^{+} was lower than that of other cations, and K^{+} in supplied water is absorbed by plants more than other ions because K^{+} requirement for plants is higher.

Sodium adsorption rates (SAR) were measured based on the average concentrations. The SAR of irrigation water was 3.6 and that of drainage water was 19.8. These levels indicate that based on the standards of water quality for agriculture, the risk of soil salinization when irrigation water from the river is used is slight to moderate, but the risk is extremely severe when drainage water is used (Soil Survey Division Staff., 1993, R.S. Ayers & D.W. Westcot, 1994). However, in the lower basin where water shortage occurred, soil salinization might have been promoted because drainage water was used for irrigation.

Table 1 Water quality of irrigation and drainage water

	Irrigation water					Draingae water				
Sampling date	EC ($dS\ m^{-1}$)	Concetration ($mg\ L^{-1}$) Na^{+}	K^{+}	Mg^{2+}	Ca^{2+}	EC ($dS\ m^{-1}$)	Concetration ($mg\ L^{-1}$) Na^{+}	K^{+}	Mg^{2+}	Ca^{2+}
2007/6/6						15.4	1220.1	33.1	349.3	341.0
2007/8/10	0.1	49.3	2.0	ND	6.3	9.2	1271.1	35.0	301.7	264.6
2007/11/25	0.7	117.7	14.6	ND	28.4					
2007/11/26						11.5	1458.5	31.0	354.4	275.0
2008/3/29	0.7	44.8	8.6	28.4	28.0					
2008/3/31						10.0	ND	ND	ND	ND
2008/12/17	0.9	155.3	19.3	11.5	ND	9.5	937.2	80.2	448.2	239.5
2009/6/5						12.4	918.2	124.1	496.6	329.1
2009/8/9	0.6	19.3	7.6	33.8	5.7					
2009/8/10						9.2	1271.1	35.0	301.7	264.6
2010/3/12	0.7	25.0	17.9	33.5	18.8					
2010/3/14						13.7	ND	ND	ND	ND
2010/7/21						12.1	2110.7	22.1	ND	370.5
2010/7/26	0.4	14.5	ND	29.7	3.6					
2010/11/26	0.9	35.2	ND	9.2	55.9					
2010/11/22						11.1	1860.0	18.1	ND	ND
2011/7/27	0.6	171.6	17.3	13.0	16.6					
2011/7/29						18.0	2179.5	76.5	369.7	459.5
Average	0.6	70.3	12.5	22.7	20.4	12.3	1576.1	48.1	386.6	322.4
SD	0.2	61.0	6.5	11.0	17.3	2.6	528.3	37.2	71.9	70.2
Variation Coefficent	0.4	0.9	0.5	0.5	0.8	0.2	0.3	0.8	0.2	0.2

Saline movement and balance

The saline load balance in Xayar district area located in the Ugen River basin was calculated from the difference between input load and output load. Each load is calculated by multiplying the average concentration of irrigation and drainage water by monthly irrigation and drainage discharge. The average concentration was calculated from the values of Table 1. In our examination, it was assumed that input derives only from supplied water for irrigation and output was the outflow through the drainage canal.

Figure 4 shows the monthly change in saline balance. Input loads increased compared with output loads in summer and vice versa in winter. Even when drainage discharge was low, the output load was high because the concentration of drainage water was higher than that of supplied water. The change in saline balance was divided into outflow and retention types (Table 2). Na^+ was outflow type and other cations were retention type. As determined by three year averages, the output loads of K^+, Ca^{2+}, and Mg^{2+} decreased compared with the input loads; however, the output load of Na^+ increased by approximately 20% of the input load. Because the soil adsorptive property of Na^+ is lower than that of Ca^{2+} or Mg^{2+}; plants require less Na^+ compared with K^+; Na^+ poorly retained in this region was assumed to run off. In addition, each load balance tended to decrease. This characteristic of decrease is because the cations retained in this region gradually flow out to drainage canals and that supplied water decreases. In addition, Ca^{2+} and Mg^{2+} loads indicate that continuous irrigation does not necessarily promote saline transfer and that salinity is retained in groundwater or soil in this region. Moreover, it is necessary to consider how Na^+ outflow to downstream areas affects the lower basin and Tarim River at long term.

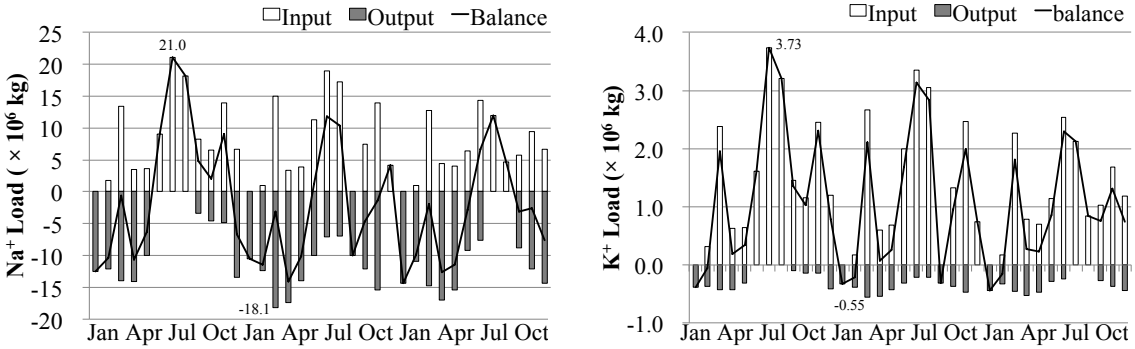

Fig. 4 Monthly change in saline load

Table 2 Saline load balance in 2007-2009

	Na^+			K^+			Mg^{2+}			Ca^{2+}		
	Input	Output	Balance	Input	Output	Balance	Input	Output	Balance	Input	Output	Balance
2007	106	89	17	19	3	16	34	22	12	31	18	13
2008	96	134	-38	17	4	13	31	33	-2	28	27	1
2009	82	125	-43	14	4	11	26	31	-4	24	25	-2
Average	95	116	-21	17	4	13	31	28	2	27	24	4

(Balance = Input - Output, Unit; $x10^6$ kg)

CONCLUSION

We analyzed discharge water and the quality of irrigation and drainage water and discussed water and saline balance in the Tarim River basin in Xayar County. We found that the saline concentration of drainage water was considerably higher than that of irrigation water. Water balance data showed that approximately 80% of supplied water was seeped into groundwater or soil. In addition, Na^+ runoff from this area was greater than that of other cations and the exhaustion of other cations was smaller than that of Na^+ because Na^+ was not efficiently consumed or retained. Considering the high exhaustion rates of Na^+, it is necessary to consider the influence on downstream areas when developing irrigation strategies in future.

ACKNOWLEDGEMENTS

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Research article

Community Participation in Saline Soil Restoration Using a Diverse Tree Planting Technique: A Case Study of Nongsim Sub-district, Borabue, Mahasarakam, Thailand

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Abstract: This research aims to restore saline soil areas using a diverse tree planting technique: a case study of Nongsim sub-district, Borabue, Mahasarakam, Thailand. The study focuses on community participation aspects in the restoration attempt, including community perspectives toward the research project, participation motivations and community's use of saline soil areas. Diverse trees both native and introduced species were planted in an approximate 1.6 ha experimental plot adjacent to a village reservoir in 2008. Community surveys were conducted on a yearly basis since 2009 to examine villager perspectives toward the project, together with workshops to inform the community about research findings and get their feedbacks. In the 4-year period, 23 tree species, including eight fast-growing natives, four fast-growing introduced and 11 coastal habitat species, over 2,000 individuals were planted, but 20 species survived. Considering survival and growth rates, potential species for saline soil restoration are *Combretum quadrangulare* Kurz., *Casuarina equisetifolia* J. R.&G. Forst., *Pandanus odoratissimus* L.f. and *Albizia lebbeck* (L.) Benth. Community surveys, including group interviews of 11 village leaders and questionnaires of over 350 villagers from all villages in Nongsim sub-district, reveal that the community strongly agreed with the research project because they wanted crop yield improvement by restoring saline soil. Planting trees could also help increase community green areas. The majority of villagers were willing to plant trees in their farmlands, but limited land and amounts of seedlings hinder them from doing so. Furthermore, the majority of farmers (94.7%, n=76) encountering saline soil problems, used their farmland especially for rice cultivation, despite low yields because of limited amount of land. The economic value estimated in 2010 from use of saline soil paddies for rice growing is 45,577.12 Baht/household/year (n = 66) or 4,245.22 Baht/Rai (1 ha = 6.25 Rai).

Keywords community participation, saline soil, restoration, diverse tree planting technique, Borabue

INTRODUCTION

The United Nations Environment Program estimates that approximately 20% of agricultural land and 50% of cropland in the world is salt stressed (Flowers and Yeo, 1995). Salt-affected soils occur in more than 100 countries of the world with a variety of extents, nature and properties (Rengasamy, 2005). Worldwide, they cover a total area of about one billion hectares (Toth et al., 2008). Table 1 summarizes the potential risks of salinisation in all over the world. Salts, mostly NaCl accumulate at the soil surface and a saline crust is formed during the dry season through capillary action (Quantin et al., 2008). The excessive salt amounts adversely affect soil physical and chemical properties, as well as microbiological processes (Lakhdar et al., 2009). Subsequently, salinity and sodicity affect plant growth and crop yields because of osmotic effects and sodium toxicity (Marschner, 1995).

Table 1 Percentage of salt-affected soils in different countries worldwide

Country	Salt-affected area	References
Australia	30% total area	Rengasamy (2005)
Egypt	9.1% total area	Mashali et al. (2005)
Hungary	10% total area	Varallyay (1992)
Iran	28% irrigated land	Khel (2006)
Kenya	14.4% total area	Mashali et al. (2005)
Nigeria	20% irrigated land	FAO (2000)
Russia	21% agricultural land	Dobrovol'skii and Stasyuk (2008)
Syria	40% irrigated land	FAO (2000)
Thailand	30% total area	Yuvaniyama (2001)
Tunisia	11.6% total area	Mashali et al. (2005)
USA	25–30% irrigated land	Wichelns (1999)

Source: Lakhdar et al., 2009

Salt affected soil is a serious problem in Thailand, especially in the Northeast Plateau where salt bearing rocks are common (Mahasarakam formation). Yuvaniyama (2003) reported that saline soils cover areas of approximately 38.7 million Rai (6.25 Rai = 1 ha) of the region's land area, of which 1.5 million Rai was classified severely saline soil, while 19.4 million Rai was considered areas of potentially affected saline soil. Usually saline soils appear in lowlands or discharge areas in which lands are suitable for rice cultivation. Arunin (1987) stated that the reason for the spread of salinisation is primarily the removal of forest cover leading to increased groundwater recharge. This factor has been exacerbated by anthropogenic activities including dam construction, low technology salt extraction, groundwater use and irrigation.

Soil salinity partly contributes to a major agricultural, economic and social problem in the Northeast. It drastically affects soil fertility and rice productivity (Quantin et al., 2008), which in turn affects farmer's income since the majority of northeasters are rice farmers. Rice yields and economic returns are about one third when grown in saline soil compared with nearby unaffected areas (Hall et al., 2004). Furthermore, the Research Institute for Thailand Development (2007) estimated the average economic costs of saline soils in 2,518 million Baht each year. Saline soil restoration is therefore very crucial for rice productivity improvement, which means possible increase of farmer's income.

Many different methods are used on reclamation, as physical amelioration (deep plowing, sub soiling, sanding, and profile inversion), chemical amelioration (amending of soil with various reagents: gypsum, calcium chloride, and limestone), and electro-reclamation (treatment with electric current) (Raychev et al., 2001). Alternatively, growing salt tolerant species represents the only cost effective means of revegetation although this means a significantly different species mix to that which existed before disturbance (Ho et al., 1999; Abdelly et al., 2006). Although many of these salt tolerant species can survive in saline soils and transpire sufficient water to lower water tables (Barrett-Lennard, 2002), they are not often used by farmers. Therefore the farmers are discouraged from participating in revegetation activities, which require long-term care. Many revegetation areas are abandoned after the restoration project is over while saline soils remain unsuccessfully treated. This research aims to restore saline soil areas using a diverse tree planting technique: a case study of Nongsim sub-district, Borabue, Mahasarakam, Thailand. The study focuses on community participation aspects in the restoration attempt, including community perspectives toward the research project, participation motivations, and community's use of saline soil areas.

METHODOLOGY

Diverse tree species planting

This research project began in 2008 by planting diverse tree species in the approximate 1.6 ha experimental plot in a discharge salt affected soil area, adjacent to Akkasatrsuntorn Reservoir,

Nong Sim Sub-district, Borabue District, Mahasarakham Province, Thailand. The land is state-owned under the Royal Irrigation Department authority, but villagers are allowed to access the land for grazing and fishing at the Reservoir. A workshop was conducted prior to the planting in which village leaders, Nongsim Sub district Administrative Organization (SAO) officials, governmental authority representatives and villagers participated in to discuss on tree species selection and possible participation in the research project. Two main criteria for the selection are survival potential and possible use of trees by the locals. Diverse trees both native and introduced species were planted in the late rainy season of 2008 with a planting space of 2x2 m. New trees were planted the following years to replace dead trees and to maintain the area with tree coverage. Tree monitoring, consisting of estimates of survival Eq. (1) and growth Eq. (2) rates, was done twice a year in March and September from 2008 to 2011.

$$\text{Survival rate of a species} = \frac{N_t \times 100}{N_0} \quad (1)$$

Where N_t = number of individuals of a species counted from the current monitoring period

N_0 = number of individuals of a species counted from the previous monitoring period

$$\text{Growth rate of a species} = \frac{[H_t - H_0] \times 100}{H_0} \quad (2)$$

Where H_t = average height of a species measured from the current monitoring period

H_0 = average height of a species measured from the previous monitoring period

Community participation survey

Community participation is one of the keys to effective natural resource management (Pagdee et al., 2006). The study aims to examine community perspectives toward the research project, participation motivations, and community's use of saline soil areas. Community surveys were conducted on a yearly basis from 2009, including village leader interviews and semi-questionnaire surveys. At the end of each research fiscal year (in September) a workshop was organized at Nongsim SAO office to inform the community about research findings and obtain their feedbacks. Data analysis is descriptive-based, including evaluation of community participation and economic valuation of saline soil areas used by the locals.

RESULTS AND DISCUSSION

During four years (2008-2011), 23 tree species, including eight fast-growing natives, four fast-growing introduced, and 11 coastal habitat species, over 2,000 individuals were planted and 20 species survived with an overall survival rate of 82.27% (Table2). Considering survival and growth rates, potential species for saline soil restoration are *Combretum quadrangulare* Kurz., *Casuarina equisetifolia* J. R.&G. Forst., *Pandanus odoratissimus* L.f., and *Albizia lebbeck* (L.) Benth. In addition to high survival and growth rates, villagers can use these trees for firewood, fodder and fiber. Furthermore, these planted trees help revegetate the area in which about 30% was barren land and the rest was only covered with grasses and forbs when the planting was started in 2008. The survey conducted in March 2011 showed that 100% of the experimental plot is now vegetated and the maximum tree height reached 3m (Fig. 1).

The community surveys (2009-2011) involved group interviews of all 11 village leaders and questionnaires of over 350 household representatives from all villages in Nongsim sub-district. The questionnaire surveys in 2008 and 2010 revealed that the majority of participants (55.5%, n=200 in 2008 and 50.3%, n=171 in 2010) did not recognize the project, and even those who did so did not clearly understand the project's main objectives. The number had decreased because of more persistent attempts to inform villagers about the project through village leaders, Nongsim SAO, village broadcast and project post. Nevertheless, the community strongly agreed with the research

project because they wanted crop yield improvement by restoring saline soil. Planting trees could also help increase community green areas. Table 3 presents villager perspectives toward the research project. Providing sufficient tree seedlings and distributing them throughout a group of villagers scored the highest number of "disagreement". Villagers expressed that they were not informed of when and where tree seedlings would be distributed. As a result, only a small group of villagers, especially those who lived in a coordinating village received seedlings, while villagers in farther away villages did not. Furthermore, the majority of villagers were willing to plant trees in their farmlands for saline soil restoration, but limited land and amounts of seedlings hinder them from doing so.

Table 2 Tree species, number of individuals survived and average tree height

No.	Species	Number of individuals survived (%)	Average height in cm (% change)
1	*Acacia auriculiformis* Cunn.	77 (100.00)	125.06 (145.22)
2	*Acacia mangium* Willd.	123 (87.86)	116.72 (25.50)
3	*Acacia tomentosa* Willd.	1 (1.28)	0.00 (NA)
4	*Calphyllum inophyllum* L.	17 (36.96)	15.02 (0.14)
5	*Cassia siamea* Lam.	169 (64.26)	46.31 (78.11)
6	*Sesbania grandiflora* Desv	22 (95.65)	5.68(-18.93)
7	*Barringtonia asiatica* (Linn.) Kurz	1 (14.29)	1.50 (50.00)
8	*Cerbera odollam* Gaertn.	6 (60.00)	61.08 (1.79)
9	*Pandanus odoratissimus* L.f.	15 (100.00)	87.21 (40.66)
10	*Pterocarpus macrocarpus* Kurz	10 (100.00)	66.45 (44.47)
11	*Hibiscus tiliaceus* L.	11 (100.00)	183.17 (46.53)
12	*Albizia lebbeck* (L.) Benth.	152 (100.00)	51.13 (21.74)
13	*Thespesia populnea* (L.) Sol. ex Correa	8 (100.00)	61.93 (-8.92)
14	*Tamarindus indica* Linn.	26 (96.30)	8.04(-10.62)
15	*Pithecellobium dulce* (Roxb.) Benth.	188 (78.99)	72.63 (23.10)
16	*Casuarina equisetifolia* J.R. & G. Forst.	50 (47.62)	192.51 (27.49)
17	*Casuarina junghuhniana* Mig.	0 (NA)	0.00 (NA)
18	*Combretum quadrangulare* Kurz.	475 (99.16)	42.39 (11.56)
19	*Azadirachta indica* Juss. var. *siamensis* Valeton	89 (91.75)	9.11 (13.83)
20	*Melaleuca cajuputi* Powell	5 (NA)	105.33 (NA)
21	*Heritiera littoralis* Ait.	2 (100.00)	13.00(-59.38)
22	*Derris indica* (Lamk.) Bennet	10 (83.33)	38.72 (-9.95)
23	*Simarouba glauca* DC	0 (NA)	0.00 (NA)
Total	20 species survived	1,457 trees survived	

Note: data recorded on March 27, 2011, NA = not applicable for calculation

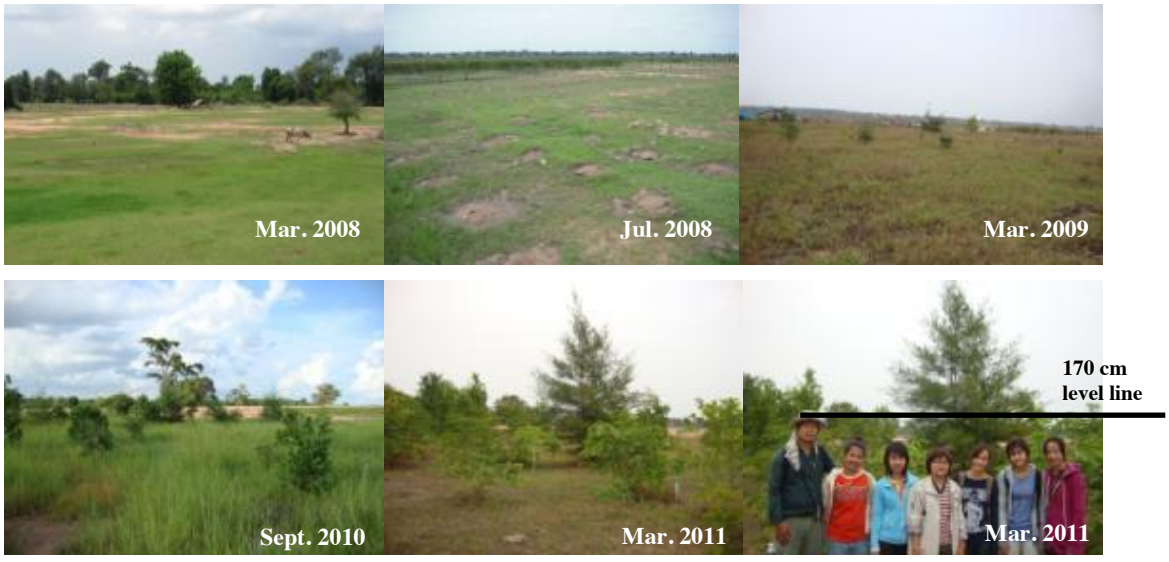

Fig. 1 Change of vegetation cover in the experimental plot (2008-2011)

Table 3 Community perspectives toward the saline soil restoration project (n=171 in 2010)

Item	Percent of respondents			
	(3)	(2)	(1)	(0)
1) Effectively inform villagers about the project	51.2	39.5	8.1	1.2
2) Clear research objectives and activities	36.0	38.4	20.9	4.7
3) Providing equal opportunity for villagers to participate in the tree selection meeting	44.2	27.9	20.9	7.0
4) Tree species planted can be used by villagers	32.6	53.5	12.8	1.2
5) The project encouraged the community to start similar saline soil restoration activities in other areas in the sub district	32.6	52.3	11.6	3.5
6) Trees planted could help reduce soil salinity in the community	43.0	43.0	11.6	2.3
7) Community participation in tree planting and monitoring was one of the keys to project success	44.2	44.2	11.6	0.0
8) Providing enough tree seedlings and then distributing them to a large number of villagers	55.3	20.0	14.1	10.6
9) Villagers gained knowledge about soil salinity	36.0	53.5	9.3	1.2

Note: (0) = disagree, (1) = slightly agree, (2) = moderately agree, (3) = strongly agree

In addition, the workshops got positive feedbacks from the community. Villagers expressed a better understanding about saline soils and reclamation techniques. Moreover, they could exchange ideas and experiences with researchers and villagers from other villages, which helped broaden their visions. Some villagers expressed their interests in participating in salt-affected soil restoration. They would start planting trees in their farmland, but needed supports from governmental agencies, especially in providing tree seedlings. Finally, the majority of villagers (94.7%, n=76) encountering saline soil problems used their farmland, especially for rice cultivation despite low yields because of limited amount of land. The economic value estimated in 2010 from use of saline soil paddies for rice growing is 45,577.12 Baht/household/year (n = 66) or 4,245.22 Baht/Rai (1ha = 6.25 Rai).

CONCLUSIONS

Soil salinity is one of the main land resource problems in the Northeast of Thailand. This research illustrates that planting diverse tree species can help to revegetate areas affected by salts. The selection of tree species needs to consider not only survival potential but also possible use by the locals. The latter will encourage villagers to participate in restoration activities since they can perceive some benefits gained from doing so and not the burden instead. Finally, informing the community on a regular basis about the restoration project, including research findings will help villagers to better understand about soil salinity as well as making them feel being part of the study. As a result, a long-term care and commitment can be possible when local communities involve in the restoration.

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Research article

Soil Carbon Dynamics during the Amelioration of Salt-Affected Areas in Northeast Thailand

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Abstract An understanding of the effect of salinization on soil carbon (C) sequestration is important for environmental management. This study aimed to investigate the effect of salinity on soil organic carbon dynamics in salt-affected areas under a tree plantation, at Amphur Borabue, Mahasarakam province, Northeast Thailand. The study area has been established with tree plantation for three years and was divided into 3 zones based on the plant community found in each zone, correlated with the flooding situation and soil salinity. Soil samples were taken from three different zones and a fallow soil (control) at the same depth (0-20 cm) with three replications beginning from the rainy season of 2010 to the summer of 2011. The results from a three year old tree plantation showed decreasing EC_e and increasing soil organic carbon when compared with the fallow soil. Moreover, microbial activities were greater under the tree plantation soils when compared to the fallow soil. It could be concluded that soil organic carbon and biological properties were improved after establishment of a tree plantation in salt-affected soils. Therefore, it indicates that tree plantations are an effective strategy for carbon sequestration to reduce the buildup of carbon dioxide in the atmosphere.

Keywords salinity, carbon sequestration, microbial activity

INTRODUCTION

An understanding of the effect of salinization on soil carbon (C) sequestration is important for environmental management. Soils in Northeast Thailand are salt-affected due to the presence of salt bearing rocks (Land Development Department, 1991), particularly in Nakhon Ratchasima, Khon Kaen, Roi Et and Mahasarakham provinces (Department of Mineral Resources, 1982). Because of their age and the extent of weathering that has taken place in the past, soils in those areas are also relatively infertile. Levels of soil fertility are often strongly influenced by soil organic carbon (SOC), with low organic matter contents due to low biomass inputs and rapid turnover.

Since the amount of C present in the soil is dependent on C inputs and losses, increasing salinity levels have the potential to decrease C inputs into the soil through their effects on vegetation and impact on C dynamics. Not only high salinity directly impacts upon plant vigour through changes in osmotic potential, ion toxicities and ion deficiencies, but indirect effects on vegetation can result from altered soil conditions such as increased dispersion and decreased permeability. Changes in salinity affect soil physical (Boivin et al., 2004) and chemical properties (Sumner, 2000), which subsequently alter nutrient cycles, aggregation and biotic activity

(Zahran,97; Sardinha et al., 2003; Rietz and Haynes, 2003) and also influence on plant growth and yield (Marschner, 1995). Among them, changes in mineralization of C and N with increasing salinity have been observed (Nelson et al., 1996; Pathak and Rao, 1998). Despite the large area affected by salinity, both in Thailand and globally, data on the changes in soil C stocks in these degraded environments is scarce.

Carbon sequestration refers to the storage of atmospheric CO_2 in the plant biomass and soils of a particular ecosystem during a period of time. Tree-based plantation is a land management option that has C sequestration potential for two reasons. First, tree biomass contains more C than annual crops, leading to more C storage in tree plantation systems than conventional agricultural systems (Sharrow and Ismail, 2004; Peichl et al., 2006). Second, tree plantation systems are expected to have more SOC due to the greater annual C input from leaf litter, tree root turnover and tree root exudates, compared to agricultural crops. Organic residues from trees are lignin-rich and contain other resistant compounds (e.g., tannins) that are slowly decomposed and thus stabilized in the SOC pool (Montagnini and Nair, 2004). Garg (1998) also reported that salt-affected soils may be reclaimed by growing salt-tolerant tree species, which improve the physical and chemical properties as well as biological activity in the soil. Therefore, ecological management utilizing tree plantations in salt-affected areas has the potential to alleviate salinity stress and increase soil organic carbon. The objective of this study was to investigate the effect of salinity on soil organic carbon dynamics under tree plantations in salt-affected areas of Northeast Thailand.

MATERIALS AND METHODS

Study area

This study was carried out at Ak-Kasatsuntorn water reservoir, Tambon Borabue, Mahasarakam Province, Thailand at latitude of 16° 01' N and longitude of 103° 05' E, and at an elevation of 178 m from mean sea level. The study site has been established for three years with a tree plantation (2710 plants of 17 species). Woody plants such as common ironwood (*Casuarina equisetifalia* J.R. & C. Forst.) and fruit plants such as manila tamarind (*Pithecolobium dulce*) are growing in a salt-affected area with a covering of native grasses and weeds, i.e., torpedograss (*Panicum repens* L.). The study area was divided into 3 zones based on the plant type located in each area where they were correlated with the flooding situation and soil salinity. Zone 1 is more prone to flooding situation and high salinity, followed by Zone 2 and Zone 3.

Soil sampling and analysis

Soil samples were taken from three randomly selected locations at each zone and from a fallow soil near the experimental site (control) at a depth of 0–20 cm beginning from the rainy season of 2010 to the summer of 2011. Samples were analyzed to determine soil chemical and microbial properties in the laboratory at the Land Resources and Environment section, Faculty of Agriculture, Khon Kaen University. Electrical conductivity in saturated paste extracts (EC_e) was measured following the method described by the United States Department of Agriculture (USDA, 1954). Total soil organic carbon (SOC) was determined by the method of Walkley and Black.

Microbial biomass C and N were determined in field moist subsamples immediately after sampling by the chloroform fumigation extraction method. For microbial biomass C (MBC), 20 g of fumigated and unfumigated soil were extracted with 100 ml of 0.5 M K_2SO_4. MBC in the extracts was determined after oxidation with $K_2Cr_2O_7$. For microbial biomass N (MBN), 20 g of soil was extracted with 100 ml of 1 M KCl. Extracts were taken from non-fumigated samples immediately after sampling. MBN was determined by the ninhydrin-reactive N method (Amato and Ladd, 1988). MBC and MBN were calculated as the difference between fumigated and unfumigated values, using k_{EC} and k_{EN} factors of 0.33 (Sparling and West, 1988) and 3.1 (Amato and Ladd, 1988) to convert extracted organic C and N to microbial C and N, respectively. Microbial activity was studied by basal soil respiration using the titrimetric method (Zuberer, 1991). This method was based on the determination of CO_2 evolved from incubated soils. Field moist soil

was placed in an airtight jar containing a vial with 15 ml of 1.0 M NaOH and incubated at 28°C. After one day of incubation, the NaOH vital was removed from the jar, 5 ml of excess 0.5 M $BaCl_2$ and 2-3 drops of phenolphthalein added to precipitate carbonate out from the NaOH solution as insoluble barium carbonate, and finally the excess NaOH was titrated with 0.5 M HCl. Soil respiration, i.e., evolved CO_2-C, was computed according to the Eq. (1) described by Anderson (1982).

$$CO_2\text{-C (mg)} = (B\text{-}V)\ NE \quad (1)$$

where B is the volume (ml) of acid (HCl) used to titrate the alkali (NaOH) of a blank solution (not incubated with soil), V is the volume (ml) of acid used to titrate the alkali solution incubated with the soil sample, N is the normality of acid (HCl), and E is the equivalent weight of CO_2-C. The metabolic quotient qCO_2 (Anderson and Domsch, 1986) of each sampling period was calculated as in Eq. (2).

$$qCO_2 = CO_2\text{-C} / MBC \quad (2)$$

where CO_2-C (mg kg^{-1} soil) is soil respiration and MBC (mg kg^{-1} soil) is microbial biomass C.

Statistical analysis: The data analysis was done using Statistix 8.0 (Analytical Software, 2003) to compare each zone at 5% probability level by using least significant different (LSD) method.

RESULTS AND DISCUSSION

The results from a three year old tree plantation with cover of native grasses showed significant effects on soil properties of this salt-affected soil. Soil texture of study area was sandy soil. There were significant differences in EC_e among the zones in all seasons (Table 1). The fallow soil (control) and zone 1 were saline soils (greater than 4 dS m^{-1}) while the others were non-saline (less than 4 dS m^{-1}), according to the classification of the USDA (1954). In the rainy season, the average EC_e was 9.02 dS m^{-1} and then decreased during the winter season (6.06 dS m^{-1}) and peaked in the summer season (12.22 dS m^{-1}), presumably due to salts in the groundwater moving up in the soil profile, accumulating on the soil surface, and consequently increasing the salinity in the summer season (Topark-Ngarm et al., 1990).

Table 1 Electrical conductivity (EC_e) and total soil organic carbon (SOC) in salt-affected soils after three years plantation

	EC_e (dS m^{-1})			SOC (g kg^{-1})		
	Rainy	Winter	Summer	Rainy	Winter	Summer
Control	17.83 a	14.20 a	26.87 a	1.80 b	2.80 c	1.71 c
Zone 1	15.54 a	9.41 b	17.39 b	3.51 ab	4.04 b	2.10 c
Zone 2	1.25 b	0.34 c	2.83 c	4.90 a	5.30 a	4.21 b
Zone 3	1.45 b	0.28 c	1.80 c	4.97 a	5.50 a	5.27 a
Mean	9.02	6.06	12.22	3.79	4.41	3.32
F-test	*	**	**	*	**	**
CV (%)	17	27	14	24	9	7

*Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, ** significantly different at P≤0.01, * significantly different at P≤0.05*

Total soil organic carbon was significantly higher in the tree plantation zones than in the fallow soil (control) in all seasons, with the highest value being in zone 3 (Table 1). It might be due to the accumulation of humus from decomposition of leaf litter and root decay, which increased soil organic C. The results confirm the findings of Mishra et al. (2004). SOC contents of all zones were higher in the winter season, whereas values for the rainy and summer seasons were lower. It could be explained that the leftover leaf and root masses might have contributed to the increase OC content during the winter season.

The activity of MBC was greatly influenced by salinity (Table 2). It was significantly higher in the zone 2 and 3 when compared to the control in all seasons. It was not different between the zone 1 and control in the summer season, indicating that the zone 1 was still affected by salinity. In the rainy and winter seasons, there was significant difference between the zone 1 and control, probably due to high soil organic carbon in the zone 1 (Table 1). Among seasons, the highest average MBC was recorded in the rainy season. In contrast, the lowest was in summer when salinity was the highest, probably due to capillary rise of salty groundwater associated with evaporation (Topark-Ngarm et al., 1990). Soil salinity can decrease the microbial activity during summer season (Rietz and Haynes, 2003), and it is probably one of the environmental stresses for microbial growth and proliferation in soil. In this study, the values of MBC were higher in soils with higher SOC contents, as a similar result of Sparling, 1997. The values of MBN showed a similar pattern to those of MBC (Table 2). It was lowest in soil with highest EC_e.

Table 2 Soil microbial biomass carbon (C) and nitrogen (N) in salt-affected soils after three years plantation

Location	Microbial biomass C (mg kg^{-1})			Microbial biomass N (mg kg^{-1})		
	Rainy	Winter	Summer	Rainy	Winter	Summer
Control	99.4 c	60.1 c	43.8 c	15.6 b	8.1 c	7.3 c
Zone 1	164.4 b	135.7 b	45.3 c	17.6 b	11.4 c	9.0 c
Zone 2	176.0 b	175.9 ab	151.5 b	28.6 a	22.6 b	18.4 b
Zone 3	228.5 a	202.1 a	183.9 a	35.9 a	28.5 a	23.9 a
Mean	168.2	143.5	106.1	24.4	17.6	14.7
F-test	*	**	**	**	**	**
CV (%)	18	22	11	21	13	11

*Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, ** significantly different at P≤0.01, * significantly different at P≤0.05*

Soil respiration, as a good index of the activity of microorganisms, was consistently lower in the control when compared to the tree plantation zones in all seasons (Table 3). It was highest in the zone 3 with highest SOC content that supports more CO_2 respiration. Variability in soil respiration mainly depends on weather variables (Kucera and Kirkham, 1971) and soil moisture (Gupta and Singh, 1981), along with the salt content of salt-affected soils (Garcia and Hernandez, 1996).

Table 3 Soil microbial basal respiration and metabolic quotient in salt-affected soils after three years plantation

Location	Soil microbial basal respiration (mg CO_2-C kg^{-1} day^{-1})			Metabolic quotient (qCO_2) (μg CO_2-C mg^{-1} MBC h^{-1})		
	Rainy	Winter	Summer	Rainy	Winter	Summer
Control	18.7 b	9.5 b	4.1 b	8.0 a	7.1 a	3.9 c
Zone 1	22.6 a	10.6 a	5.0 b	5.8 b	3.3 b	3.1 c
Zone 2	22.7 a	12.7 a	10.1 a	5.5 b	3.0 b	2.8 b
Zone 3	23.1 a	17.6 a	11.6 a	4.2 b	3.6 b	2.6 a
Mean	21.8	12.6	7.7	5.9	4.3	3.1
F-test	*	*	**	*	*	*
CV (%)	6	19	11	16	28	14

*Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, ** significantly different at P≤0.01, * significantly different at P≤0.05*

The metabolic quotient (qCO_2) was higher in the control when compared to the tree plantation zones in all seasons. It was probably as a result of stress by salinity on soil microflora (Anderson and Domsch, 1993; Rasul et al., 2006), whereas it tended to lower in the tree plantation zones. A low metabolic quotient implies that the microbial populations were energetically efficient, i.e., allocating proportionally more carbon to growth (biosynthesis) than to maintenance (Zak et al.,

1994). It was highest in the most saline soils, which may indicate low substrate quality (Smith, 1993) and low efficiency of organism functioning (Anderson and Domsch, 1990).

There were negative correlations between EC_e and SOC (r= -0.90, P≤0.01, n=36), between EC_e and MBC (r= -0.78, P≤0.01, n=36), between EC_e and MBN (r= -0.77, P≤0.01, n=36), between EC_e and soil respiration (r= -0.42, P≤0.01, n=36). These relationships revealed the detrimental effects that soil salinity had on the soil microbial activity. There was also a positive correlation between MBC and SOC (r= 0.83, P≤0.01, n=36), possibly because MBC is a part of SOC (Sparling, 1997). According to Rao and Pathak (1996), carbon is an important factor influencing microbial activity in salt-affected soils. Therefore, increased soil microbial activity might be due to the ameliorative effects of trees and consequently organic matter inputs.

CONCLUSION

The amelioration of salt-affected soil grown with tree species showed decreasing of EC_e and increasing of soil organic carbon. In addition, there were greater microbial activities in salt-affected soil under tree plantations. It could be concluded that soil chemical and biological properties were improved after establishment of a tree plantation in salt-affected soil. Therefore, it indicates that tree plantations are one of the most effective strategies for carbon sequestration to reduce the buildup of carbon dioxide in the atmosphere.

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Research article

Short and Long Term Fate of Environmental Pollutants and Their Management

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Abstract There has been an increasing demand of chemical substances during this and the last century. The use of chemicals for a long time has been identified as a negative impact on the environment since it became apparent that residues could be transferred through the food chain; remain in soil or sediment as intractable substances. Chlorinated pesticides stand as a classic case of intractable substances and their residues remain dispersed throughout the world. Even though banned, their use continued because of their effectiveness as insecticides and availability. The effective use of DDT (dichlorodiphenyltrichloroethane) for control against malaria was recognized following its removal but was reinstated for controlled situations. Arsenic is another classic case because its residues from the application of its compounds as insecticides for cattle dips remain as buried residues that are intractable. The soil from such repositories requires remediation. The recognition of problems associated with the lifetime of long persistence substances led to the need to use low persistent pesticides for insect control. The impact of increasing use of pesticides and herbicides is now offset by available data which shows that for many compounds, residues are undetectable in soil and groundwater. The USGS found no significant build-up of low persistence pesticides in groundwater over a 15 years period. Long-persistence or intractable compounds require specific techniques of soil remediation to deal with their effects on plants and animals. Examples of substances that may require soil remediation are arsenic, dioxins and DDT. A classic case of dioxin in soil was spotted at Bien Hoa, Vietnam, where 1 ppm TCDD (2,3,7,8-Tetrachlorodibenzo-*p*-dioxin) was found in soil. A remediation plan was put in place and the TCDD residues were excavated and disposed in a repository. While exceptions occur, it is important to recognise that degradable chemicals should be used wherever possible in order to avoid future remediation problems.

Keywords: pesticides, fate, long and short persistence, soil remediation

INTRODUCTION

The use of chemicals by mankind has become a necessary and inseparable activity for the maintenance of livelihood, industrial, agricultural and recreational activities. Such use has led to innumerable cases of contamination and transfers through the food chain damaging ecology and poisoning people as occurred with methyl mercury at Minamata, Japan. The use of chemicals with long persistence in the environment has been identified as a negative feature since it became apparent that residues could be transferred through the food chain; remain in soil or sediment as intractable substances. Chlorinated pesticides stand as a classic case of intractable substances as their residues remain dispersed throughout the world. Even though banned, their use continued because of their effectiveness as insecticides and availability. The use of DDT for control against malaria was recognised following its removal but was reinstated for vector control and remained in use under limited and controlled situations.

The recognition of problems associated with the lifetime of long persistence substances led to the need to use low persistent pesticides for insect control. Although firmly in place, the general theory is that all pesticides, including those having low persistence, are bad because of the

reputation of previously-used compounds, e.g. DDT (dichlorodiphenyltrichloroethane), dieldrin, chlordane, etc. The impact following the increasing use of pesticides and herbicides is now offset by available data which shows that residues are undetectable in soil and groundwater for many compounds in use. Exceptions are compounds like endosulfan which is essentially a chlorinated compound and is often found as a residue in sediment (Boonthai-Iwai, 2007). The USGS (Gilliam et al. 2006) found no significant build-up of low persistence pesticides in groundwater over a 15 years period. However, organochlorine pesticide compounds that were found in stream bed sediments and fish tissue were no longer in use by 1990. Only dachtal, endosulfan, lindane, methoxychlor and permethrin were used during the study period (Gilliam et al. 2006).

Long persistence or intractable compounds require specific techniques of soil remediation to deal with their effects on plants and animals. In-situ treatments are preferred for their removal from soil. Management practices that control erosion of soil may also help to reduce transport of pesticides and their degradates to streams. However, in some cases, it may be necessary to remove soil and treat it elsewhere to remove contaminants. Examples of substances that may require soil remediation are arsenic, dioxins and DDT. While exceptions occur, it is important to recognise that degradable chemicals should be used wherever possible in order to avoid future remediation problems.

The key aspects to be considered with particular reference to pesticides and herbicides are: (i) persistence of chemicals in the environment; (ii) long persistence causes intractable residues and contaminated waste; (iii) benefits of short term persistence chemicals and (iv) role of environmental management to minimise risks.

GENERAL PERSISTENT CHEMICALS IN THE ENVIRONMENT

There are many examples where the use of persistent chemicals has led to serious pollution episodes.

The use of arsenic compounds is a classic case. Residues from application as insecticide for cattle dips in Australia remain buried and intractable (Ng et al., 2003). The soil from such repositories requires remediation as it is contamination from an anthropogenic source. Arsenic solutions for cattle tick control were widely used in Queensland and New South Wales from 1895 to 1955. Chemical investigations (Beard et al., 1992) of arsenic contaminated soils, obtained from around 1600 government-owned cattle dip sites near north eastern NSW, have revealed levels of arsenic ranging up to 3000 mg/kg in the soil. Comparative bioavailability data were determined in 16 randomly selected soil samples with arsenic concentrations ranged from 700 to 2100 mg/kg and showed that a large proportion of arsenic (III) was present (Table 1) (Ng et al., 2003). An extensive cleanup program has been in place for several years to deal with the clean-up of contaminated cattle dip soils.

Table 1 Arsenic speciation from 16 cattle dip soil samples (Ng et al., 2003)

Soil I.D.	Total Arsenic (mg/kg)	Arsenic (III) %
1	730	68
2	730	70
3	860	38
4	1300	75
5	700	70
6	2000	71
7	1400	57
8	980	72
9	750	30
10	2100	59
11	800	43
12	1000	74
13	1100	88
14	2000	67
15	830	80
16	900	57

A classic example of dioxin in soil is located in Bien Hoa, Vietnam, where 1 ppm; 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD or TCDD) was found. The build up from the residues of TCDD in Agent Orange storage at the former US air base resulted in a highly concentrated zone (Quynh, 2005). Run-off accumulated in a nearby lake led to accumulation of TCDD in fish and other food items consumed by local people who received a significant dose of TCDD and thus were affected. A remediation plan was put in place and the TCDD residues have been excavated and disposed in a repository.

Although many toxic organochlorine pesticides are now banned in Vietnam, they are still in use and cause concern to people. Herbicides used during the Vietnam War severely polluted areas of Southern Vietnam. The study of the distribution of chemical impurities from herbicide application during the war has been useful for finding appropriate control measures (Quynh, 2005). Methods for sampling and analysis of organochlorines in soils, animal, human fat tissue and blood sample collection were applied and samples sent to international laboratories for dioxin analysis by high resolution gas chromatography – high resolution mass spectrometry (HRGC-HRMS). A study of organochlorine pesticides and polychlorinated biphenyls (PCBs) in food samples from Ho Chi Minh City 1989 showed that the most notable compound detected in biological tissue was DDT. Concentrations of DDT, hexachlorocyclohexane (HCH) and polychlorinated biphenyls (PCBs) in the soil in Tay Ninh and Binh Duong provinces in 1992 were also high where DDT was sprayed. PCBs contamination of cultivated land occurred during the war. Organochlorine pesticides and PCB levels in food samples from various sites were measured in Vietnam in 1992 and showed the presence of pollution of foodstuffs with PCBs, DDTs, HCHs, aldrin and dieldrin that were widespread in Vietnam. Dioxin accumulation has been observed in soil, animals and humans. In some limited sites it has been observed under geographical conditions, where Agent Orange herbicide drums were stored. The development of measures to solve contamination problems and prevent effects to the health of people has continued.

BENEFITS OF SHORT PERSISTENCE CHEMICALS

Chemicals which act quickly to induce an action or to control a pest are clearly preferred to those which remain active for decades. Pesticides are widely used in agriculture to control pests (weeds, insects or pathogens) and thereby increase yield and farm income. They remain an essential tool for agricultural industries in the production of high quality products and are a key component of integrated crop management (ICM) in cropping systems worldwide with around 2.56 million tonnes used per year (Pretty, 2005). Pesticides are generally applied as sprays to produce coverage of droplets containing the active ingredient on the target (e.g. an insect, leaf surfaces or part of a plant). Spray may be lost to non-target areas within a crop such as deposition on the soil or non-target plant surfaces and the action of wind may result in spray moving from the sprayed area. There are increasing concerns over the effect of pesticides in the environment, particularly when they move beyond a field boundary. By utilising techniques that maximise deposition on the spray target, it is possible to both improve the efficacy of pesticide applications and limit the movement of liquid droplets away from their point of release, both within and outside a target area.

For optimum control of pests and weeds in agricultural cropping situations, the grower is required to take careful consideration of many factors (Dorr et al., 2006). These include chemical selection, crop type, pesticide resistance, crop yield, costs of production, farmers revenue, spraying equipment (e.g. type of sprayer, nozzle selection, operating parameters), spraying techniques (e.g. buffer zones, no spray areas), meteorology (temperature, relative humidity, wind speed and direction) and sensitive areas downwind (e.g. non-target crops, livestock, aquatic organisms and areas that people occupy). Managing these factors in an integrated, holistic manner is often very complex. It requires combining tools, resources and information from several sources to optimise the application. Many parameters can also change during application (e.g. wind speed and direction) and application techniques must then be modified to prevent possible contamination of non-target areas. Failure to rapidly and appropriately manage these complex inter-related parameters has been the reason behind many pesticide drift incidents.

An important observation in the USGS study (Gilliom et al., 2006) was that the pesticides most frequently detected in streams and groundwater were those with greatest use either during the study period or in the past and with the greatest mobility and/or persistence in the hydrological system. Subsurface drains may help protect deep underground water, but increase pesticide transport to streams.

ROLE OF ENVIRONMENTAL MANAGEMENT TO MINIMISE RISKS

Risks to public health and the environment associated with pesticide use can be minimised if correct management decision is made. For a spray operation to be effective it needs to control pests (and hence increase crop yield and gross income) with a minimum of off-target environment and public health damage (Dorr et al. 2007). By combining spray models which give pesticide exposure and dose-response models with decision theoretical tools, various management options can be evaluated to maximise the effectiveness of plant protection products and minimise risks to public health and the environment from agricultural spraying activities. Risk assessment is a process for organising what we know about health and environmental risk and making judgements about risk (Ricci, 2006). It commonly adopts the following model: (i) Hazard Identification; (ii) Dose – Response (Toxicity) Assessment; (iii) Exposure Assessment; and (iv) Risk Characterisation.

In the risk assessment process, exposure studies of biota need to take account of formulation of the pesticide and its bioavailability. It is necessary to combine good quality application data with pesticide chronic toxicity data, generally the data required for registration of a pesticide. The risks to the environment need to take account of effects on: (i) terrestrial species; and (ii) aquatic species (Suter II, 1995). Other key areas include drinking water area exposure assessments and protection of non-target sensitive crops.

The control of contaminated waste is best dealt with by minimising its creation. Prevention of pollution requires attention to source reduction, the use of recycling, treatment and disposal options. Pollution prevention more broadly requires managing chemicals to reduce risk by identifying their presence and estimating all releases. Waste minimisation can be enhanced by applying source reduction and introducing product changes.

The recognition of the limits of science and technology has been proposed as reasons why science and technology alone cannot solve pollution problems or meet the challenges of sustainable development (Huesmann, 2003). The key aspects cited were: (i) Failure of reductionism; (ii) Limits imposed by conservation of mass principle; (iii) Order at expense of more disorder; (iv) Myths about recycling and renewable energy – trapping in environmental cycles; (v) Technology factor cannot be eliminated in order to improve eco-efficiency; and (vi) Long term protection of the environment and sustainable life style are not primarily technological but social and moral issues.

It is recognised that both biology and chemistry determine the availability of toxic chemical species in soils and sediments. The transport of solutes in soil is dominated by diffusion and is demonstrated by the significant presence of more polar herbicides such as atrazine found extensively in US streams (Gilliom, 2006). The precise nature of chemical and biological interactions depends on bioavailability and the role of bioturbation-driven chemical release processes.

Existing standards and guidelines for exposure to individual pesticides may not address all potential effects because actual exposure is most often a mixture of multiple pesticides and degradates (Gilliom, 2006). Additional research is required regarding the toxicities of mixtures to humans, aquatic life, livestock and wildlife because of the wide range of chemicals now found in organisms (Hileman, 2007).

CONCLUSIONS

An increasing demand for chemical substances during the last century led to the use of chemicals with long persistence in the environment. This activity has been identified as a negative feature since it became apparent that residues could be transferred through the food chain, remains in soil

or sediment as intractable substances. Chlorinated pesticides stand as a classic case of intractable substance and their residues remain dispersed throughout the world. Even though banned, their use continued because of their effectiveness as insecticides and availability. Arsenic is another classic case and its residues from application of its compounds as insecticides for cattle dips remain as buried residues that are intractable and requiring remediation. The recognition of problems associated with the lifetime of long persistence substances led to the need to use low persistent pesticides for insect control. The impact of increasing use of pesticides and herbicides is now offset by available data which shows that many compounds residues are undetectable in soil and groundwater. The USGS found no significant build-up of low persistence pesticides in groundwater over a 15 years period. Long-persistence or intractable compounds require specific techniques of soil remediation to deal with their effects on plants and animals. Examples of substances that may require soil remediation are arsenic, dioxins and DDT. A classic case of dioxin in soil could be seen in Bien Hoa, Vietnam, where 1 ppm TCDD was found in soil, requiring a remediation plan to excavate and dispose the TCDD residues in a repository. While exceptions occur, it is important to recognise that degradable chemicals should be used wherever possible in order to avoid future remediation problems.

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Research article

Input of Pollutants by the Tributaries of Lake Yojoa, Honduras

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Abstract Lake Yojoa is the only freshwater lake in Honduras. Its principal water sources are Yure and Varsovia Rivers and Cianuro Creek. There are three principal contaminants of the Lake Yojoa: agrochemical contaminants, microbiological pathogens and heavy metals. So, the main objective of this study is to evaluate and quantify the amounts of pollutants that each water source deposits in the Lake Yojoa. Based on the historical data of precipitation over the watersheds, water samples taken from each water source were analyzed for calculating specific load in each watershed. The specific load was calculated by multiplying the water flow with the concentration and then divided by the area of each watershed. In addition, statistical analysis was conducted employing "SPSS 15". As a result, there was no statistical difference in the amounts of monthly rainfalls among watersheds. The water flow, concentration as well as load and specific load differed among water sources. The results indicated that there was a tendency for Cianuro Creek to be the highest in specific load of organic matter and the only one in nitrogen as nitrite among water sources. The highest in specific load of potassium and chlorine was observed in Yure River. In addition, the quantity of pollutants discharged into the Lake Yojoa from water sources presents a threat of water degradation, especially eutrophication. A need of mitigating and reducing the amounts of pollutants is a reality. The high load of sulfate released by Cianuro Creek and Yure River present a threat not only for wild life, but also for humans that live near the lake. It was proposed that a filtering system should be prepared specifically to extract the pollutants carried by water sources that can be easily applied.

Keywords pollutants, eutrophication, specific load, Lake Yojoa

INTRODUCTION

Lake Yojoa is the only freshwater lake in Honduras and was designated as Protected Area Number 5 in the category of multiple uses according to the 71st decree of 8th of December 1971 by the government of Honduras. It is located 75km to the south of San Pedro Sula in the area where the departments of Comayagua, Santa Bárbara and Cortés converge. It is a monomictic lake, that is, the water mixes once a year.

The lake is surrounded by the National parks Meámbar and Cerro Azul and the mountain Santa Barbara from where 100% of the water is provided to the lake. Its principal water sources are Yure and Varsovia rivers. These two are artificially diverted to the lake, and the Cianuro Creek that has the higher water flow comparing to the other creeks,such as Horconcitos, La Jutosa, Balas, and La Pita creeks.

Table 1 General information of Lake Yojoa

Altitude (masl)	Length (km)	Width (km)	Perimeter (km)	Surface (km^2)	Average depth (m)	Average temp. (^oC)
632	16.2	4	88	54	28	24

Source: AMUPROLAGO, 2010

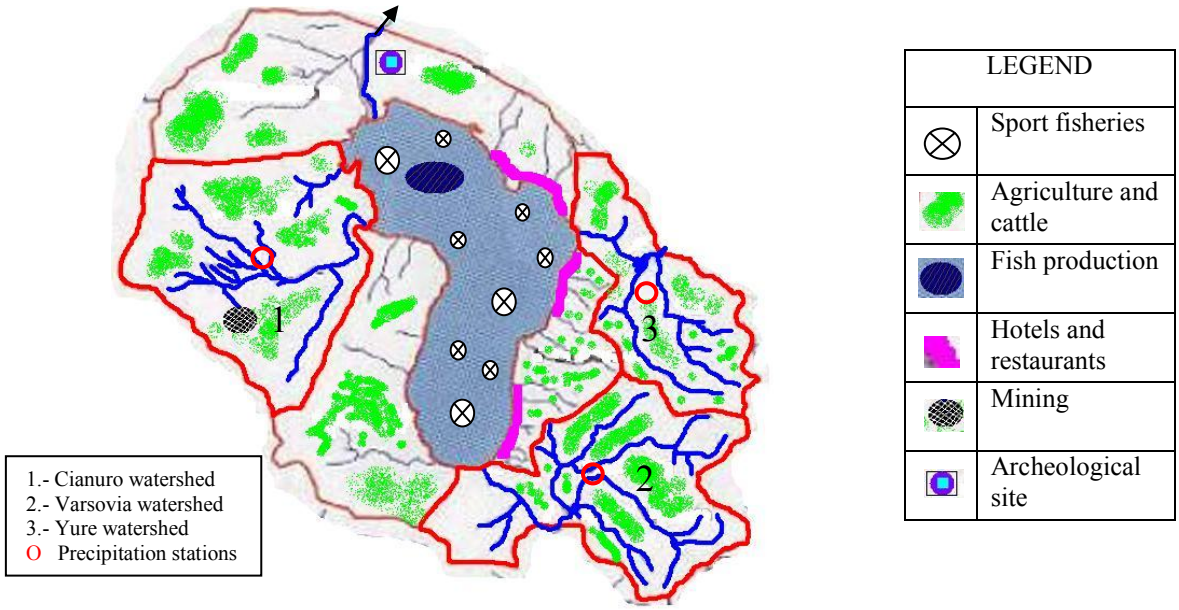

Fig. 1 Land use map of Lake Yojoa

In the world, different water management techniques have been developed (de Vries et al., 2008; UNDP, 1999; Pebbles, 2003; Lee, 2005). Most of the treatments are focused on reservoirs rather than on their water sources. Another approach is the management of water usage of the reservoir and other zones for reduction of water degradation (Queen's printer, 1999; British Land Company, 2008; Georgia Water Council, 2008). And the last is the maintenance of storm water to improve the water quality of a reservoir (Heiker, 2005).

There are three principal contaminants of the watersheds of the Lake Yojoa: agrochemical contaminants, mostly nitrogen, phosphorus and potassium (N P K), microbiological pathogens, mostly from coli forms, and finally heavy metals. There is nearly no information on agrochemical contaminants in the lake or the water sources, little on the microbiological pathogens and certain quantity of information on heavy metals. Most of the investigations done are focused on the lake (House, 2002; Studer et al., 2007; Figueroa, 1976) although (Borjas et al., 1999) water quality data taken from the top part of the Meámbar zone resulted in no contamination from the highest parts.

Data presented by Vaux et al. (1993) showed coli form level in the lake to be higher than those permitted in public beaches in USA (200 cfu/100 ml); but showed that the samples taken were very different from site to site. Samples varied from 1 cfu up to 240,000 cfu per 100ml.

Currently, water pollution in Lake Yojoa has become a big concern in Honduras. So, attention has been paid to the amounts of pollutants discharged into the Lake Yojoa. So, the main objective of this study is to evaluate and quantify the amounts of pollutants that each water source deposits in the Lake Yojoa. Also a secondary objective is to determine the need for a pollution mitigation plan to be set up and carried out.

METHODOLOGY

Research site

The watershed of Cianuro Creek is located to the west of Lake Yojoa and has an extension of 6,212.89 ha, where Las Vegas municipality represents 84% of the total extension. Las Vegas is the biggest human settlement in the region.

The Varsovia River watershed is located to the south east of Lake Yojoa. It has an extension of 5,379.17 ha. This river does not drain directly to the Lake Yojoa but is connected to it by a man made earth channel.

Yure River watershed is located to the south east of the Lake Yojoa, north to Varsovia watershed. It has a territorial extension of 3,558.41 ha. Although this river does not drain directly to the lake, it's connected through a concrete channel.

Table 2 Land coverage

River watershed	Total area (ha)	Human settlement (ha)	Farmland (ha)	Woodland (ha)	Pasture (ha)	Water bodies (ha)	Wetland (ha)	Naked land (ha)
Cianuro	6,212.89 (100%)	252.32 (4.06%)	1,082.82 (17.43%)	2,792.76 (44.95%)	1,965.11 (31.63%)	0.03 (0.0004%)	15.50 (0.25%)	104.35 (1.68%)
Varsovia	5,379.17 (100%)	35.48 (0.66%)	268.61 (4.99%)	3,747.45 (69.67%)	1,280.68 (23.80%)	0.90 (0.02%)	12.23 (0.23%)	33.82 (0.63%)
Yure	3,558.41 (100%)	34.59 (0.97%)	66.95 (1.88%)	2,503.62 (70.36%)	882.62 (24.80%)	45.27 (1.28%)	15.44 (0.43%)	9.92 (0.28%)

Source: AMUPROLAGO, 2010

The land considered as overused is represented by the percentage of farmland and pasture that does not have a resting period. Mining is the main income source for the population in Cianuro watershed. Overused land is 43.26%. Agriculture and cattle husbandry are the main income sources for the population in Varsovia watershed. The overused land in Varsovia watershed is 22.68%. Cattle production is the main income for the population in Yure watershed. The 23.59% of the land is in overuse.

Research methods

Historical data recorded by the Honduran National Electric Energy Company (ENEE) on precipitation over the watersheds of the main rivers and creek that discharge to the Lake Yojoa was acquired. Precipitation data comprised the monthly precipitation from 1988 to 2010. Collecting stations are placed strategically in sites representing the three main watersheds to Lake Yojoa (Fig. 1). Due to the high percentage of woodland in all the sites, calculations for pollutants were made from water collected before the effect of human activities during the day to avoid alterations in the quality.

Six water samples were taken from the water sources on July 21st 2011. The samples were taken as follows.

Two samples were taken from each river at the same time; the samples were taken at 6:30 am and 7:30 am as to avoid human activities of that day. Each sample site was marked by a GPS. At the same time span, the water flow of each river was observed in sites.

Water samples were analyzed for organic matter (OM), pH, electric conductivity (EC), phosphorus (P), potassium (K), chlorine (Cl^-), nitrogen as nitrite (NO_3^-), and sulfate (SO_4^{2-}).

Samples taken from each water source were analyzed for calculating specific load in each watershed. All the data were introduced to "SPSS 15 for Windows" program for the statistical analysis (α=0.05). The specific load was calculated as follows.

$$SL = (Q \text{ x } C) / A \quad (1)$$

where SL (kg/s/km^2) is specific load, Q (l/s) is water flow, C (kg/l) is concentration and A (km^2) is area of the watershed.

RESULTS AND DISCUSSION

Precipitation and water flow

The rainfall data collected showed that there was no statistical difference in the amounts of monthly rainfall among watersheds. The water flow showed statistical differences among water sources although precipitation did not show statistical difference. Table 3 shows the mean of the water flow of each water source during the sampling period.

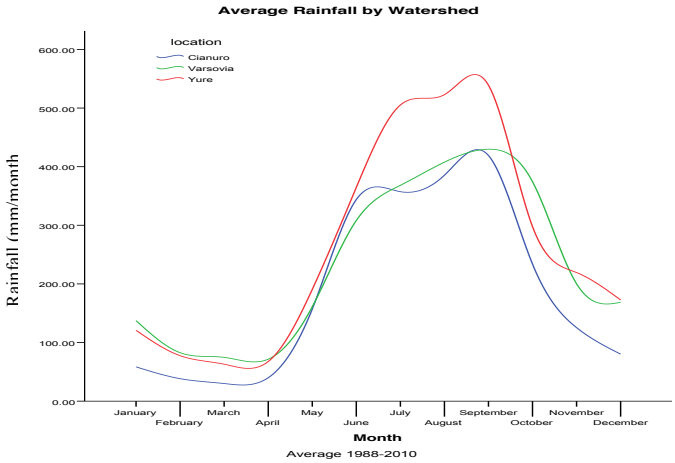

Fig. 2 Average monthly rainfall by watershed 1988-2010

Table 3 Average water flow towards the Lake (July, 2011)

Water source	Cianuro (m^3/s)	Varsovia (m^3/s)	Yure (m^3/s)
Water Flow	2.48^c±0.16	3.65^b±0.04	5.66^a±0.13

Different super indexes indicate statistical difference at 99% between columns

Input of pollutants to Lake Yojoa

The analyzed water samples showed that none of the three rivers transported phosphorus. In almost all of the analyzed nutrients there were statistical differences, placing the Cianuro Creek as the highest NO_3 carrier. In spite of this difference, to determine which river transports more amount of pollutants to the lake, the specific load was used. In Table 4, the specific loads of each water source were summarized.

The analysis showed that there was a statistical difference between Yure and the other two water sources and no difference between Cianuro and Varsovia water sources regarding pH, organic matter and chlorine. Yure River had the highest specific load of potassium, chlorine and sulfate. No difference in the potassium load among the sources. Cianuro Creek indicated the highest specific load of nitrogen in the form of nitrate that may create an environment for the super population of water plants. This super population of plants in the lake can cause the decrease in

dissolved oxygen at night causing problems to the lake's water life. These nitrogen components may be derived from fertilizers applied to the farmlands in the watersheds.

Table 4 Mean separation of specific loads of each river (July, 2011)

Water source	pH	EC (mS/cm)	OM ($kg/s/km^2$)	K ($kg/s/km^2$)	Cl ($kg/s/km^2$)	NO_3 ($kg/s/km^2$)	SO_4 ($kg/s/km^2$)
Cianuro	7.72^a	28.50^a	0.13^a	0.11^a	0.42^b	0.38^a	1.29^a
Varsovia	7.68^a	41.00^a	0.15^a	0.26^a	0.49^b	0.00^b	0.37^b
Yure	7.10^b	19.00^a	0.03^b	0.66^a	1.13^a	0.00^b	1.51^a

Means in the same column with different letters are statistically different at a significance of 0.05

Vevey (1990) took samples of the sediments inside the Lake Yojoa and found high levels of contamination of heavy metals, the highest point near the outflow of Cianuro Creek. Although these high levels were found, they were not bio-available as the concentrations in fish and wildlife are very low.

Table 5 Land use versus specific loads of pollutant by Pearson correlation

Correlations	pH	EC	OM	K	Cl	NO_3	SO_4
Human settlement	0.470	-0.093	0.270	-0.558	-0.500	0.933**	0.408
Farmland	0.682	0.064	0.509	-0.716	-0.714	0.919**	0.148
Woodland	-0.558	0.032	-0.367	0.625	0.589	-0.936**	-0.309
Pasture	0.440	-0.113	0.238	-0.534	-0.469	0.930**	0.439
Water bodies	-0.970**	-0.473	-0.948**	0.842*	0.996**	-0.479	0.636
Wetland	-0.959**	-0.505	-0.959**	0.816*	0.984**	-0.393	0.712
Naked land	0.717	0.095	0.551	-0.741	-0.750	0.909*	0.097

** Correlation is significant at the 0.05 (2-tailed)*
***Ccorrelation is significant at the 0.01 (2-tailed)*

Nitrate is affected by human settlement, farmland and pasture creating an increase in the load as the extension of land use increases. Woodland affects negatively the NO_3 specific load due to the high amount of absorption by trees concerning water and nutrients. Cianuro Creek was the only water source that presented NO_3. This is due to the amount of farmland, pastures and naked land located in the watershed.

CONCLUSIONS AND RECOMMENDATIONS

Lake Yojoa, the only freshwater lake in Honduras, needs to be protected. The amount of pollutants carried by the water sources has to be evaluated in order to further protect the Lake Yojoa from eutrophication and other types of contamination.

Nitrate concentration was affected heavily by the land usage and that effect in time can easily be the same for all of the other pollutants.

The high load of sulfate released by Cianuro Creek and Yure River presents a threat not only to wild life but also to humans that live near the lake.

As a recommendation, a filtering system should be prepared specifically to cover all of the pollutants carried by rivers that can be easily applied to all the water sources of the Lake Yojoa. This system has to remove organic materials and nutrients directly from the water.

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Research article

Water Quality Improvement by Natural Meandering River Surrounded by Woods in Agricultural Watersheds

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Abstract Changes on nitrogen concentration and load of river water during down flow were examined in five rivers flowing through agricultural watersheds in the Tokachi district of eastern Hokkaido, Japan. The upper reach of each watershed is intensively covered by cropland whereas the lower reach is covered by forest. The river form also differs between the upper reaches, which have been artificially straightened by meander cutoff, and the lower reaches, which remain in their natural meandering condition. The lower the reach measured was, the lower the nitrogen concentration was, and this decrease in concentration was even more pronounced in the natural meandering sections than in the straightened sections. The decrease of nitrogen load by natural purification in straightened sections and natural meandering sections was examined using L_{self}, which was introduced as an index of natural-purification-related nitrogen load decrease. In contrast to the changes in concentration, nitrogen load did not decrease in the natural meandering section.

Keywords cropland, straightened river, naturally meandering river, nitrogen, self-purification

INTRODUCTION

River water contamination by agricultural nitrogen has been a serious problem in the Tokachi district of eastern Hokkaido, Japan, where cropland cultivation is the major industry. A survey of river water quality in agricultural areas in the Tokachi district by Tabuchi et al., (1995), Okazawa et al., (2009, 2010, 2011), Woli et al., (2002, 2004) revealed a strong correlation between the proportion of cropland area in a watershed and the concentration of nitrate nitrogen in the river water. They showed that the relationship between the two could be expressed as a linear function. As a result, it is suggested that decreasing the area of cropland as a proportion of the watershed area would be effective in decreasing the nitrogen concentration in the river water; however, such a measure is not realistic because reducing the area of cropland would reduce the agricultural production.

It has been known since ancient times that the water in meandering rivers (i.e. those whose channels have not been artificially straightened) is purified by natural mechanism of self-purification (e.g. Ajayi et al., 1984). It has been proven that, in such naturally meandering rivers, biological, chemical and physical processes eliminate contaminants from the water during the course of the water's flow through the meander sections (Heidenwag et al., 2001).

In formulating river improvement plans for areas whose main industry is cropland farming, improvement of a river's natural ability to purify itself can be an effective way of solving problems

in the water environment of the area. Preservation of natural watercourses and the use of construction methods to restore streams (i.e. ecological and near-nature hydraulic engineering) can be effective.

This study reports two years of water quality observations in watersheds in the Tokachi district of Hokkaido. The subject area has croplands at the upper reaches and forests at the lower reaches of its rivers, and we call such an area a "combined agricultural area". We clarified the self-purification ability of the natural streams at the forested lower reaches by observing the degree of natural degradation of the nitrogen components emitted from the cropland field areas at the upper reaches.

METHODOLOGY

Study sites

The subject watersheds are shown in Fig.1. The survey was conducted in the watersheds of seven rivers in the Tokachi district of Hokkaido. The basic data on each river and the watershed are shown in Table 1. The watersheds denoted as PE, PA, UR, PO and PN are those whose upper reaches are mainly cropland fields and lower reaches are forest or pasture. Hereinafter, the subscripts "U" and "L" will respectively denote the upper and lower reaches.

PE_U, PA_U, UR_U, PO_U and PN_U croplands account for 70% to 86% of the total area, which is high percentage. In these areas, the rate of forest is 11% to 27%, and most of the forests are windbreaks for croplands. Potatoes, legumes, wheat, feed corn and sugar beets are the main crops. Cattle farming is also common in these upper-reach areas. Rivers have been converted to drainage canals by straightening of the channels and concreting of the banks.

In areas at the lower reaches (PE_L, PA_L, UR_L, PO_L, and PN_L), the rate of forest is 59% to 94%. Cropland accounts for 6% to 41% of the areas, a large portion of which are pastures of the National Livestock Breeding Center (NLBC). Naturally meandering river channels are preserved in the NLBC.

Watersheds BO and SY are at the NLBC. The rate of cropland is 55% and 63%, respectively, for these watersheds, and most of the area is pasture. The streams in the two watersheds are naturally meandering.

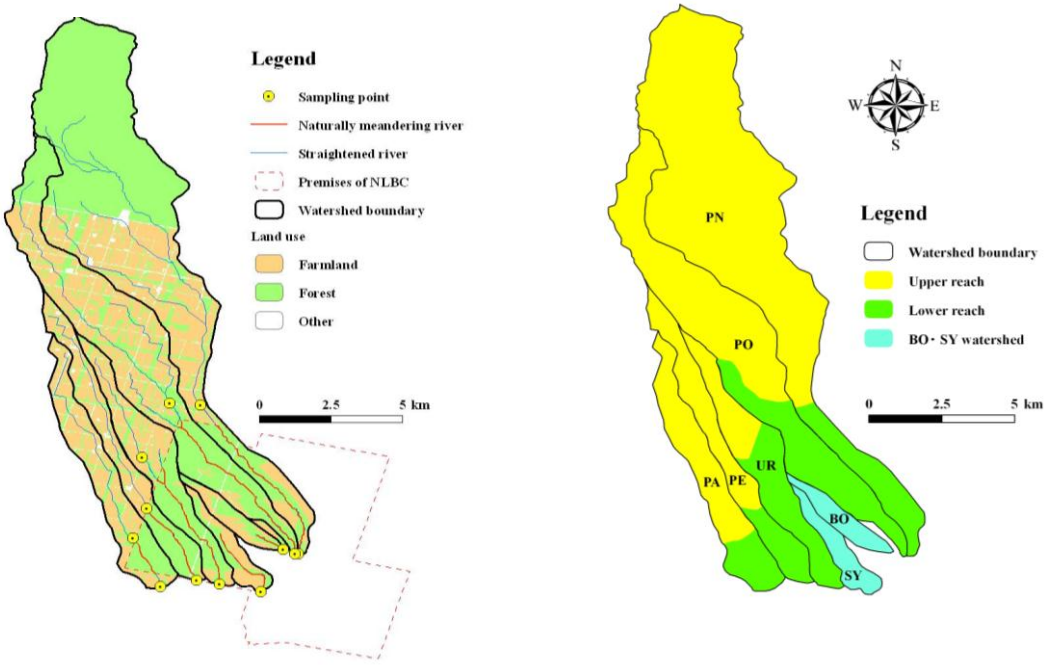


Fig. 1 Location maps of the investigated watersheds

Table 1 Characteristics of investigated watershed

River	Reach	Sampleing point	Area (km^2)	Land use (%)			Straightened river (km)	Meandering river (km)	Total (km)	Cattle (Head)	Sample Number
				Cropland	Forest	Other					
Penkeuretoi (PE)	Upper	PE_1	5.16	83	13	4	7.67	0.00	7.67		21
	Lower	PE_2	2.04	35	65	0	0.58	1.43	2.01		21
	Whole area		7.20	69	28	3	8.25	1.43	9.68	509	
Pankeuretoi (PA)	Upper	PA_1	4.38	84	13	3	8.01	0.00	8.01		18
	Lower	PA_2	2.04	6	94	0	0.00	3.05	3.05		18
	Whole area		6.42	59	39	2	7.96	3.10	11.06	102	
Uranenai (UR)	Upper	UR_1	2.68	85	12	3	3.93	0.00	3.93		19
	Lower	UR_2	4.39	27	73	0	1.59	5.03	6.62		19
	Whole area		7.07	49	50	1	5.59	4.96	10.55	104	
Ponchin (PO)	Upper	PO_1	12.39	70	27	3	14.41	0.00	14.41		9
	Lower	PO_2	6.46	26	73	1	4.90	4.70	9.60		9
	Whole area		18.85	54	43	3	20.41	3.60	24.01	145	
Penkechin (PN)	Upper	PN_1	31.04	33	64	2	17.44	9.48	26.92		18
	Lower	PN_2	3.82	41	59	0	1.34	5.36	6.70		18
	Whole area		34.86	34	61	2	14.46	19.16	33.62	1,079	
Bokujyo (BO)	BO	BO_1	1.82	55	45	0	0.00	0.96	0.96		25
Syuba (SY)	SY	SY_1	2.09	63	37	0	0.00	2.67	2.67		20

*Cropland consist of upland and pasuture.

Hydrological survey method

The survey period was from June to November in both 1999 and 2000. Discharge measurement and river water sampling were done once or twice per month when the rivers were at normal water level. Sampling locations for the watersheds PE, PA, UR, PO and PN are denoted by adding the subscript "1" for upper reaches and "2" for lower reaches. River water samples for each sampling location numbered between 9 and 25.

The items for water quality analysis are total nitrogen (T-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N) and ammonium nitrogen (NH_4-N). Ion chromatography was used to analyze NO_3-N and NO_2-N, and a technique recommended by the JIS was used to analyze T-N and NH_4-N.

RESULTS AND DISCUSSION

River discharge: upper vs. lower reaches

The mean and standard deviation (S.D.) of the river discharge measured at each observation point are shown in Fig.2. The river discharge values at PE, PA, UR, PO and PN are higher for the lower-reach points than for the upper-reach points (significances, $P<0.01$). This reveals that in these watersheds, large amounts of inflow are supplied from areas at the lower reaches of the river.

Comparison of upper-reach vs. lower-reach points in terms of nitrogen concentration

Fig.3 shows nitrogen components measured at each observation point. NO_3-N accounts for 60% to 80% of the T-N at the observation points on the rivers in areas PE, PA, UR, PN and PO. Therefore, the high proportion of NO_3-N in T-N in the river waters in areas PE, PA, UR, PO and PN are attributed to the high proportion of cropland fields in those areas.

Fig.4 shows the mean and standard deviation (S.D.) of T-N in river water sampled at each observation point.

At BO and SY, T-N concentrations are 0.50 mg/L and 0.53 mg/L respectively, which are lower than those of other areas. The values are lower than 1 mg/L, being this value the environmental standard of Japan, based on which it was determined that the water environment of the areas is good. The watersheds of BO and SY consist mainly of forest and pasture.

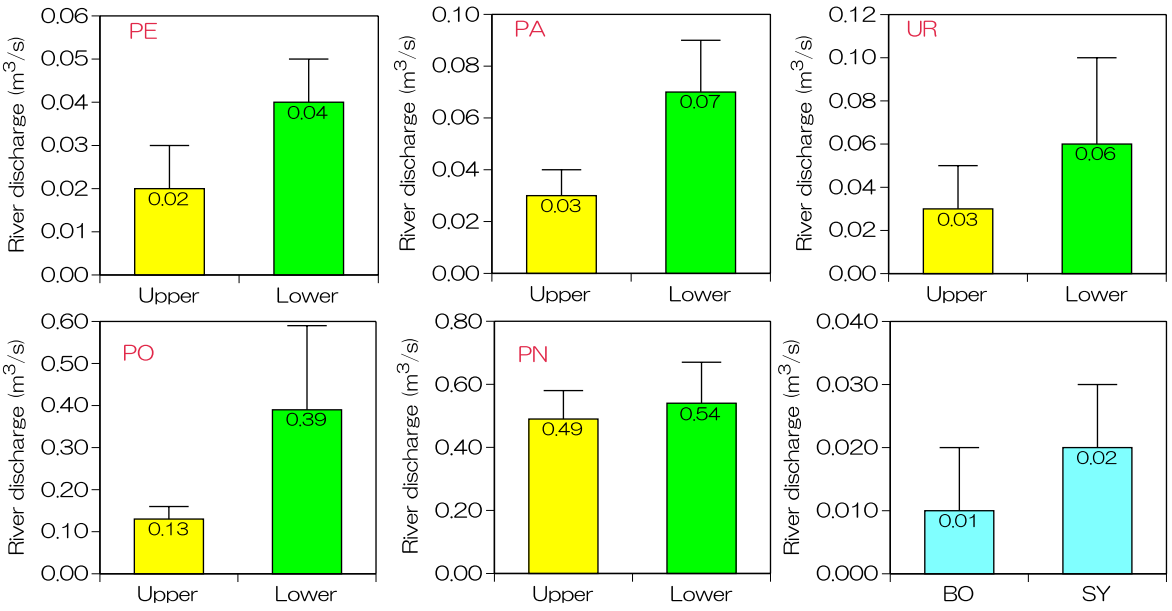


Fig. 2 Mean and standard deviation (error bar) of river discharge for each investigated point

Statistically significant differences (P<0.01) were observed between discharge at upper-reach point and at lower-reach point in the watershed "PE, PA, UR, PO and PN"

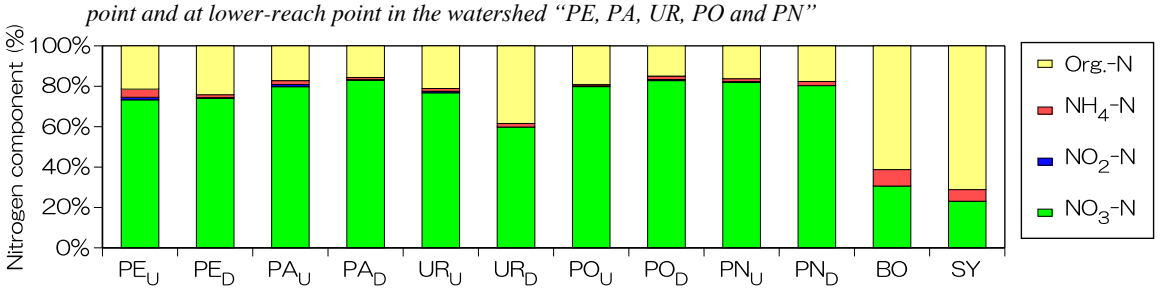


Fig. 3 Percentage of nitrogen components for each investigated point

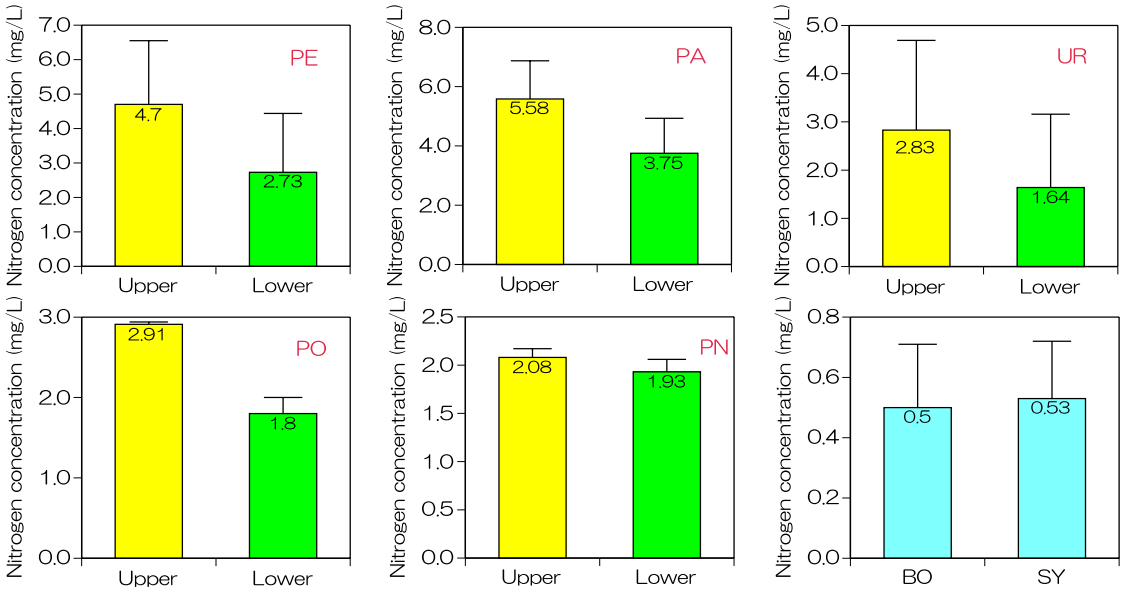


Fig. 4 Mean and standard deviation (error bar) of T-N concentration for each investigated point

Statistically significant differences (P<0.01) were observed between nitrogen concentration at upper-reach point and at lower-reach point in the watershed "PE, PA, UR, PO and PN"

Nitrogen fertilizers are not used in forest or on pasture, and the water flowing from such areas contains only small amounts of nitrogen, which accounts for the low nitrogen concentration in the river water. However, in rivers in areas PE, PA, UR, PO and PN, nitrogen contamination exceeding the T-N environmental standard of 1 mg/L is observed.

When T-N concentrations for the upper and lower observation points of areas PE, PA, UR, PO and PN are compared, T-N concentrations for the lower-reach points are found to be lower than those for the upper-reach points. For each river, the difference in T-N concentration between the upper-reach point and the lower-reach point is significant (P<0.01). The above findings clarify that water high in nitrogen flows from cropland field areas at the upper reaches through rivers to the lower reaches. It was also clarified that the nitrogen concentration of the river water from the upper-reach areas decreases while flowing through the naturally meandering rivers in the forested areas at the lower reaches.

Nitrogen load balance at the lower reaches

The nitrogen balance at the lower reaches is shown in Fig.5. Equations (1) and (2) for nitrogen balance are also shown below. By using these two equations, the self-purification ability (L_{self}) of river at the lower reaches was evaluated.

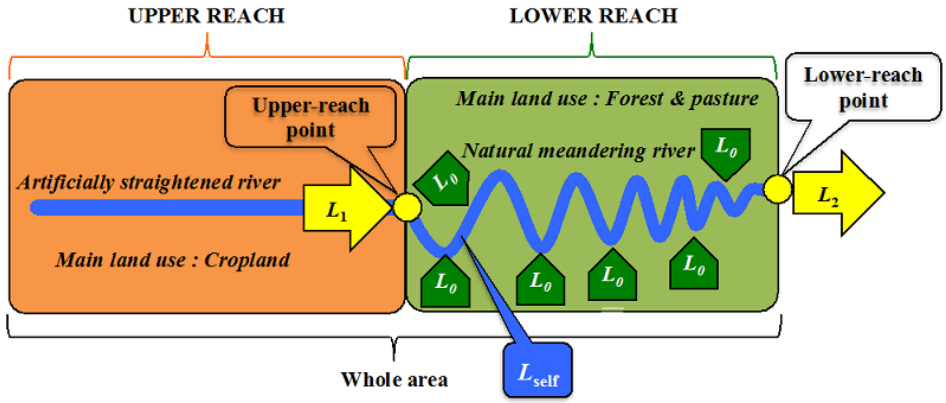


Fig. 5 Concept of nitrogen balance in the combined agricultural area (The watershed "PE, PA, UR, PO and PN")

$$L_2 = L_1 + L_0 + L_{self} \quad (1)$$

$$\therefore L_{self} = L_2 - L_1 - L_0 = (C_2 \cdot Q_2) - (C_1 \cdot Q_1) - [(Q_2 - Q_1) \cdot C_S] \quad (2)$$

L_1 : Load at the upper reaches (g/s)
L_2 : Load at the upper plus lower reaches (g/s)
L_0 : Load from the areas at the lower reaches (g/s)
L_{self} : Self-purification and self-contamination of nitrogen at the river of lower reaches (g/s)
C_1 : Nitrogen concentration at the upper-reach point (mg/L)
C_2 : Nitrogen concentration at the lower-reach point (mg/L)
C_S : Nitrogen concentration in water sampled at the natural river section of the watershed PA (0.75 mg/L, Table 2)
Q_1 : Discharge at the upper-reach point (m^3/s)
Q_2 : Discharge at the lower-reach point (m^3/s)
$Q_2 - Q_1$: Discharge from the lower reaches (m^3/s)

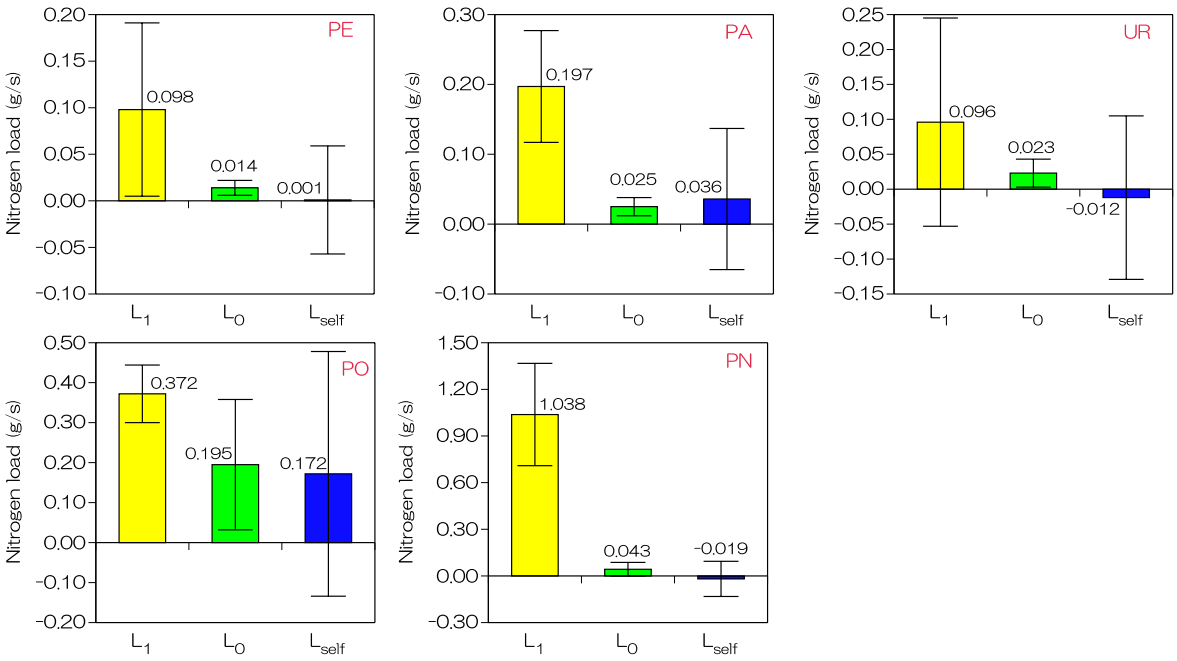
When L_{self}<0, the nitrogen load is purified in the naturally meandering streams; when L_{self}>0, the nitrogen load flows out of the naturally meandering streams. L_0 was obtained by multiplying the surplus discharge at the lower-reach point relative to the discharge at the upper-reach point (Q_2-Q_1) by the mean nitrogen concentration of the water from tributaries that flow into the natural river section (0.75 mg/L, Table 2).

Table 2 Mean nitrogen concentration of inflow water from PA_1 to PA_2

	T-N	NO_3-N	NO_2-N	NH_4-N
Mean	0.75	0.03	0.03	0.00
S.D.	0.40	0.04	0.02	0.00

n=12, 〔mg/L〕

As shown in equation (1), L_2 consists of L_1, L_0, and L_{self}. Fig. 6 shows the mean and standard deviation of L_1, L_0, and L_{self} . L_{self} for each river was smaller than the load from the upper reach (L_1), which means that the total nitrogen load from the upper reaches cannot be totally purified at the lower reaches. The mean L_{self} for rivers in watersheds UR and PN showed negative values, which confirms that the natural sections of these rivers have high purification ability. In all of the surveyed rivers, the standard deviation of L_{self} is greater than the mean L_{self}, because of which L_{self} can take a positive or a negative value. In the naturally meandering sections of the surveyed rivers, natural purification at the lower reaches and nitrogen inflow from land at the lower reaches can occur. Natural purification occurs, but the reduction in nitrogen load is thought to be small.



L_1 : Load at the upper reaches (g/s)
L_0 : Load from the areas at the lower reaches (g/s)
L_{self} : Self-purification and self-contamination of nitrogen at the river of lower reaches (g/s)
If L_{self} is a positive value (+), the nitrogen load flows out of the naturally meandering streams.
If L_{self} is a negative value (−), the nitrogen load is purified in the naturally meandering streams.

Fig. 6 L_1, L_0, L_{self} of mean and standard deviation (error bar) for each river

CONCLUSION

The following was clarified in this study.
1. Water contaminated with nitrogen at high concentrations from the cropland fields in the areas at the upper reaches flows into the natural river sections at the lower reaches.
2. Nitrogen concentration in the river water decreases during the course of the water flowing down to the lower reaches. This is attributed to dilution by abundant inflow of water with low nitrogen concentration from areas at the lower reaches.
3. In a watershed where land use is categorized as “combined agriculture” consisting of cropland fields at the upper-reach areas and forest at the lower-reach areas with naturally meandering rivers,

it was suggested that the nitrogen load supplied from the upper reaches to the lower reaches may be decreased by the river's self-purification ability. It is clarified that nitrogen load is also generated in naturally meandering river sections.

The above findings suggest that naturally meandering rivers are able to achieve self-purification and self-contamination. Future studies should clarify the self-purification mechanisms of naturally meandering rivers. By clarifying the conditions that foster a river's self-purification ability, it is possible to enhance that ability by establishing engineering technologies for conserving river water.

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Research article

An Analysis on the Policy of Promoting Rubber Trees Cultivation for Replacing Garlic and Longan Growing: A Case Study of Chiang Mai, Thailand

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Abstract The acceptance of farmers' participation in promoting rubber trees cultivation for replacing garlic and longan growing has been studied. Interview schedule, in-depth interview and focus group discussion techniques were used to obtain required data from eighty participants, sixty-two non-participants of rubber cultivating project and three representatives from the Office of Rubber Replanting Aid Fund. The collected data were analyzed by descriptive statistics. It was found that more than one-third (38%) of farmers decided to participate in the project and the rest (71.98%) did not want to participate because the cultivation area was under drought. In 2003, there were 1,127 farmers in Chiang Mai participating in the project with a total cultivation area of 6,770 acres. Thirty participants (37.50%) changed longan orchard to rubber cultivation, 218 acres in area. This was equivalent to 422 farmers and 3,074 acres of cultivation area comparing to the total number of participants and rubber cultivation area in Chiang Mai. During 2003-2004, Chiang Mai had a total longan cultivation area of 94,925 acres. However, this project could help reduce longan cultivation area by only 3.23%. Meanwhile, few participants changed garlic cultivation area to rubber cultivation area. It indicated that only longan orchard area could be reduced but garlic cultivation area could not. Besides, some participants changed other crop growing areas to rubber cultivation area. These would have effects on long-term food security of Thailand. Moreover, during 2011-2012, participants begin to earn income from rubber latex. This might motivate some non-participants to take part in the project due to high prices of rubber latex. However, they should place importance on the appropriateness and cares of rubber cultivation areas. As a whole, the policy was not successful as it should be.

Keywords policy, rubber trees cultivation, longan orchard, Chiang Mai

INTRODUCTION

The launching of Chino-Thai free trade caused import of agricultural products from China, especially garlic. This has lowered the prices of Thai garlic. At the same time, there was an oversupply of longan yields. Thus, Thai government prepared a guideline for reducing garlic and longan growing areas. That is, rubber trees cultivation has been promoted since 2003. At the initial stage it took about 3 years (2004-2006), supported and promoted by the Office of Rubber Replanting Aid Fund (ORRAF). In fact, most of the farmers who got involved in the project had never done rubber cultivation before (Sriprasit, 2008). The supporting fund for project promotion was worth 1,397 million baht (Noonsong, 2003). For the second period, the rubber trees growing promotion was conducted in 7 northern provinces, namely: Chiang Mai, Chiangrai, Lamphun,

Phayao, Lampang, Tak and Mae Hong Son. This was particularly done in the areas where garlic yield was lower than 390 kg per acre. It was expected that 5,139.79 acres of land would be replaced with rubber trees cultivation with the supporting budget of 16,950,000 baht (the Or Por Thor News, 2009).

The previous policy of promoting rubber trees cultivation for replacing garlic and longan growing in Chiang Mai faced a lot of problems. This was because of top-down approach of government. Therefore, it is essential to explore problems in farmer's adoption of this policy as well as their needs. The purpose of this study was to explore how to promote farmers to change garlic and longan growing to rubber trees cultivation in Chiang Mai, Thailand.

METHODOLOGY

Purposive sampling was used from the population of 925 farmers in 17 districts of Chiang Mai, who were participants in rubber cultivating project. The sample group consisted of 10% of farmers in Phrao, Fang, Chaiprakarn and Hod districts which were leading garlic and longan growing areas of Chiang Mai. The sample group was divided into 2 sub-groups: 1) 80 farmers participating in the project and 2) 62 farmers who did not participate (they still grew garlic and longan but some of them did rotation cropping such as rice and garlic in a year). They were chosen by simple random sampling. In addition, there were 3 representatives of the ORRAF, Chiang Mai.

A set of scheduled interviews were used for data collection. Besides, in-depth interview and focus group discussion techniques were used. Data analyses were done by descriptive statistics.

RESULTS

General information of participants and non-participants of rubber cultivating project

Most of the farmers were male. Percentage of male among participants was 81.25% and that for non-participants was 85.48%. Average ages of both groups were close. They had 4 family members on average. The proportion of fourth year elementary school was 37.50% and 51.61%, respectively. They have worked in agricultural sector. The participants had 2 years of experience in agriculture. Less than one-half of participants(40.00%) were dependent on rain for farming. However, more than one-half of non-participants (58.06%) used public water sources for farming. It was also found that the ratio of full time farmers among non-participants was higher than that for the participants (56.45 and 46.25% respectively). Both groups were similar in agriculture career and supplementary job career (Table 1). This implied that agriculture production alone could not generate enough income for daily expenses, even though some of them changed to grow rubber trees.

In addition, most of the participants (85.00%) had their own land (9.68 acres on average). Very few of them (1.25%) encroached reserve forest for farming. However, less than one-half of non-participants (45.16%) had their own land and an income from the agricultural sector was higher than that of those who attended the project (281,854.84 and 172,045.45 baht per year). This might be because many farmers still wanted to grow garlic and longan. Most of the farmers of both groups were members of the Bank of Agriculture and Agricultural Cooperative (BAAC). Besides, they got a short-term loan for farming from the bank. However, sums of their loans for non-participants were higher than those of e participants (179,137.93 and 62,727.27 baht, respectively). The interest of the loan was 7.50 baht per year (Table 1). This meant that income earned from the agricultural sector of non-participants was higher than that of participants due to high cost of the investment.

Farmer adoption to participate in the project

Most of farmers received project news through the Office of Sub-District Agriculture and Office of District Agriculture (81.25%) and had no knowledge about rubber trees before (80%).

Table 1 General information of participants and non-participants of rubber cultivating project

General information	Participants (n=80)		Non-participants (n=62)	
	F	%	F	%
Sex				
Male	65	81.25	53	85.48
Female	15	18.75	9	14.52
Age				
40 years and below	9	11.25	2	3.23
41-50 years	29	36.25	21	33.87
51-60 years	23	28.75	32	51.61
More than 60 years	19	23.75	7	11.29
$\bar{x}$	**52.41**		**52.95**	
Educational attainment				
Fourth year elementary school	30	37.50	32	51.61
Sixth year elementary school	9	11.25	14	22.59
Lower secondary school	13	16.25	7	11.29
Upper secondary school	17	21.25	7	11.29
Higher certificate and higher	11	13.75	2	3.22
No. of family members				
1-3 peoples	21	26.25	19	30.65
4-6 peoples	55	68.75	40	64.51
More than 6 peoples	4	5.00	3	4.84
$\bar{x}$	**4.25**		**3.90**	
Agricultural experience				
20 years and below	27	33.75	25	40.33
21-30 years	21	26.25	18	29.02
More than 30 years	32	40.00	19	30.65
$\bar{x}$	**27.44**		**25.37**	
Water used for agriculture				
Rain	32	40.00	0	0.00
Public canal	23	28.75	36	58.06
Irrigation and others	25	31.25	26	41.94
Main and supplementary job career				
Full-time farmer	37	46.25	35	56.45
Agriculture and trading	13	16.25	14	22.58
Agriculture and hired worker	17	21.25	0	0.00
Others	13	16.25	13	20.97
Land holding for farming				
Own	68	85.00	28	45.16
Rental	1	1.25	12	19.35
Own and rental	4	5.00	21	33.87
Others	7	8.75	1	1.62
Source of income				
Agricultural sector	37	46.25	34	54.84
Non-agricultural sector	3	3.75	0	0.00
Agricultural and non-agricultural sector	40	50.00	28	45.16
Annual income from agricultural sector in average	**172,045.45**		**281,854.84**	
External capital source (n=51, n=47) *				
The BAAC	43	84.31	40	85.11
Village Fund	5	9.80	1	2.12
Agricultural Cooperatives	3	5.89	6	12.77

**Only farmers who have got an external capital source for rubber tree cultivation*

More than a half (68.75%) decided to participate in the project due to the governmental promotion (not more than 5.93 acres). But 31.25% of them were farmers having potential in the capital for investment. More than one-third of them (37.50%) grew rubber trees in the areas ichused longan orchards (about 213.49 acres). This was equivalent to 422 farmers and 3,074 acres of cultivation area comparing to the total number of participants and rubber cultivation area in Chiang Mai, respectively. During 2003-2004, Chiang Mai had a total longan cultivation area of 94,925 acres (Longan Information Center, 2010). However, this project could help reduce longan cultivation area only to 3.23%. Surprisingly, only one farmer (1.25%) grew rubber trees in the areawhichused to garlic growing. It indicated that Longan orchard area could only be reduced into a small number but not for garlic cultivation area.

About one-half of farmers (51.25%) were not sure about the return obtained from rubber cultivation. However, some of them (20.00%) expected to earn a monthly income from rubber cultivation for about 1,000 baht. They believed that the project was a good one. Less than one-half of them (41.24%) stated that it was because there was staff of the ORRAF that often gave them advice about rubber trees growing. About one-fourth of them (23.75%) thought that their livelihood would be better due to an increase of income. Only 10% of the farmers stated that the project took long time to give yields and it was costly for care-taking.

The project implementation in accordance with the government's policy

The project implementation in 2003 lacked readiness in various aspects such as a number of concerned personnel, budgets and that farmers did not have knowledge and understanding about rubber trees cultivation. At the initial stage, farmers must register to be enrolled in the project at the Office of District Agriculture. They had to grow rubber trees alone without assistance of c or any suggestion. This was due to limited budgets allocated to concerned agencies. In 2004, however, government had allocated the budgets through ORRAF, aimed to provide knowledge and understanding about rubber trees cultivation for farmers. It takes 7 years and 6 months for rubber trees to give yields. Nowadays, ORRAF is still responsible for providing knowledge and understanding about rubber trees cultivation.

The ORRAF revealed that the project was not so successful because of the following factors:

1. The project implementation was based on political objectives. Thus, at the initial stage of the project there was no concerned agency for project monitoring. Moreover, farmers in northern Thailand did not have experience in rubber trees cultivation before.
2. Farmers did not adequately take care of rubber trees which they had grown i.e. grass mowing, fertilizer application, prevention of insects and diseases.
3. Budgets allocated by government were small

Based on the farmers, the following was concluded:

1. The prepared rubber seedlings were inadequate.
2. Lack of knowledge, extension, and monitoring caused farmers to misunderstand rubber trees cultivation, e.g. distance between rubber trees; growing rubber seedling with longan and weeds. These had an effect on growth performance of rubber trees.
3. There were no concerned agencies for giving farmers advice when they had problems. Thus, farmers had to do trial-and-error by themselves.

Needs of the farmers who did not participate in the project

More than one-half of non-participants (64.90%) used to receive policy news through television. Nevertheless, they did not attend the project because they did rotation cropping. They were cultivating rice from July to December and garlic from January to April, and so that the cultivation land areas were inappropriate for growing rubber trees. Some of them (14.52%) stated that longan and garlic were giving yields even though their prices were quite low. So, they needed the government to assist them in terms of price of longan and garlic, reduction of production costs and agricultural products imported from neighboring countries, especially from China.

From the focus group discussions with farmers, the following were revealed:

1. Inappropriateness of the cultivation areas - Most of the cultivation areas were rice paddy fields which were inherited from parents and limited. Some farmers sold their lands to capitalists and could not expand their cultivation areas because they were close to reserved forest.
2. Worthiness - Longan growers did not want to cut their longan trees since they were giving yields once a year. Longan trees were worthy since longan growers only had to work hard at harvesting season. On the other hand, it took a long time for rubber trees to give yields.
3. Agricultural experience - Farmers were confident in their long time longan and garlic growing experiences, and believed that they were better at growing longan and garlic than rubber trees. Yet, some farmers showed interest in growing rubber trees and they were waiting to see the success of rubber trees growing of others.
4. Assistance of the government
4.1 Farmers wanted the government to assure their income and yields. This was because they were not able to grow other crops since they had long experience in longan and garlic growing. If the government could do it, it might motivate the new generation to grow rubber trees. Surely, selling the cultivation lands to capitalists would be decreased.
4.2 Farmers wanted the government to provide them with production factors e.g. fertilizer, pesticide, insecticide, etc. This could be done through the village fund management by the community.
4.3 The government should reduce import quota of Chinese garlic. This was because its price is lower than that of Thai garlic. Although there are garlic and red onion grower cooperatives in Thailand,Thai garlic could not compete against garlic from China.

DISCUSSION

It is essential that the policy determination for local development be relevant to the needs of the community. Also, it must place importance on environmental conditions. This must be supported by various social sectors as well as local people. Besides, collaboration and coordination among concerned parties based on the participatory process are required in order to achieve the goals (Mingchai and Yotsuk, 1998). As the rubber trees cultivation replacing garlic and longan growing is the political policy, it lacked the readiness in planning, personnel, and budgets. There were a lot of problems at the initial stage. Moreover, farmers did not have experience in rubber tree growing. More than 200 farmers failed to join the project. This was a wasteland in providing budgets for rubber seedling. After the government had allocated the budgets to ORRAF in 2004, some concerned agencies assisted and provided knowledge to the farmers more than ever. However, the project was not so successful on promoting the reduction of longan and garlic growing areas. This was because few farmers that joined the project changed to grow rubber trees (213.49 acres, 442 farmers). In fact, Chiang Mai has longan growing areas of 92,738.45 acres (Longan Information Center, 2010). However, this project could decrease longan growing area at a very low level. At the same time, garlic growing areas could not be decreased at all. Some farmers used the areas usually for growing other crops to grow rubber trees. This might have a long-term effect on food security of the country and the world.

Based on the policy, SWOT analysis revealed that the policy is supported by the government focusing on agricultural development and villagers' livelihood. There were some concerned parties assisting the project such as Office of District Agriculture; Office of Provincial agriculture, and ORRAF. On the other hand, the project was under urgent polic, and sothe government sometimes made modifications which might have an effect on the project management and discontinuation of care-taking. Moreover, farmers did not have enough knowledge about rubber trees cultivation. Besides, lack of holistic operation and no complete coordination among concerned agencies were the policy's weaknesses. Farmers might be interested in joining in the project due to a high demand of rubber in the world and an income might satisfy them. But, it is difficult to expand rubber growing areas since there is a limitation on land holding and reserved forest encroachment. Also, the limitation on external loan sources and high interest rates are the policy's threats.

CONCLUSION

The project was under a policy of promoting rubber trees cultivation for replacing garlic and longan growing. This aimed to avoid the competition of yields against the neighboring countries due to China-Thai Free Trade Agreement and to increase the income of farmers for better livelihood. Since it is an urgent policy, there were problems to be resolved in terms ofthe : 1) *structural deficiency* - this policy needs coordination among concerned parties such as the Ministry of Agriculture and Agricultural Cooperatives, the Ministry of Commerce, and other agricultural institutes, which was not found in this project; 2) *the deficiency on risk management* - risk factors include natural calamities, diseases, insects, etc. Indeed, the government did not promote yield assurance management as well as rubber market; 3) *development of agricultural sector for the reduction of unfair treatment* - Goals of the project did not focus on unfair treatment such as income and yield assurance systems and the diffusion of information about said systems; and 4) *stakeholder participation* - the policy still lacked collaboration among production sector, market sector and concerned agencies in terms of agricultural planning and development for the reduction of environmental impacts.

As a whole, the initial stage of the project was not so successful. However, there is a high tendency that farmers of the two groups will join the project and expand rubber growing areas in the future. The farmers who did not join the project were waiting for the project outcomes performed by their neighbors. The rubber trees will give first yield during 2011-2012. They might become interested in growing rubber trees if they find that it is worthwhile to grow them. Thus, the project might be successful in a long-term if there is further investigation and evaluation in the near future.

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Research article

Isolation of Phosphate-Solubilizing Bacteria from Different Fields Crop Productions

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Abstract There are many factors involved in the availability of P through phosphatases efficiency such as the microbial fauna, soil temperature, bacteria communities, plant physiological state, type of rooting system, age of the plant and the location of ectomycorrhiza on the root. To assess the effects of different crop productions on the diversity and the efficiency of phosphate-solubilizing bacteria (PSB), this study isolated phosphate-solubilizing bacteria from paddy fields and eggplant fields before and after harvest in Kochi prefecture in Japan. The results showed that a total of 9 heterotrophic bacterial isolates present different degrees of mineral tri-calcium phosphate ($Ca_3(PO_4)_2$)-solubilizing activities. *Klebsiella pneumonia* in the paddy field with water and in the eggplant fields which solubilize $Ca_3(PO_4)_2$ better than $FePO_4$ and $AlPO_4$. Especially, *Klebsiella pneumoniae* strain M-AI-2 and *Gluconacetobacter sp*. isolate code Ek01 in the eggplant fields seem to have the capacity to solubilize insoluble forms of $AlPO_4$ and $FePO_4$ which are the main forms of insoluble phosphates in acid sandy soils.

Keywords phosphate solubilization, phosphate-solubilizing bacteria, field crop production

INTRODUCTION

Phosphorus is considered as the principal yield-limiting nutrient along with nitrogen (Zahran, 1999). Phosphorus deficiency is a primary constraint to plant growth in many terrestrial ecosystems (Bonser et al., 1996) especially, in acid sandy soils with high levels of P fixation by Fe and Al oxides. Plants use phosphorus for adenosine triphosphate (ATP) synthesis. ATP is an essential energy-provider molecule for the metabolism of organic compounds containing P such as sugar phosphates, phospholipids, nucleic acids, nucleotides and coenzymes which are key molecules for biological metabolisms (Schachtman et al., 1998). Plants dependent on symbiotic N_2 fixation have therefore high ATP requirements for nodule development and function (Ribet and Drevon, 1996) and need additional P for signal transduction and membrane biosynthesis.

Normally, plants and microorganisms produce phosphatases which are released in the rhizosphere and catalyze the hydrolysis of organic phosphate esters to orthophosphate anions. Radersma and Grierson (2004) concluded that root exudation of acid phosphatases and organic acids increase the P solubility in the rhizosphere. The phosphatases efficiency is related to various factors such as the microbial fauna, the soil temperature and humidity and more particularly the

associated bacteria communities (Zahran, 1999). Phosphatases activity can be induced by low inorganic phosphorus concentrations in the soil solution, but other factors can play a significant role as the environmental conditions, the physiological state of the plant, the type of rooting system, the age of the plant and the location of ectomycorrhiza on the root (Antibus et al., 1997).

Within the rhizosphere, the solubility of phosphate can be enhanced by the secretion of organic acids in root exudates and enable phytic acid to be more available to microorganisms responsible for its mineralization. Despite its importance in soils and particularly in different crop productions, the isolation of phosphate-solubilizing bacteria and their P solubilization capacity in the phosphorus cycle remains poorly studied and only few studied have aimed at exploring the microbial diversity and its role in the regulation of the cycle of the phytic acid. Finally, the analysis of the ability of bacterial isolates to hydrolyze phytic acid will enable to create a highly valuable basis for the use of these isolates as bio-inoculums or for the use of enzymes in the food industry. The objectives of this research were to isolate phosphate-solubilizing bacteria (PSB) from different field crop productions in Kochi, Japan, evaluate their P solubilization capacity and identify the PSB.

METHODOLOGY

Isolation of phosphate solubilizing bacteria by enrichment culture

The experiment was conducted in Kochi prefecture, Japan. Kochi prefecture is characterized by a semiarid tropical climate with a distinct rainy season from May to September. Soil samples were collected from paddy fields and eggplant fields from the soil surface until a depth of 10 cm. To isolate phosphate-solubilizing bacteria, 5 g of soil samples were transferred to the National Botanical Research Institute phosphate growth medium (NBRIP). Per liter, this growth liquid medium contains 10 g glucose with 5 g of different insoluble forms of phosphate ($AlPO_4$, $Ca_3(PO_4)_2$ and $FePO_4$), 5 g $MgCl_2 \cdot 6H_2O$, 0.25 g $MgSO_4 \cdot 7H_2O$, 0.2 g KCl and 0.1 g $(NH_4)_2SO_4$. Additionally, modified NBRIP media, containing either $FePO_4$ or $AlPO_4$ as the sole source of P, were also used for the initial screening step. The pH of the agar medium was adjusted to 7.0. Tricalcium phosphate was autoclaved separately and the other sterile ingredients were aseptically mixed after autoclaving. Erlenmeyer flasks containing 50 mL of the medium with inoculants were incubated for 7 days at 30 °C on a IWAKI Incubator shaker at medium speed (150 cycles min^{-1}). For the following week, 5 ml of this incubated medium with inoculants were transferred into 50 mL Erlenmeyer flasks again with new liquid medium for 7 more days at 30 °C on a IWAKI Incubator shaker at medium speed (150 cycles min^{-1}). At the end of each week in NBRIP growth liquid media, aliquots of each dilution were spread on NBRIP medium and incubated at 30 °C for 14 days. Colonies were selected from the plates on the basis of the appearance of a clear halo; the clones were further purified on minimal medium based on each insoluble phosphate forms.

Mineral phosphate solubilization assays

The phosphate solubilizing (PS) activity of each of the isolates was determined by molybdenum-blue method (Murphy and Riley, 1962). The isolates were grown in NBRIP liquid medium containing different insoluble forms of phosphate ($AlPO_4$, $Ca_3(PO_4)_2$ and $FePO_4$) for 3 days at 30 °C on a IWAKI Incubator shaker at medium speed (150 cycles min^{-1}). The solubilization efficiencies were determined by reaction with ammonium molybdate for phosphorus compounds as ammonium phosphomolybdate and reduced with a compound ascorbic acid to molybdenum blue. Then, the isolates were incubated for 30 min at room temperature for color development. And finally, the absorption of light in the wavelength range 595 nm was measured by 680 XR Microplate Reader.

PCR amplification of 16S rRNA and sequencing

The gene-encoding 16S rRNA was amplified from selected strains by the polymerase chain reaction (PCR) using bacterial universal primers proR2 (5′-AGAGTTTGATCMTGGCTCAG-3′) and 907R (5′-CCGTCAATTCCTTTRAGTTT-3′) (Weisburg et al., 1992). The PCR mix consisted of 0.25 μM of each primer, 1X PCR buffer and 0.2 U of Taq DNA polymerase. A suspension of cells on MilliQ water, coming from a fresh colony grown on Nutrient Agar, was used as target DNA. The following cycle conditions were used: 85 °C for 5 min, followed by 35 cycles of 95 °C for 1 min, 55 °C for 1 min and 72 °C for 2 min, and a final extension step at 72 °C for 3 min (Lane, 1991).

The PCR products were purified from agarose gels with the PCR Clean-up Gel Extraction Kit (Macherey-Nagel, Germany) and sequenced. The nucleotide sequences were compared using the BlastN program (Altschul et al., 1997), and the closest match of known phylogenetic affiliation was used to assign the isolated strains to specific taxonomic groups.

RESULTS AND DISCUSSION

Isolation of PSB from soil samples

The screening strategy employed during this research enabled the identification of PSB colonies on NBRIP medium containing different insoluble forms of phosphate ($AlPO_4$, $Ca_3(PO_4)_2$ and $FePO_4$) as sole P source. No colonies exhibiting a clear halo were observed on agar plates supplemented with either $FePO_4$ or $AlPO_4$. Approximately 9 bacterial isolates showed clear halos of $Ca_3(PO_4)_2$ solubilization. Some obvious differences in the size of the halos of different isolates were observed (not shown). This preliminary observation suggested the existence of bacterial isolates exhibiting different degrees of PS efficiencies in the soil samples collected. To confirm this observation, the 9 purified isolates were tested following the protocol of Murphy and Riley (1962), a method previously shown to be a reliable and qualitative indicator of the PS activity of different bacterial isolates. Table 1 shows the OD595 nm shift of the culture supernatants of each of the 9 PSB isolates after a 3-day cultivation period in NBRIP medium. Indeed, some isolates did not show any significant change in the absorbance of the supernatant while others exhibited OD595 nm changes in the absorbance. Furthermore, we noticed that the most dramatic changes in the color of the supernatant correlated with a total solubilization of $Ca_3(PO_4)_2$ in the medium. Based on these results we selected 9 isolates exhibiting the highest PS activities for further studies. The solubilization efficiencies of these isolates were calculated and are shown in Table 1. After evaluating their P solubilization capacity, we concluded that all of the 9 isolates can solubilize $Ca_3(PO_4)_2$ better than $FePO_4$ and $AlPO_4$ especially the isolates with the codes Rk02, Rk03 and Ek04. Moreover, isolate codes Ek01 and Ek04 look interesting for solubilizing $FePO_4$ and $AlPO_4$, which are the main forms of insoluble phosphates in acid sandy soils.

Table 1 Phosphate solubilizing effectiveness of tested bacteria, 3 days after inoculation

Isolate Code	Solubilized Phosphate (mgP/l) from		
	$Ca_3(PO_4)_2$	$FePO_4$	$AlPO_4$
Rk01	1,015b	0c	0b
Rk02	1,534a	0c	0b
Rk03	1,580a	0c	0b
Ek01	805d	93a	0b
Ek02	941bc	0c	0b
Ek03	943bc	0c	15b
Ek04	1,548a	47b	161a
Ek05	770d	0c	0b
Ek06	912c	0c	0b

Identification of PSB isolates

Nucleotide sequencing of PCR-amplified 16S rRNA genes and sequence comparison with available data in the GenBank using the BLAST algorithm (Altschul et al., 1997) allowed us to identify the majority of the PSB isolates (Table 2). Based on a sequence identification of 94% or greater (Van Waasbergen, 2004), they were all affiliated to the β- or γ- sub-divisions of the Proteobacteria: three isolates were similar to species of the *Klebsiella* genus, another three were similar to *Gluconacetobacter sp*. and one was closely related to *Sphingobacterium sp*. *Klebsiella pneumonia* in the paddy field with water and in the eggplant fields which solubilize $Ca_3(PO_4)_2$ better than $FePO_4$ and $AlPO_4$. *Klebsiella pneumonia* strain M-AI-2 seems to be more interesting to solubilize $AlPO_4$ and $FePO_4$. Moreover, *Gluconacetobacter sp*. isolate code Ek01 in the eggplant field in Kochi University can solubilize $FePO_4$ as well.

Table 2 Identification of PSB isolates from soil samples of paddy fields and eggplant fields in Kochi by 16S rRNA sequencing after inoculation

Isolate Code	Length of 16S rRNA gene sequenced	GenBank accession no.	Most closely related organism/ Species (Strain)	Accession no.	Gene identity (%)
Rk01	503	lcl/23633	*Gluconacetobacter sp*.	EF493039.1	97
Rk02	814	lcl/45645	*Klebsiella pneumoniae*/ BRp_2A	JN644536.1	100
Rk03	488	lcl/20369	*Klebsiella pneumoniae*/ BRp_2A	JN644536.1	99
Ek01	546	lcl/19025	*Gluconacetobacter sp*.	EF493039.1	99
Ek02	710	lcl/39135	*Gluconacetobacter sp*.	EF493039.1	99
Ek03	990	lcl/26231	*Gluconacetobacter sp*.	EF493039.1	99
Ek04	938	lcl/51159	*Klebsiella pneumoniae*/ M-AI-2	FJ828890.2	99
Ek05	966	lcl/30399	*Uncultured bacterium* clone MS-115	GQ477848.1	99
Ek06	983	lcl/27533	*Sphingobacterium sp*. 21	CP002584.1	94

CONCLUSION

Klebsiella pneumoniae showed the highest P solubilization capacity in the paddy field with water and eggplant fields. *Klebsiella pneumoniae* strain M-AI-2 and *Gluconacetobacter sp*. isolate code Ek01 in the eggplant field in Kochi University seem to have the capacity to solubilize insoluble forms of $AlPO_4$ and $FePO_4$.

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Research article

Groundwater Resources Development by Riverbank Filtration Technology in Thailand

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Abstract Riverbank Filtration (RBF) is the influx of river water to the aquifer induced by a hydraulic gradient and it is a low-cost and efficient alternative water treatment for drinking-water applications. The objectives of the project are to study the feasibility of RBF technology, design the pilot system, evaluate the feasibility of the project on socio-economic and environmental impact and transfer the knowledge of RBF technology to the state enterprise organizations, local administrative authorities and other related parties. The project consists of 3 phases, fesibility study (11 months), design and construction (14 months) and operation and maintenance (12 months). Therefore, the specific objective of this paper is to review the basic concepts of the first phase and present some case studies such as Kompahangpet area for detailed study prior the design and construction phase. The target areas are initially focused along the main river courses in Thailand such as Mekong, Ping and Chaophraya Rivers. The study procedure consists of detailed investigations: hydrology, hydrogeology, water demand, suitable socio-economic conditions, and appropriate environments. Mathematical groundwater modeling will be employed to evaluate the suitability of the selected sites. Then we will design pilot system for large scale groundwater resources development to verify that the method could be successfully employed for water resources management and could be further expanded to other areas and extended to other interested parties or organizations in the future.

Keywords riverbank filtration technology, groundwater and surface water conjunctive use, hydrology, hydrogeology, water resources management

INTRODUCTION

Riverbank Filtration (RBF) is the influx of river water to the aquifer induced by a hydraulic gradient. Collector wells located on the banks in a certain distance from the river (Figs. 1 and 2) create a pressure head difference between the river and the aquifer, which induces the water from the river to flow downward through the porous media into the pumping wells. By applying this system of water supply extraction, two different water resources (surface and shallow groundwater) are in conjunctive use. Riverbank Filtration (RBF) is a low-cost and efficient alternative water treatment for drinking-water applications. There are two immediate benefits to the increased use of RBF: minimizing need for adding chemicals like disinfectants and coagulants to surface water to control pathogens, and decreasing costs to the community without increased risk to human health. RBF has been successfully practiced for more than 100 years in European countries and is a current

method for water supply in many countries. For example, 50% of potable water supplies in the Slovak Republic, 45% in Hungary, 16% in Germany and 5% in the Netherlands are obtained from the riverbank filtration system (Grischek et al., 2002; Hiscock and Grischek, 2002; Tufenkji et al., 2002 and Lee and Lee, 2010). RBF has also been applied to acquire drinking water in many cities in the United States.

In Thailand, the Department of Groundwater Resources (DGR) awarded financial support to a consultant consortium to carry out the study on the feasibility of developing the RBF project along the major rivers to mitigate water shortage problem and provide optional supplementary water sources for domestic and industrial consumption. One of the main tasks in the RBF development project is the first phase, which is costly and time consuming. It is expected that after the pilot RBF system in Thailand is constructed and completed, the knowledge and know-how from the project will be used for the development of the master plan for the RBF system in the whole country. The RBF project, if successful, will demonstrate the systematic and sustainable integrated management of surface water-groundwater conjunctive use so as to increase efficiency in the mitigation and remediation of yearly water shortage problem in the future.

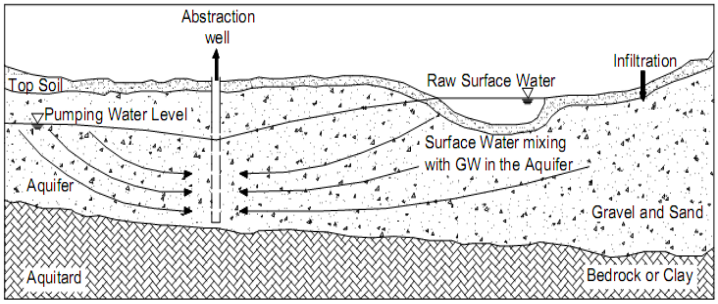

Fig. 1 Generalized schematic section of a riverbank filtration site (After Ray, 2002)

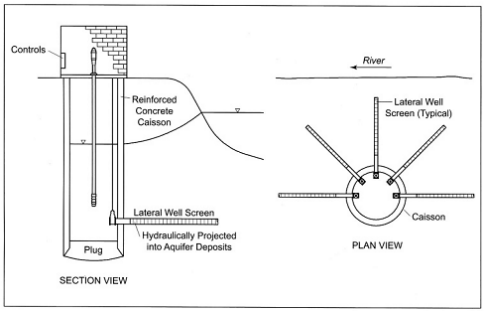

Fig. 2 Cross section and plan view of a horizontal collector well (After Hunt, 2010)

METHODOLOGY

There are five main tasks conducted during the feasibility study phase (I) as shown in Fig. 3, namely 1) Data collection, compilation and analysis, 2) Selection of the potential areas for RBF construction (at least 8 sites), 3) Field investigations, 4) Public dissemination and participation, and 5) Formulation of the master plan of RBF for Thailand.

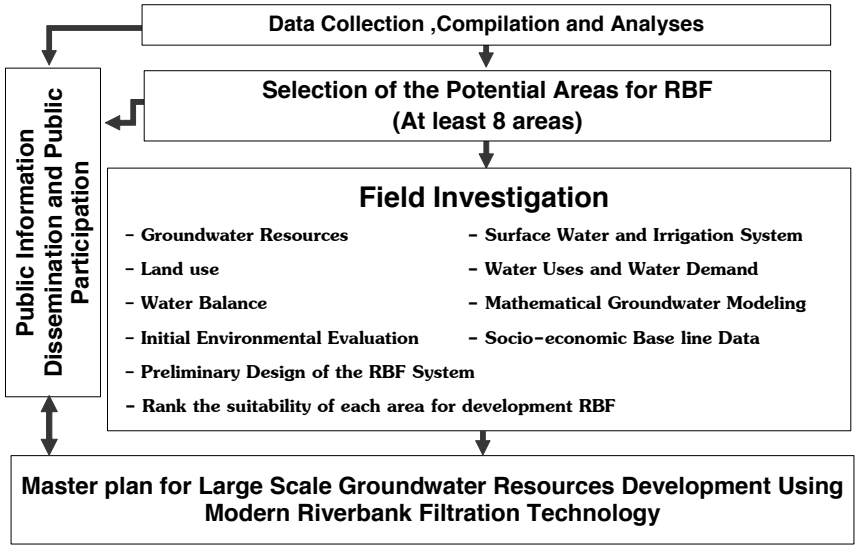

Fig. 3 Protocol of the feasibility study phase (I)

DEVELOPMENT OF THE SITE SELECTION PROCEDURE

In this study, the development of the site selection criteria for the RBF was initiated by reviewing and compiling existing RBF case studies worldwide. The various site selection criteria from the available case studies were focused upon the key performance indicators for RBF system. Essential data clusters and necessary specific parameters were identified and categorized. The selection procedure is divided into 3 steps (Fig. 4), namely; Step 1: Potential River Basin Level, attempts to identify the RBF potential areas in Thailand at the river basin (regional) scale; Step 2: Potential Local Areas Level, attempts to identify the RBF potential local areas within the potential river basins obtained from Step 1; Step 3: Potential Site Level, attempts to identify the RBF potential sites and locations within the local areas obtained from Step 2. The potential sites and locations obtained from Step 3 will be used for more detailed site investigations to determine the RBF key performance parameters for the RBF system design and construction. After more detailed examination of existing available data was carried out, a new adjustment and arrangement of data groups and selection procedure was conducted. Considering the site selection procedures, steps and selection criteria in Fig.4, a series of thematic maps were compiled or prepared for each selection steps. River basin map in Thailand (Fig. 5) and the distribution of areas 2-km away from main riverbank were acquired to overview the availability of surface water. The thematic map from Quaternary geologic map was overlaid on the groundwater quality map to obtain the RBF hydrogeologic suitability map. The preliminary potential areas for the RBF system derived from Fig. 6 covering approximately 15,839 km^2. The river hydrograph information shows that the river flow of the main rivers varied from 4 - 12 months flow duration.

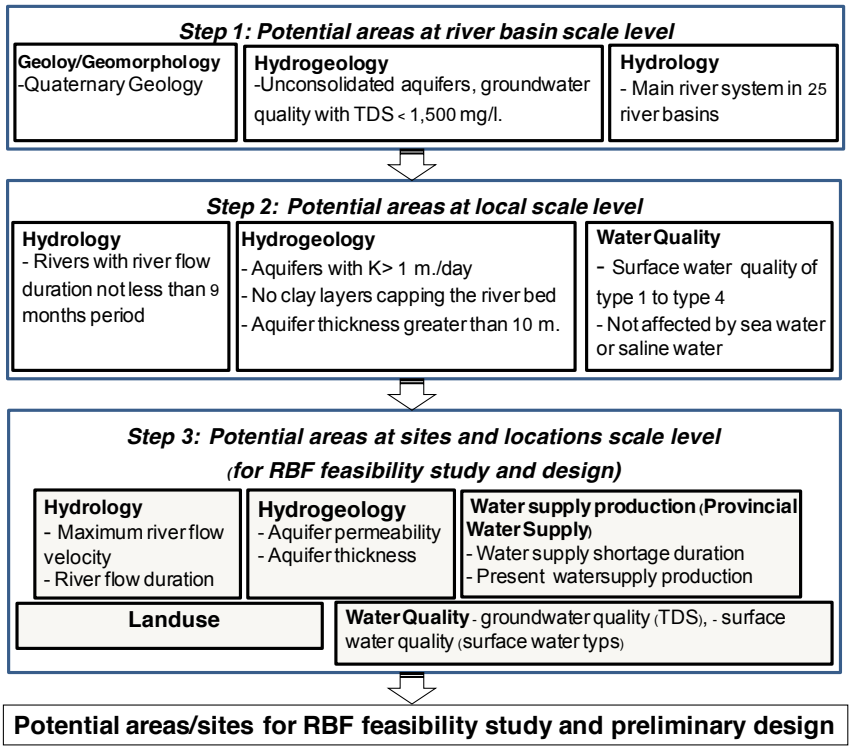

Fig. 4 Overall procedures for RBF site selection

River water quality map was obtained from the Department of Pollution Control. The RBF aquifer thickness and aquifer permeability were reviewed and compiled from the existing RBF system case studies and the range of practical aquifer thickness and aquifer permeability values were identified and the suitable range was selected to fit the existing available data for Thailand. A total number of 13,581 available groundwater wells were compiled from the National Groundwater Database, DGR. A number of 4,881 groundwater wells with well logs were sorted and 414 wells satisfied the criteria. The distribution of 414 groundwater wells were prepared as well as

hydrologic data consisting of existing 190 river gauging stations, river cross sections and profiles, river hydrographs, and river flow velocity were compiled and analyzed. Land use data and maps of various scales were compiled from the existing database of the Department of Public Works and the Department of Land Development. The expected main water users from the RBF system in Thailand are the Provincial Waterworks Authority. Water demand for provincial water supply is, therefore, considered as one of the parameters for RBF system site selection. The water demand for provincial water supply as of 2010 was compiled.

At the local and site suitability scale level, the considered site selection criteria include 5 components, namely, hydrology, hydrogeology, water quality, land use, and provincial water supply production capacity as categorized, scored and weighted in Table 1. Based on the scoring and weighting of the selection criteria, there are twelve potential areas as indicated in Fig. 6. Subsequently, the RBF system key performance parameters for preliminary RBF system will be systematically analyzed for designing and constructing for the first two sites in the phase II. The site investigation data determined from this stage of data acquisition as shown in Figs. 7, 8 and 9 are representing one of the detailed case studies (Kamphaengphet area).

Table 1 Scoring and weighting of selection criteria

Type	Selection Criteria	Unit	Score			Weight
			1	3	5	100
1	**Hydrology**					
1.1	River Flow Velocity	m/sec	0.5-1	1-1.5	≥ 1.5	10
1.2	River Flow Duration	Month	9	10-11	12	15
2	**Hydrogeology**					
2.1	Aquifer Thickness	m.	10 – 14.9	15 – 19.9	≥ 20	20
2.2	Aquifer permeability	m./day	1 – 4.9	5 – 9.9	≥ 10	10
3	**Water Quality**					
3.1	Surface Water	Water Type	4	3	1 - 2	5
3.2	Groundwater (TDS)	Mg/l	601 - 1,500	301 - 600	≤ 300	10
4	**Landuse (RBF system construction site)**	Landuse Type	Community/ industry	Agriculture	Open/ public	5
5	**Water Supply Production (Provincial Water Supply)**					
5.1	Raw water shortage	Month	< 1	1 - 3	≥ 3	5
5.2	Present Water Supply Production	mil. cu.m. /year	<1	1-5	≥ 5	20

CASE STUDY

Kamphaengphet area (No. 6 in Fig. 6) was selected by a ranking procedure, where the detailed study including hydrologic and hydrogeologic investigations was conducted. The Ping River is the major river flowing across Kamphaengphet Province which is located in Central Thailand. Hydrologic investigation consists of the study of river morphology, infiltration tests (field and laboratory), stream profile measurements and water quality sampling as shown in Fig. 7. There are 32 observation wells (diameter of 2 inches) and 12 test wells (6 inches), pumping tests and quantity and quality monitoring of surface and groundwater was conducted over the area of 70 km^2 during the year 2011. A hydrogeologic map under a scale of 1:50,000 was constructed in order to evaluate the yield of shallow groundwater and interaction between river water and shallow groundwater. Subsequently, detailed physical and chemical parameters were analyzed and then a numerical flow model was applied to determine the available yields of groundwater and the behavior of interaction of river water and groundwater. Moreover water demand from Provincial Waterworks Authority of Kamphaengphet Province and initial engineering design, public hearing and SWOT analysis

(Strength, Weakness, Opportunity and Threat) from the local communities will be evaluated for the final site selection prior the construction phase (Phase II).

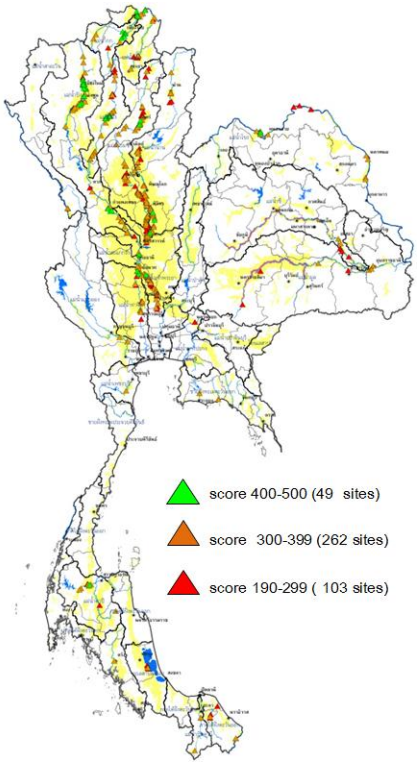

Fig. 5 Locations of the potential areas for RBF feasibility study

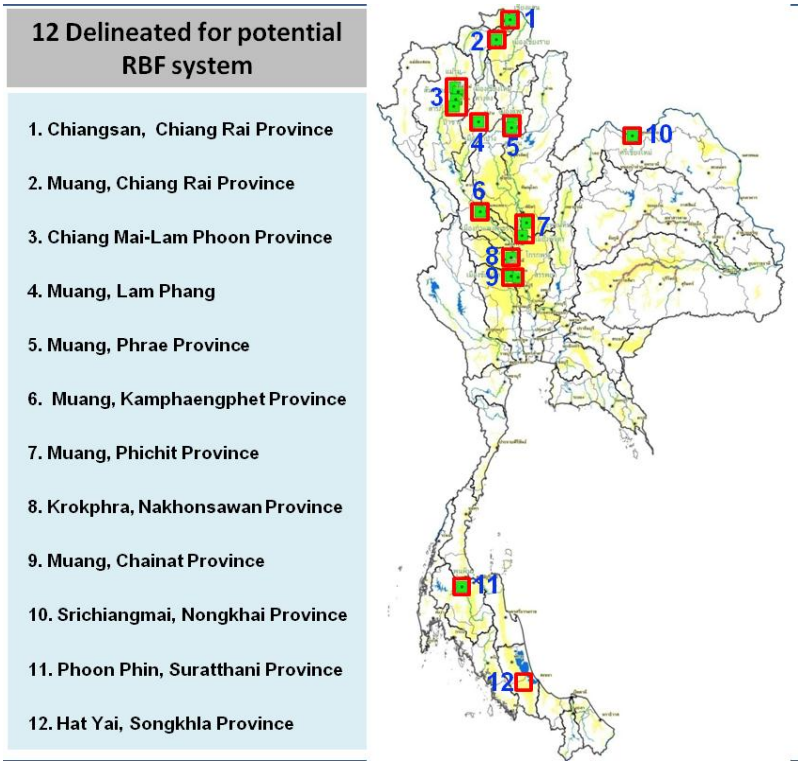

Fig. 6 Twelve areas delineated for potential RBF system detailed feasibility study and design Case study: Kamphaengphet Area

SUMMARY AND CONCLUSIONS

RBF has the potential to supply water to numerous cities around the world. Many cities are currently using surface water that is often of poor quality. Gradual conversion of surface water intakes to bank filtration can help improve the water quality. The development of the site selection criteria for the RBF system was initially commenced by identification of selection criteria for regional area scale site selection and then zoom-in into the local area scale level and finally to the site and location scale level. The established key performance criteria for the RBF system site selection include 5 groups of data sets, namely; hydrology, hydrogeology, water quality, land use in the construction site, and water demand. Once the potential sites or locations for the RBF system are finally selected, a detailed field investigations program was made for the RBF site characterization. The obtained site parameters will be used for preliminary RBF system design and pilot construction.

By the way, RBF system is a new technology of conjunctive use of surface and groundwater resources for Thailand. RBF also offers an innovative solution for water resources management of the project. It offers many advantages in terms of low cost, simplicity, robustness etc. A successful project depends upon strong technical understanding combined with support by government, water authorities and communities.

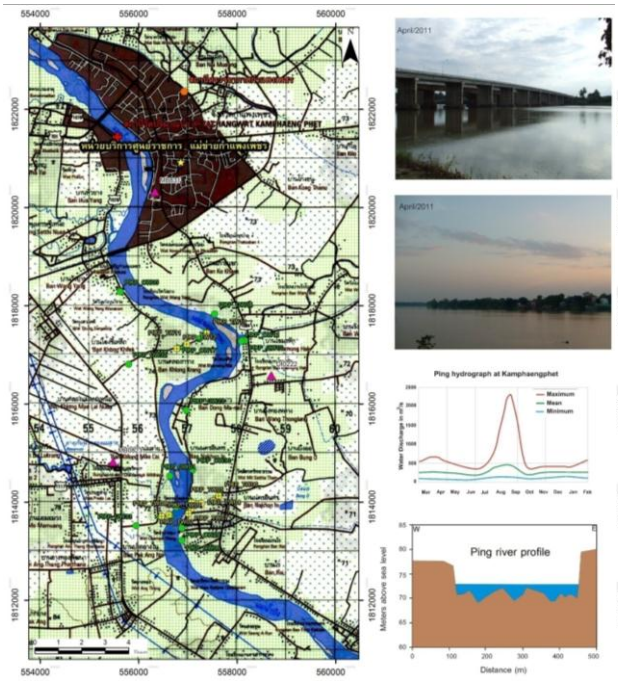

Fig. 7 Topography and hydrology of Kamphaengphet area

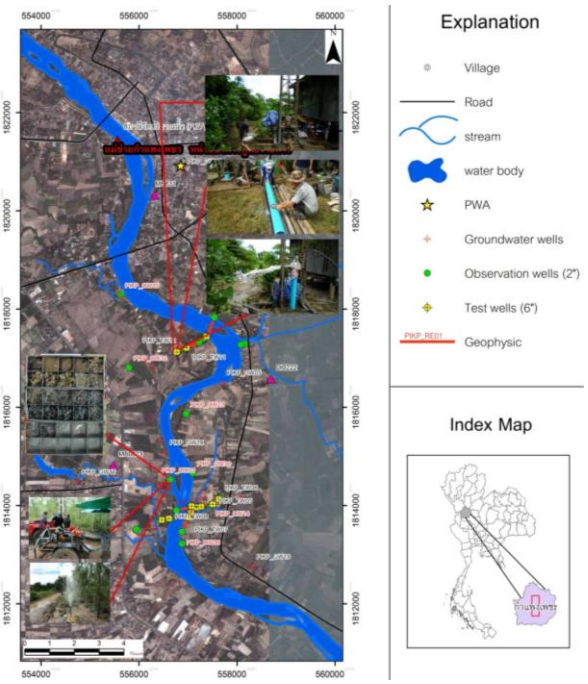

Fig. 8 Hydrogeologic investigations: observation well and test well drilling and monitoring

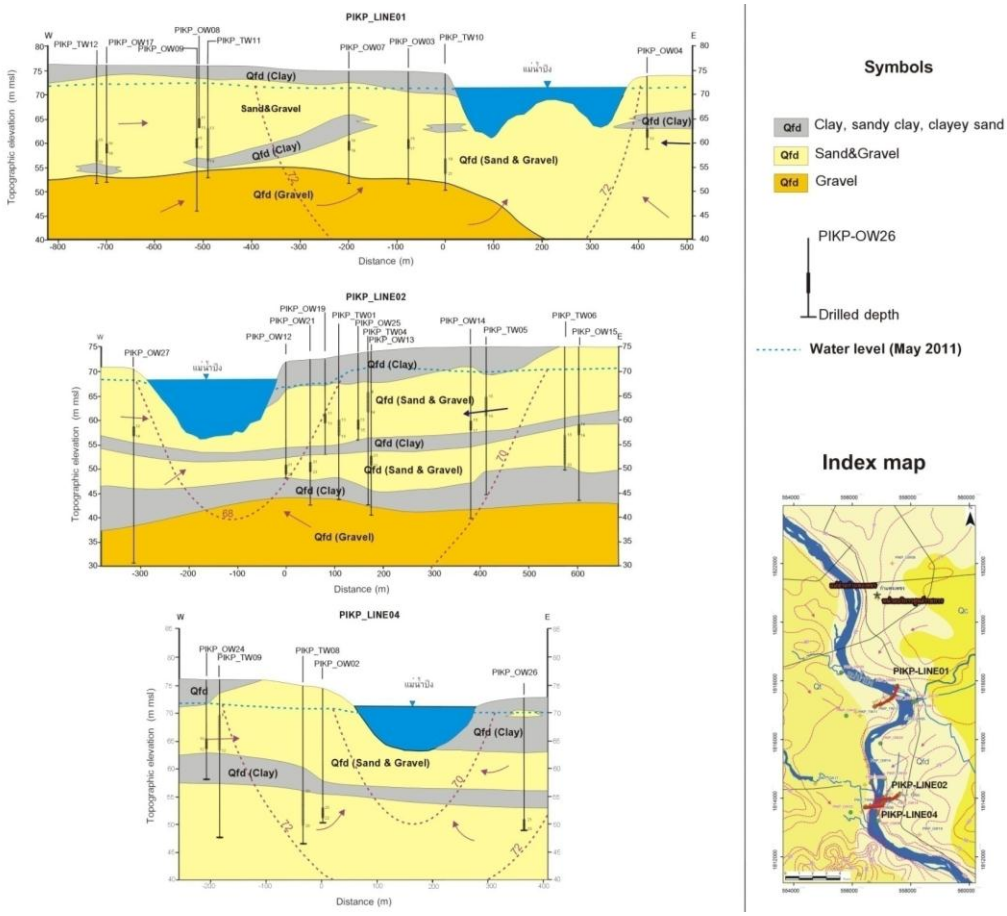

Fig. 9 Hydrogeologic cross sections of the potential RBF site (Kamphaengphet Area)

ACKNOWLEDGEMENTS

Our appreciations and thanks are delivered to the Department of Groundwater Resources (DGR), Ministry of Natural Resources and Environment, Thailand, for providing financial support to the first phase of the RBF project. Special thanks to the participating research staff from the Groundwater Research Center (GWRC), Khon Kaen University, for assistance in graphic preparation and arrangement.

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Research article

Farmers and Wastewater Management - A Case Study of Integrated Urban Wastewater Management and Agriculture in Hanoi, Vietnam

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Abstract The amount of wastewater utilized by urban farmers worldwide is expected to increase due to the rising amount of wastewater generated from urban population. Despite the contribution of urban farmers to generate vast quantity of urban waste including solids and wastewater through agricultural practices, these activities are little recognized by municipal's management authorities or looked down by the communities, resulting in informal, unplanned and spontaneous practices. Twenty nine farmers from two communities in peri-urban area of Hanoi were involved in the participatory investigation of individual managerial capacity on farming related to wastewater irrigation, i.e., personal characteristics and skills. GIS application and water sampling technique were employed to study the physical environment; questionnaires, in-depth interviews and participatory observation were used to investigate the social, economic and institutional environment that was hypothesized to influence farmers' managerial capacity. From the assessment of water quality, it can be seen that wastewater irrigation has the potential to be reused for farmers in terms of nutrient recovery and income generation as well as brings high risk for human health relating to pathogens. The factors that influenced farmer's capacities of wastewater irrigation governance can be categorized into: *Internal factors:* (1) age of farmers, (2) experience in wastewater irrigation, (3) knowledge and skill, (4) motivation in wastewater agriculture; *External factors:* (1) institutional environment including regulation on agricultural wastewater use, decentralized/centralized wastewater management, spatial separation on governance responsibilities of different department, state of participatory in local cooperatives; (2) physical environment such as climate change, diseases outbreak, constituent in wastewater; (3) social environment consists of social linkage and norms; (4) economic environment: consumer buying behavior and income from wastewater agriculture. This research concludes that the farmers' managerial behavior were driven more by economical and physical factors, while institutional and social factors appeared to discourage farmers from high performance in wastewater farming.

Keywords farmer managerial capacity, wastewater irrigated agriculture, sustainability and urban wastewater management.

INTRODUCTION

Due to the improper management of wastewater in many cities in Vietnam, a large number of urban and peri-urban farmers are engaged in the practice of wastewater for irrigation and aquaculture. Especially in Hanoi, the total area irrigated with wastewater is 43,778 ha involving 658,300 farmers (Raschid-Sally and Jayakody, 2008). Despite the amount of wastewater utilized by urban farmers, it is expected to increase due to the rising amount of wastewater generated from urban population, and the contribution of urban farmers to generate vast quantity of urban waste

including solids and wastewater through agriculture practices (Brody Lee et al, 2010), these activities neither received much recognition by municipal's management authorities (Do et al., 2006) nor looked down by the community. Hence, wastewater unitization by urban farmers remains as informal, unplanned and spontaneous practices.

The farmers' managerial capacity of wastewater irrigation was studied from both individual aspect of farmers' management capacities (i.e. personal characteristics and skills including drives and motivations, abilities and capabilities and biography) and farmers' performance in the environment that is influenced by various factors. Boehlje and Eidman (1984) distinguished four major dimensions: (1) the institutional environment; (2) the social environment; (3) the physical environment; and (4) the economic environment.

MATERIALS AND METHODOLOGY

Study area: Two communities in peri-urban, Thanh Liet and Dong Ba in Hanoi were selected due to their typical practices of wastewater irrigation and characteristics of participatory irrigation management (Fig. 1).

Thanh Liet is located about 9 km to the southwest of Hanoi along the 2 major drainage rivers of metropolitan areas of the city (To Lich River to the East and Nhue River to the Southwest). Domestic and industrial effluent from urban areas of Hanoi is diverted to the field with an area of approximately 194.51 ha through pumping stations along the Tolich River, which involved 201 Farmer Households. There were 105 ha of agriculture land used for cultivating rice; however, due to contamination of wastewater, those rice paddies were converted to integrated rice paddy, aquatic plant and fish ponds. Fish and aquatic plant cultivation generates main income for farmers in Thanh Liet.

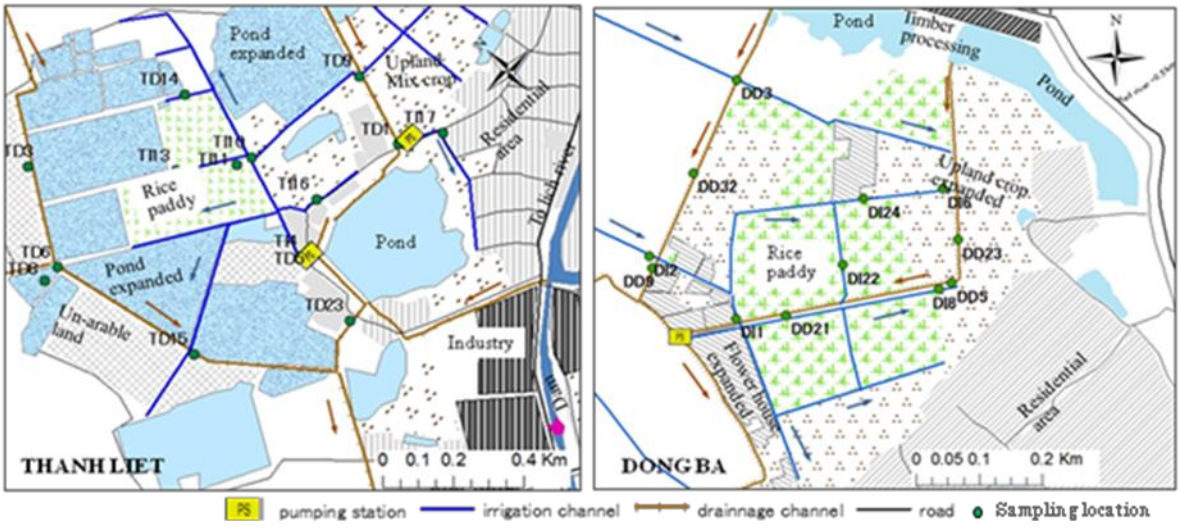

Fig. 1 Agricultural land use map of study areas: Thanh Liet (left) and Dong Ba (right)

Dong Ba is located about 15 km from the centre of Hanoi. In dry season due to water shortage, 24 ha of agricultural area are irrigated with diluted wastewater which is the mixture of rainwater and wastewater generated by the village's daily activities. The dominant crop is rice with a yield of 5.15 ton/ha. 525 farmer households in Dong Ba only produce rice for family consumption. Compared to Thanh Liet, agriculture production in Dong Ba does not have much economical value.

Site survey and water sampling: GIS device was used to map the study area, irrigation systems, water sampling points and cropping pattern. Physical characteristics of irrigation water (temperature, pH, conductivity) were measured onsite using Hanna Instruments, portable measurement instrument. Chemical characteristics were measured onsite using test kits from Kyoritsu Chemical Check Lab. Corp, Japan. Samples were stored in plastic bottles (PET) to

examine Coliform and E.coli in laboratory using bacteria detection paper from SUNCOLI, Japan. The samples were then diluted and incubated in 35-37 ^{o}C for 24 hours.

Data from water sampling (Table 1) showed that many water quality parameters in both areas neither meet the National technical regulation on surface water quality - QCVN 08: 2008/BTNMT nor National Standard -Water quality guidelines for irrigation - TCVN 6773:2000, especially showing very high value of detected E.coli and total coliforms. However, when distributing into the plots, the quality of water showed some improvement from flowing through long distance of channels and undergone natural treatment (Fig. 2).

Table 1 Irrigation water quality in the study area at different points in March 2011

Parameter	QCVN	TCVN	Dong Ba		Thanh Liet			
Sample ID			DI31	DD9	TD22	TD24	TD31	TD32
pH	5.5 - 9	5.5 - 8.5	8.56	7.52	7.37	7.42	7.46	7.46
Conductivity (mS/cm)	-	-	0.27	0.32	0.67	0.65	0.89	0.99
Dissolved oxygen (mg/l)	≥4	-	>9	6	4	<1	<1	<1
Total Dissolved Solid (mg/l)	-	$\leq 10^{+3(1)}$	130	150	345	342	460	500
Chemical oxygen demand (mg/l)	≤30	-	5	20	20	45	120	120
Ammonia Nitrogen(mg/l)	≤0.5	-	1	5	>10	>10	>10	>10
Nitrate-Nitrogen (mg/l)	≤10	-	2	2	2.2	0.1	0	0
Phosphate –Phosphorus (mg/l)	≤0.3	-		0.2	1.5	1.1	2	2
Total Iron Fe^{3+}+Fe^{2+} (mg/l)	≤1.5	-	<0.3	<0.3	0.4	0.8	0.5	0.5
Copper Cu(mg/l)	≤0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc Zn (mg/l)	≤1.5	$\leq 1^{(2)}$ $\leq 5^{(3)}$	0.2	0	0.5	0.5	0.5	0.2
Lead Pb (mg/l)	≤0.05	≤0.1	-	-	0.2	0.5	0.5	0.5
E.coli (MPN/100ml)	≤100	$200^{(4)}$	200	-	233	1400	-	-
Total coliforms (MPN/100ml)	≤7500	-	$38x10^4$	-	$26x10^4$	$23x10^5$	-	-

Note:
DI31: sample taken at the inlet of Dan Phuong water gate.
DD9: sample taken at the drainage canal to the pump station in Dong Ba
TD24: sample taken at the Tolich river
TD22, TD31, TD32: samples taken at the Ba Xa drainage canals

(1) applied for agriculture land with irrigation system
(2) applied for agriculture soil with pH≤6.5
(3) applied for agriculture soil with pH>6.5
(4) applied for restricted crops (vegetables and crops that eaten raw)

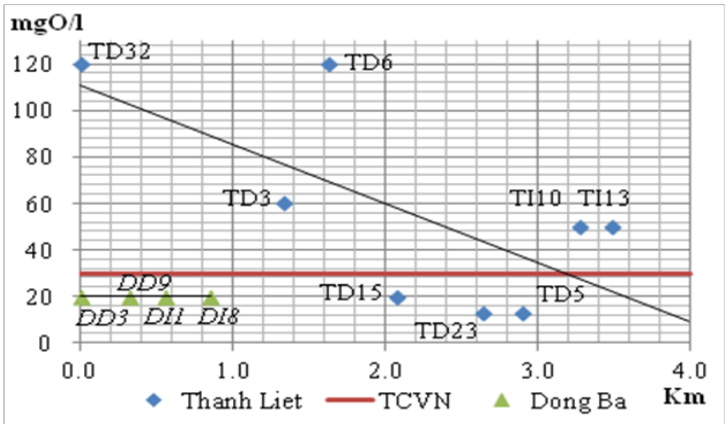

Fig. 2 Chemical Oxygen Demand (COD) variation along main channels, March 2011

The risk of diarrheal disease from consumption of vegetables irrigated with wastewater were estimated of 2 x 10^{-3} (WHO, 2006). Wastewater irrigation in the studied areas has some potential

to be reused by farmers in terms of nutrient recovery (e.g. rich content of Nitrogen and Phosphorus) and income generation. However, it brings about high risk for human health relating to pathogen and other hazardous substances.

Interview and participatory observations: General information of the communities and agriculture activities of the farmers were obtained from key informants. Combined informal interviews and participatory observation were conducted to farmers either at the field when working or at their homes.

A total of 29 farmers were interviewed from both areas (Thanh Liet 13/Dong Ba 16). The number of female participants outnumbered men (18 female /11 male farmers). Most farmers interviewed were between age 40 and 60 (72.4%); all were literate with primary and upper education and most were involved in rice cultivation. Farmers in Thanh Liet were more exposed to wastewater than Dong Ba farmers in terms of exposure time and concentration of wastewater because they spend more time on the field for vegetable farming. Most farmer households have access to hygienic latrines with septic tank while fewer farmer households have access to tap water.

RESULTS AND DISCUSSION

Perceptions on wastewater irrigation: Farmers in Thanh Liet have more experience in wastewater agriculture compared to farmers in Dong Ba. They have more knowledge about the contaminants and risk posed by wastewater, mainly from physical symptoms and experience of diseases. Dong Ba farmers on the other hand are more concerned about invisible risks since they were informed by various channels such as the media or relatives or neighbors, but they insisted that the irrigation water in Dong Ba is from Red river, and therefore it is clean.

Regarding willingness of farmers to adopt measures in 2 study areas, 59% farmers agreed to wear protective clothes; and 76% consider that keeping food and drinks hygienic are effective to keep their physical health.

Behavioral outcome: It is observed that many farmers in Thanh Liet wear protective clothes, especially rubber gloves and rubber boots to protect the skin from contacting the wastewater. This practice can be seen on both women and men. In contrast, very few farmers in Dong Ba answered that they wear gloves and boots, and many of them said it is not necessary and uncomfortable.

Endogenous environment: Managerial capacity can be reflected from age and experience of farmers. Most farmers interviewed were aged above 40. Hence, they gained more experience in managing the farm including irrigation to increase productivity compared to younger farmers. Through practicing wastewater agriculture they receive more knowledge and develop management skill to minimize wastewater risks on crops and health. But on the other hand, old farmers were more hesitating to new technology adoption or carry out new experiments on crops; they prefer their own way of farming that resulted from many years of experience or learnt from parents.

Motivation in farming also affects farmer's managerial behavior by encouraging them to develop knowledge and skills, invest labor and money in wastewater irrigation techniques to increase productivity. Income from fish and flower farming in 2009 ranges from about 150 mil to 700 mil VND (7,500- 35,000 USD) per ha a year, therefore farmers have more motivation to invest money and labor to improve irrigation condition, i.e. making settling ponds or pumping oxygen to boost wastewater treatment processing in the pond and extracting groundwater.

Exogenous environment: The quality of water seems to affect the crop pattern. Thanh Liet farmers show more adaptation than Dong Ba farmers, they shift from rice to other aquatic vegetables. For over the past 10 years, it is estimated that rice paddies were converted to more than 60 ha of fish pond area of a total of 85 ha in Thanh Liet. While in Dong Ba, 9 ha area of rice paddy were converted to flower field (Fig. 1).

Sewage and drainage systems in Thanh Liet and Dong Ba were not served by Hanoi Sewage and Drainage Company (SADCO) but were provided by local irrigation, drainage and sewerage sectors under the Commune's PCs. Wastewater discharged from the communes' everyday activities were collected through combined covered sewage ditches. These ditches transport wastewater to open drains or nearby ponds, being the water area in the commune without any treatment of

effluent. Some ditches are connected directly to irrigation channel or drain channel in the agriculture areas. Wastewater irrigation management by farmers in these areas were recognized as informal, short-term and self-interested due to the separation of farmers from urban wastewater management, ignorance of wastewater irrigation agriculture in the urban food supply chain and lack of regulation relating wastewater reuse and food safety for wastewater irrigated crops. In addition, centralized urban wastewater system in Hanoi makes barriers for farmers in utilizing nutrients in wastewater without bearing the risks of hazardous constituents.

Participation in wastewater irrigation is a fundamental concern for wastewater governance at local level. However, farmers are less motivated to participate and are more dependent on LCs management scheme (normally 2 or 3 times a week), or by the state if the water is taken from Red River through Dan Phuong water gate (about 1.5 km away from Dong Ba). They only need to pay for irrigation service fee and leave the rest to the LCs' responsibilities.

Physical environment includes weather, diseases on crops and state of wastewater influence on productivity, cropping pattern and agricultural land use. These physical factors could either encourage or discourage farmers' motivation to improve the irrigation condition.

Weak social linkage among farmers, between farmers and local authorities, and between farmers and consumers influence the information sharing, which prevent them from applying innovation in farming. Moreover, the contamination of irrigation water seems invisible and is not considered important compared to the normal understanding of dirt. These results are not enough motivation to improve irrigation quality, while more efforts are put on making products look fresh and clean.

Economic environment plays an important role in controlling farmers' behavior toward economic benefits and consumer buying habits. Most of wastewater crops and fish were supplied to urban or nearby markets. However, consumers are not aware of the irrigation aspect but only care about appearance and price. This further induces farmers to produce cheaper products with nice appearance, while, according to farmers, investment in better irrigation conditions does not bring much benefit compared to selling wastewater irrigated products.

SIGNIFICANCE OF THE STUDY

Wastewater irrigation system in Hanoi peri-urban agriculture and urban wastewater management system were found as an integrated system. Despite being linked together regarding urban wastewater and urban food chain, waste-water farmers behaved independently and self interested among peers and others, which results in some short terms measures such as to generate income from wastewater fed fish ponds, aquatic plants or non-food crops, to reduce occupational health risks or to keep food and drinks clean to improve health.

Factors that influence farmer's capacities of wastewater irrigation governance are determined as: internal factors: (1) age of farmers, (2) experience, (3) knowledge and skill, and (4) motivation in waste-water agriculture; external factors: (1) institutional environment including regulation on wastewater use in agriculture, decentralized/centralized wastewater management, spatial separation on governance responsibilities of different departments, state of participatory in local cooperatives; (2) physical environment such as climate change, diseases outbreak, constituent in wastewater; (3) social environment consisting of social linkage and norms; and (4) economic environment: consumer buying behavior and income from wastewater agriculture.

Farmers' behavior was more driven by economical and physical factors while institutional and social factors appeared to discourage farmers from high performance of farming.

Findings from this research were more focused on personal characteristics of farmers and the external factors that influence management capacity of farmers on wastewater irrigated agriculture. However, it is suggested that farmer's managerial capacity should involve decision making process to try to optimize, or at least influence the technical and biological process at farms and to include the assessment of farm results. Nevertheless, a farmer who has favorable characteristics is more likely to have good results in management practices even if there might have some faults in his decision making process.

RECOMMENDATIONS

From the dynamics of internal and external driving factors, the authors suggest that more efforts should be made in institutional and social aspects of urban wastewater management relating to reuse of wastewater taken by farmers. The resilience transition of the system could be enhanced by empowering farmers' managerial capacity toward institutional and social environment. Two mechanisms for strengthening farmers' managerial capacity on wastewater governance via wastewater irrigation are proposed, i.e. strengthening social participation and institutional involvement of farmers.

Farmers should be more involved in the management of wastewater irrigation practice. There is a need for a farmer organization, which acts as a wastewater user association. This organization should be given full authority including planning, design, operation, maintenance, re-habilitation, resource mobilization and conflict resolution.

Cooperation of different governmental bodies and stakeholders along the urban wastewater chain and food chain are vital for supporting and strengthening farmers' managerial capacity. Each stakeholder has to recognize the common goal of safe wastewater irrigated products. Farmers should be recognized as the stakeholder in the management of urban wastewater systems. In this manner, farmers could have access to information to get control over risks and to optimize benefits from wastewater reuse and at the same time, have responsibility over their products. This could therefore prevent farmers from behaving like self-interested or *spot-market*, and could lead to more sustainable and long-term management.

Projects relating farmer capacity building for wastewater irrigation in particularly, NGOs and donors should consider managerial capacity of farmers within the wastewater farming. Farmers are more likely to participate in irrigation management if they have more motivation in wastewater agriculture and they could count on wastewater irrigation as the provision of their livelihood.

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Research article

Growth Situation of *Phragmites australis* (Cav.) Trin. Used in Artificial Floating Islands for Water Purification in Cold Regions

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Abstract In this study, growth experiments of *Phragmites australis* (Cav.) Trin., used as part of artificial floating islands for water purification, were conducted. The Lake Mizusawa, which is the study area, is located in Biei Town, Hokkaido. The area around this lake is hilly and mostly comprises farm fields . Due to the topography and land use, soil particles and fertilizer flow into the lake after heavy rains. This is the most important cause of lake eutrophication. One way to clear up this eutrophied lake is to place artificial floating islands using the *Phragmites* on the lake surface. The *Phragmites* used for the artificial floating islands absorb nitrogen, including the contained in lake's water, to promote lateral buds sprouting. After that, grown lateral buds are cut and hence the pollution is carried away outside the system. However, this method has been little tested in cold regions such as Hokkaido. Thus, on July 2010, we put artificial floating islands in the biotope which was developed on a drained paddy close to the lake. The *Phragmites* grew steadily. There were about four hundreds lateral buds sprouting by October 2010, and the maximum plant length of lateral buds was 0.74 meters. Observed artificial floating islands were left in the biotope during winter. In 2011, the lateral buds sprouted and grew in a shorter period of time compared to 2010. Similarly, maximum plant length of lateral buds was 1.86 meters. Ear emergence was also observed, although it was not observed in 2010. Therefore, it is considered that there was no damage to the *Phragmites* due to the cold. From these results, it was found that the *Phragmites* used for the artificial floating island were able to grow in cold region. Thus, this method is a promising way to improve water quality of Lake Mizusawa.

Keywords water purification, *Phragmites australis* (Cav.) Trin., lake eutrophication, cold region

INTRODUCTION

Biei-cho, Hokkaido, is one of the areas with the most beautiful scenery in Japan. Lake,Mizusawa a representative scenic spot, is known as a stopover for migratory birds and is familiar to people as a precious waterside space. Conservation activities are therefore undertaken in this area to protect the beautiful landscape and local environment.

However, Lake Mizusawa suffers from a significant eutrophication problem arising from the topography and land use of this area. The terrain around this lake is hilly and mostly comprises

farm fields. During periods of agricultural production, large amounts of fertilizer are applied to the fields to increase yield. However, following heavy rains, soil and fertilizer flow into the lake. This is the most important cause of lake eutrophication, which negatively affects the ecosystem and landscape around the lake and leads to occurrence of blue-green algae and generation of an unpleasant smell. Therefore, to preserve this beautiful landscape and local environment, it is necessary to improve water quality.

One way to clear up eutrophied lakes is to place artificial floating islands of *Phragmites australis* (Cav.) Trin. on the lake surface. However, this method, which was suggested by Uchida et al. (1999, 2001), Uchida and Maruyama (1998), and Tazaki et al. (2002), has been little tested in cold regions such as Hokkaido. Tsuji et al. (2009) studied the artificial floating islands of *Phragmites* and confirmed sprouting of lateral buds. However, they were unable to fully examine the subsequent growth because most *Phragmites* plants could not adapt to the changing water level and died as a result of dehydration.

In the present study, we observed the growth of *Phragmites* for 2 successive years. In the first year, the artificial floating islands of *Phragmites* were placed in the biotope in July, and the growth of *Phragmites* was examined. The artificial floating islands were left in the biotope during the subsequent winter to examine the winter hardiness of *Phragmites*. In the second year, the growth was examined from July to September. The results were used to assess the possibility of using the artificial floating islands of *Phragmites* for water purification.

METHODOLOGY

Study area

The study area was at Lake Mizusawa (Fig. 1), a man-made lake at latitude 43°32′14″ north and longitude 142°29′41″ east located at Biei-cho in the central part of Hokkaido. The area (approximately 2×10^6 m^2) around this lake comprises hillside farms. Most farms in this area grow potatoes, beet, and corn, which require large amounts of fertilizer. According to Ote et al. (2011), the amount of nitrogen applied on these hillside farms was 1.8×10^3 kg in 2010. Because the rate of nitrogen runoff from farms was 11%, the nitrogen loading into Lake Mizusawa was estimated to be 2×10^3 kg (Ote et al., 2011).

The biotope on which the artificial floating islands were placed adjoined Lake Mizusawa. This biotope was developed on a drained paddy.

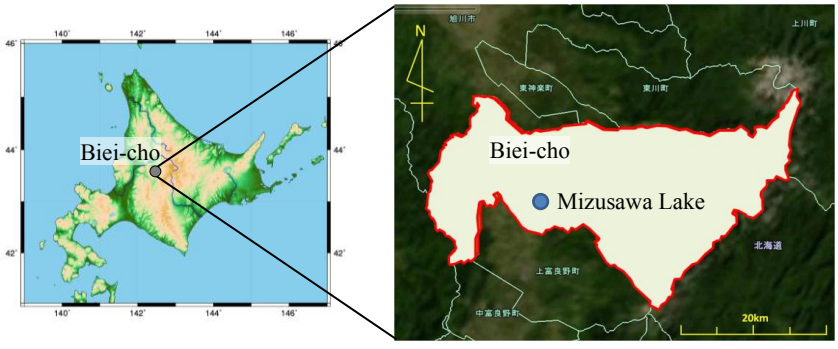

Fig. 1 Study area in Lake Mizusawa located at Biei-cho, Hokkaido

Construction of artificial floating islands

Figure 2 shows the drain mat (Yoshiharakakou Co., Ltd.) used to form the artificial floating islands of *Phragmites*. The mat measured 0.50 m × 0.50 m × 0.02 m (length × width × height). The completed island comprised a drain mat and stems of *Phragmites* plants that were growing wild around Lake Mizusawa. As shown in Fig. 2, 5 stems cut to about 0.50 m were inserted into holes in the mat. Twenty-one artificial floating islands were constructed in this way and they were wired

each other (Fig. 3). As shown in Fig. 3, the mats were arranged in two rows and were placed in the biotope.

Fig. 2 Drain mat used to make artificial floating islands for water purification

Fig. 3 Artificial floating islands wired each other and placed on biotope surface

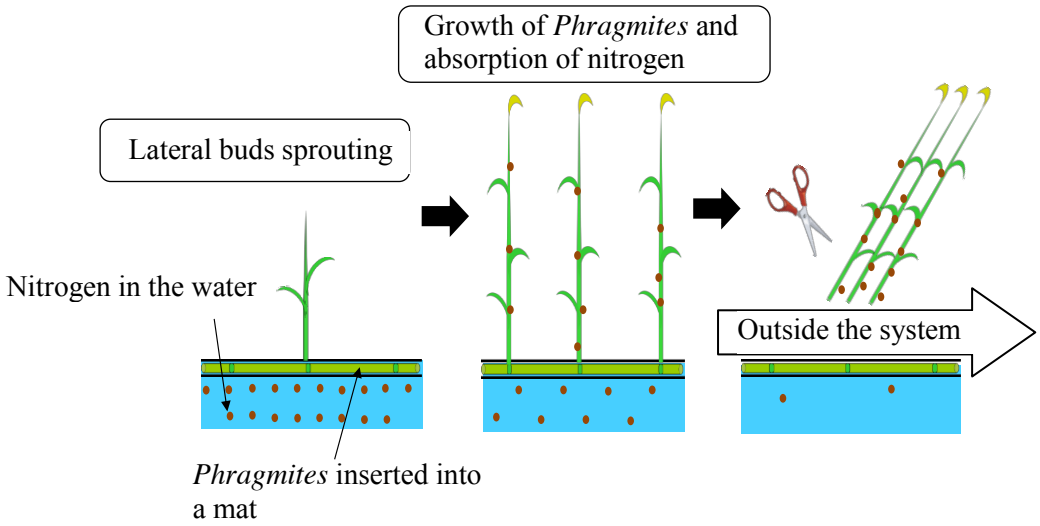

Fig. 4 Outline of the water purification scheme using artificial floating islands of Phragmites

Figure 4 shows the outline of the water purification scheme using the artificial floating islands of *Phragmites*. The scheme comprises the following 3 steps: First, the artificial floating islands are placed on the surface of eutrophied water, and lateral buds sprouting from nods of *Phragmites* plants are inserted into the drain mat. Second, after lateral buds have sprouted, they grow and

absorb large amounts of nitrogen, including nitrogen from the eutrophied water. This is an important step in water purification using *Phragmites*. Finally, in autumn, *Phragmites* plants, which accumulate nitrogen, are cut and transported outside the system. The artificial floating islands are left in place during winter and reused next year.

Growth of *Phragmites*

The stem length and sprouting rate of the plants were recorded every 2 weeks in 2010 and 2011. The sprouting rate is the ratio of the total number of sprouts to the total number of nods. Because more than 2 lateral buds sprout from a nod, the sprouting rate generally exceeds 100%.

In 2010, growth was assessed from July 4 to October 31. After the last assessment in 2010, the artificial floating islands were left in the biotope to evaluate their winter hardiness. The growth of the overwintered *Phragmites* plants was assessed between July 7 and September 21 in 2011. In addition, to check the growth of rhizomes, the mats that were fixed to the ground surface in the biotope were dug up on October 21, 2011.

RESULTS

Growth of *Phragmites* in 2010

Figure 5 shows changes in the sprouting rate and maximum and average stem length during 2010. The artificial floating islands were placed in the biotope on July 4. After 2 weeks, sprouting of lateral buds was observed. At this time, the sprouting rate and maximum stem length were 4% and 0.15 m, respectively. From late July to mid-September, both the sprouting rate and maximum stem length increased steadily with increasing air temperature. However, the maximum stem length stopped increasing on September 8. In contrast, the sprouting rate increased moderately after that date because lateral buds continued sprouting. On October 31, 419 lateral buds sprouted and the sprouting rate was 153%.The maximum stem length was 0.74 m. After examination in 2010, the artificial floating islands were left in the biotope during winter to examine the winter hardiness of *Phragmites*.

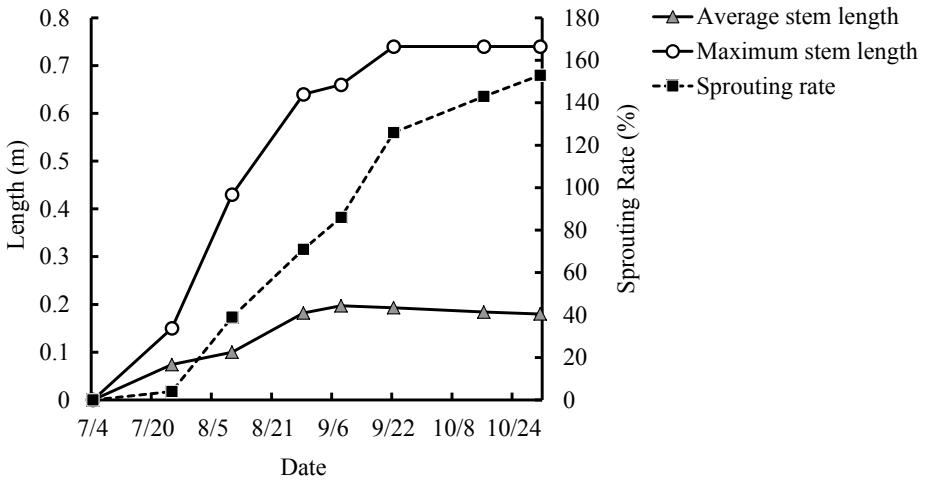

Fig. 5 Seasonal changes in sprouting rate and average and maximum stem length in 2010

Growth of *Phragmites* in 2011

The growth of *Phragmites* plants that had overwintered on the floating artificial islands was assessed in 2011. Figure 6 shows changes in the sprouting rate and maximum and average stem length. As shown in Fig. 6, the overwintered plants grew more steadily in 2011 than in 2010. When

the first evaluation was made on July 7, 2011, the sprouting rate was already 578% and the maximum stem length was 1.35 m. However, although the sprouting rate increased steadily until late September, the maximum stem length showed little increase after August. In contrast, ear emergence was observed in 2011, although it was not observed in 2010. Figure 7 shows a *Phragmites* rhizome photographed during growth examination on October 21. This figure shows that *Phragmites* took root in the biotope.

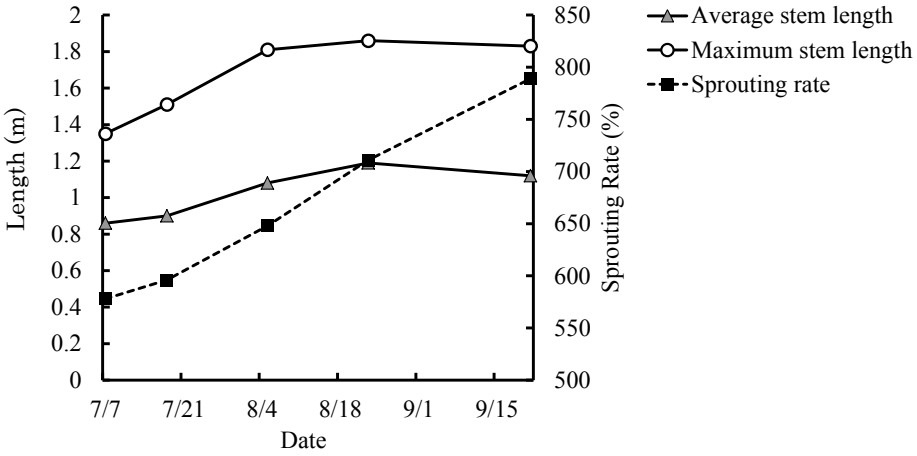

Fig. 6 Seasonal changes in the sprouting rate and average and maximum stem length in 2011

Fig. 7 *Phragmites* rhizome on October 21, 2011

DISCUSSION

On October 31, 2010, the sprouting rate and maximum stem length were 153% and 0.74 m, respectively (Fig. 5). In summer, both these values increased rapidly with increasing air temperature, indicating that *Phragmites* plants used to form the artificial floating islands were able to grow in the warm season in a cold region such as Hokkaido. However, the artificial floating islands were left in the biotope during the subsequent winter to evaluate the growth of *Phragmites* plants that had overwintered.

The *Phragmites* plants on the artificial floating islands grew more steadily in 2011 than in 2010, and on September 21, 2011, the sprouting rate and maximum stem length were 788% and 1.89 m, respectively (Fig. 6). Two factors were considered to cause the difference in growth increment: first, the *Phragmites* plants were not damaged by cold and second, the plants could absorb nutrient salts more effectively because their rhizomes had grown steadily (Fig. 7).

These results show that *Phragmites* used in the artificial floating islands for water purification can grow for multiple years without difficulty. Thus, this method could be put to practical use for water purification of the eutrophied Lake Mizusawa.

CONCLUSION

The use of the artificial floating islands of *Phragmites* was suggested to improve water quality of the eutrophied Lake Mizusawa. However, because this method has been little tested in cold regions, we placed the artificial floating islands in the biotope near Lake Mizusawa and examined the growth of *Phragmites* plants on these islands in 2010 and 2011. The plants grew steadily both in 2010 and 2011. From the results obtained in 2011, we observed that the *Phragmites* plants were not damaged by cold during the preceding winter. These results indicate that *Phragmites* plants on the artificial floating islands can grow in cold regions. Thus, it could be possible to improve water quality by use of the artificial floating islands of *Phragmites*.

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Research article

Effective Governance Strategy: Key to Sustainable Collaborative Management in a Wildlife Sanctuary in South-Eastern Part of Bangladesh

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Abstract The Forest Department of Bangladesh piloted collaborative management, also known as co-management, in five protected areas, through its Nishorgo Support Project from 2004 to 2009. This paper documents one of the pilot co-management sites, specifically for the Teknaf Wildlife Sanctuary comparing actual governance to the framework for good governance for protected areas. Through stakeholders and key informant interviews and observation of council and committee meetings, the research revealed that the co-management structure was an appendum in the forest department's organizational structure. Unwillingness to share responsibilities and decision-making was the major obstacle to effective co-management in the protected area. The lack of legal recognition and limited functional arrangements to support co-management resulted in weak managerial performance and poor governance. Thus, extraction of resources from the reserve continued. Moreover, no quick solutions to deal with environmental threats of land encroachment inside the sanctuary were undertaken. For co-management to result in effective forest and wildlife conservation, more focus on good governance and provision of socio-economic opportunities is needed.

Keywords protected area, Teknaf Wildlife Sanctuary, co-management, governance

INTRODUCTION

Depletion of forests is occurring worldwide. In Bangladesh, only 10.2% of the country's landmass remains under forest cover (Laurance, 2007). Forests continue to be degraded due to encroachment of forest land for habitation and cultivation (Muhammed et al., 2008) with 50% of the nation's forests destroyed in the last two decades of the 20th century (Huda & Roy, 1999). To halt this destruction and preserve biodiversity, the Government of Bangladesh established one protected area in the 1980s and increased the number of protected areas to 28 in 2011 (Chowdhury et al., 2009). However, due to ineffective management, protected areas are subject to the same degradation as state forests, wetlands and other land-use resources (FSP, 2001). DeCosse & Roy (2005) found that the principal cause of destruction of parks and other protected areas in Bangladesh are the local elites who extract resources from protected areas for their own benefit, not that of the poor. Commercial demand for timber and firewood is the leading cause of forest loss with the poor engaged as hired hands to carry out this work for the elites (DeCosse & Roy, 2005).

Realizing the importance of protected areas for biodiversity conservation, a collaborative management approach was formally introduced in the protected areas of Bangladesh in the year 2004 (Sharma et al., 2008; Roy & DeCosse, 2006). One of the major emphases of applying co-management in protected areas was to ensure a congenial situation for governance as a recognized

requirement for sustainable development (DFID, 2001). The Forest Department initially piloted co-management in five protected areas in 2004. The focus of this paper is to look at co-management in one of these areas, namely the Teknaf Wildlife Sanctuary (TWS), located at 21^0 00′ N and 92^0 20′ E in the Teknaf Peninsula of Cox's Bazaar district in south-eastern Bangladesh. The total area of the sanctuary is 11,615 hectares, which is composed of tropical evergreen and semi-evergreen forests (Green, 1990). This sanctuary is surrounded by 115 settlements with a total population of 119,950 (Mollah et al., 2004). The wild elephant, sambar, barking deer, leopard, Bengal tiger, panther etc. were common in this area but now most of these animals are extirpated or the population has dwindled, due to habitat destruction. Now, megafauna are restricted to a few small areas (Mollah et al., 2004; IPAC, 2009). In 2004, only a few small patches of natural forest remained in the sanctuary (Mollah et al., 2004) due to economic activities diminishing the forest by: fuel wood collection for household use and brick making; illegal timber extraction for commercial sale; non-timber forest products (mainly bamboo and rattan) collection; betel-leaf cultivation; and grazing of domestic animals (Studd, 2004).

Governance is considered to be the single most important factor for sustainable forest resource management (Larson, 2004), which highlights the need for analyzing the quality of governance at TWS. Realizing good governance is needed to ensure wildlife conservation and biodiversity, a two tier governance structure consisting of a 1) co-management council (henceforth called 'council') and 2) a co-management executive committee (henceforth called 'committee') that was formed with diverse stakeholders (NSP, 2006). Stakeholders include tribal people, forest villagers, local resource users, the middle class and elites. The business class has a strong role in land encroachment, including local elites, political leaders, law enforcing agencies, and forest headmen (Mollah et al., 2004), and must be engaged to prevent further habitat destruction and shift practice.

Principles of good governance for protected areas

Governance determines who has power and makes decisions, how other stakeholders make their voices heard and what accountability measures are in place. Sustainable protected area management usually requires participation of local people in decision-making process, devolution of power, equitable benefit sharing, and building transparent and responsive institutions to ensure good governance (UNESCAP, 2007). Governance is also influenced by history, culture, legal and customary rights, access to information, economic outlook etc. Creating a suitable system of governance for protected areas in a country is of high importance in which government agencies at the national level usually play an eminent role (Borrini-Feyerabend et al., 2005). An analysis of governance focuses on the formal and informal actors involved in decision-making, implementing the decisions made, and the structures that have been set in place to arrive at and implement the decisions (UNESCAP, 2007). Analyzing and taking action about governance of protected areas provide a powerful and insightful learning process. The management authority or stakeholders can establish criteria, principles and values to guide action to achieve good governance (Borrini-Feyerabend, 2003).

Five principles of good governance for protected areas developed by Graham et al. (2003) based on United Nations governance principles are: 1) legitimacy and voice, 2) accountability, 3) performance, 4) fairness, and 5) direction. These five principles are harmonized with the eight major characteristics of good governance principles namely 1) participation, 2) consensus-oriented, 3) accountability, 4) transparency, 5) responsiveness, 6) effectiveness and efficiency, 7) equity and inclusiveness, and 8) devotion to rule of law, identified by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP, 2007), in Table 1.

METHODOLOGY

This in-depth case study used semi-structured interviews and participant observation from August 2007 to February 2008. Six interviews were conducted with site coordinators of the project and Forest Department (FD) officials for the three ranges namely Whykong, Shilkhali and Teknaf.

Information about the governance structure of the council and committee formation process, legal matters, working mechanism of those bodies and experiences from performing activities through co-management was collected.

The researchers attended committee and council meetings to observe participation of representatives from different stakeholders. Each of the three committees was comprised of 18-19 members who were elected from 51-55 council members in those ranges. Formal interactive interviews were conducted with local government, non-government organization (NGO) groups, local elites, ethnic communities, forest department, resource user and other government representatives in committee using a semi-structured questionnaire. Descriptive responses from the interviewees were gathered and cross-checked through field observation and discussion with key informants working at forest beat level (smallest administrative unit for forest management) including individuals from tribal community, forest villagers and patrol team members. Overall, an inductive approach was followed in the research process by moving to broader generalization from specific observations and results. Direct observation methods were followed to observe phenomenon and collect information on participants' behavior and field condition. Based on these findings an analysis of actual governance compared to the framework for good governance for protected areas developed by Graham et al. (2003) and (UNESCAP, 2007) were made in Table 1 which is a similar approach to that taken by Lockwood (2010) for other projects.

RESULTS

The changes in governance attained by the re-arranged governance structure developed for co-management are analyzed by each governance principle (Table 1) and explained below.

Governance by co-management authority in TWS.

1. Legitimacy and voice: participation and consensus oriented *(principle one)*

Co-management was legitimated by a 2006 government gazette notification, which established three co-management committees and assigned them responsibilities. However, only 12% of the committees are made up of resource users, limiting their influence. The committees have a number of business persons with vested interest in the sanctuary, who do not play a convening role. A NGO representative in Whykong committee said: "I did not get any direction to interact with other local NGOs and don't know how I will collaborate.*"* Forest Department workers are not included in council and committee and often do not attend field meetings, which results in suboptimal effort in co-management activities and is of concern to Community Patrolling Groups, as they need assistance and enforcement from these field level employees.

Attendance in monthly committee meeting is poor as some members are unwilling to provide voluntary service but attendance is better for council meeting representatives. Forest users' group meetings often do not take place due to lack of both participants and representatives from the committee. Activities at the field level are highly influenced by planning made at higher levels as activities and financing are not decided at the site office.

2. Accountability and transparency *(principle two)*

The co-management committee members' accountability is demanded only at the monthly meetings. The committees do not have access to information on operations and budget expenditures of a part of the Nishorgo Support Project (NSP) as it was implemented by the Forest Department (FD) only. Committee members' do not have any established mechanism to convey learning and engage their own constituency. Although linkages have been established between forest user groups and community patrolling groups with the Forest Department, activities and requirements of the groups were not monitored: a Divisional Forest Officer (DFO) refers to this divide: "It is not pleasing for FD to work with local NGOs in co-management. Some of our staffs have shared their uncomfortable feeling on losing territorial control and authority in their work with groups in field".

Table 1 Analysis of whether the Teknaf Wildlife Sanctuary Co-management meets good governance principles and responsibilities

Good governance Principles	Governance responsibilities	How governance principles and responsibilities are working in the study area?
1. Legitimacy and voice	1.1.1 Free expression of views with no discrimination	All committee members are encouraged to express their opinion in meetings. Field level employees and group's representatives still too vigilant to speak before elites.
1.1 Participatory	1.1.2 Dialogue and collective negotiation	Interaction occurs but dialogue is limited to project objective specific agendas. Limited discussion was performed on burning but sensitive issues.
1.2 Consensus-oriented	1.2.1 Stakeholders trust each other and have the feeling of owning the rules	Lack of trust is evident from absence of important stakeholders in meetings. Rules and agendas are fixed *ex-situ* having local stakeholders at supportive role on site.
2. Accountability and transparency	2.1 Accountability should be accessible to all	Very limited accountability of committee members and Forest Department staff.
	2.2 Accountability is linked to appropriate rewards and sanctions	Rewards and sanctions mechanism is not free from nepotism by influential members. No graduated sanctions are applied *de facto* for extracting resources and illegal felling.
	2.3 Clarity and transparency of responsibility	No posting of names & duties of committees, ongoing activities and budget in site offices.
3. Performance 3.1 Responsiveness	3.1.1 Capable administration with sufficient institutional and human capacity to carry out required responsibilities	Co-management council have symbolic role only. Insufficient staff and dissatisfaction of working groups made large area conservation tough. Committee and participants are learning from training and visits to other protected areas.
3.2 Effectiveness and efficiency	3.2.1 Dealing with complaints and criticisms in constructive manner	Lively discussion on co-management activities in meetings. Forest Department staff will not give up control but linkages with field groups are made.
	3.2.2 The management structure should be robust, resilient, and capable to perform adaptive management	Activities depend on project funding but earning money from eco-tourism has started. The co-management institutions on site are precarious and has not attained self-sustaining situation yet.
4. Fairness 4.1 Equity & inclusiveness	4.1.1 Conservation efforts should not humiliate or harm people's normal life 4.1.2 Vulnerable ones should have opportunity to maintain their own happiness	Tribal community, forest users and women were minimally involved. Alternative income generating initiatives were few compared to needs of forest depended households. Tribal community was not integrated well in decision making process and received little financial and material support for community economic development
4.2 Rule of Law	4.2.1Consistent application of laws and regulations 4.2.2 Fair opportunities for conflict management and non-discriminatory option to justice	Committee is often reluctant to apply regulations to committee members. A number of committee members are known well for past illegal activities in the sanctuary. Community people depend on local leaders for conflict resolution. Conflicts related to the sanctuary are discussed in monthly committee meeting.
5. Direction 5.1 Strategic vision	5.1.1 Peoples concerns should be listened and effective leadership with consistent vision for long term development should prevail	A vision for efficient co-management of the sanctuary is discussed but committee and council members seldom play leadership role or start initiatives.
5.2 Embracing complexities	5.2.1 Context of the area should be clearly understood and innovative ideas and processes should be supported	Innovative ideas like establishing biogas plant, fuel-efficient improved cooking stove making are encouraged through arranging demonstration and training programs.

3. Performance: responsiveness and efficiency *(principle three)*

Co-management authorities empowered under government order are reluctant to apply rules to control extraction of resources, which allows widespread breaking of the rules. The field level groups cannot hand-over any violator to law enforcing agencies without consulting FD employees. With very limited alternative income generating support and other financial incentives, the forest patrolling groups are unwilling to provide voluntary service. On the other hand, NSP field staffs working in remote locations are unsatisfied with governance and facilities. A project field staff said: *"*Major decisions and planning of co-management activities on ground is performed at higher levels which don't reflect the acceptance of field level employees and conscious people. But the system of adding our field experience to planning is not well established".

Senior project staffs and academics discussed three aspects that mainly have prevented FD from efficient management of the sanctuary. These are: 1) administrative faults 2) policy & legal loopholes and 3) weak enforcement of rules. Co-management did not result in any organizational or logistical changes in FD, as this has to be approved by central government in cabinet.

4. Fairness: inclusiveness and rule of law *(principle four)*

The three committees include 57 representatives from the different stakeholder groups of which 31 (54%) are from local government or are local elites who rarely visit the sanctuary, 14 (24.5%) are institutional stakeholders and 12 (21%) are from resource user including ethnic communities. Only six (11%) were women (Rahman, 2008). Although some effort was made to be inclusive, the inclusion of different stakeholders did not result in a concerted effort towards viable income generating activities. A head from tribal community in Whykong union complained about lack of resources for performing co-management activities:

"We are not included in [the] true sense in most of the development initiatives in TWS area including activities under the Nishorgo Support Project. We are given responsibilities to implement small-scale projects like making handicraft[s] but incentives provided for implementing those were very insufficient. So, it is difficult to sustain these businesses. Again, we take part in performing big responsibilities like preventing illegal logging in the sanctuary but often do not get information about the proceedings and do not have decision-making power. We are not happy with activities of both FD and NSP officials".

One of the FD field level officials reported about how the corruption disrupts law and order:

"Many times we are bound to do what the influential people in the area want. FD employees are asked to give privileges to them and gets [an] offer to take [a] bribe even from committee members, otherwise we will be harmed. TWS is a very dangerous area for prevalence of armed robber groups, smuggling gangs and illegal migrant. Local law enforcing agencies find it much difficult to keep control over the fragile law and order situation".

5. Direction: **strategic vision and embracing complexities *(principle five)***

A participatory visioning exercise named *'Nishorgo vision 2010'* was conducted with the stakeholders by FD staff, which identified a number of future threats to TWS and other protected areas, and identified co-management as an effective way to deal with these threats (FD, 2007). Innovative ideas, like planning for ecotourism, public-private partnership, local entrepreneurship etc., were identified as promising prospect in co-management.

CONCLUSION

Considering the constant deterioration of forest in the TWS and decline in the population of flora and fauna, effective co-management is necessary to prevent unlawful use and extraction of resources from the sanctuary. The governance framework linking institutions with different stakeholders in the community holds promise to reduce forest degradation. Some good governance principles were observed, which include finding direction through both strategic vision exercises and embracing complexities. As well, fairness was evident in efforts to include many diverse stakeholders on committees. Regarding the fairness principle, efforts were made to support alternative income generating initiatives but these were small relative to the need. Improvements are still needed regarding legitimacy and voice, to ensure participation without discrimination and

build the trust required for a true consensus-orientation. A real weakness was the lack of accountability and transparency. As well, performance was poor in its effectiveness and efficiency with insufficient staff for the large conservation area resulting in continued environmental degradation. However, justice and the rule of law were not applied with many committee members continuing to engage in the sanctuary based illegal businesses. This study was useful for scrutinizing governance performance of the organizations involved in co-management in TWS but ongoing mechanisms for review would improve the governance function.

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Research article

Using Soil Improvement Materials for Enhancing Drought Tolerance of Rubber Plant

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Abstract A study on the effects of applying a type of clay minerals on drought tolerance of rubber plant was carried out by incorporating bentonite at 0, 2, 4, and 8 percent w/w into loamy sand soil (Roi-et series). Factorial arrangement in CRD (complete randomized design) with 3 replications was performed in this research study. It was found that mixing bentonite 0-16 percent w/w with sugarcane bagasse, coconut fluff, peanut husk, black-burned rice husk, and fresh rice husk caused the water holding capacity to be in the ranges of 41.50-58.88, 44.3-105.0, 9.1-20.4, 128.6-154.2, and 3.1-21.3 percent, respectively. After 14 days of application for rubber varieties RRIM600 and RRIT251 grown on loamy sand, using bentonite 0, 2, 4, and 8 percent w/w caused the drought tolerance without irrigation to be 31-35 and 29-47 days, respectively. It was also found that small and medium sizes of rubber seedlings showed higher drought tolerance than those of big sizes because they still survived without irrigation 40-48, and 38-43 days, respectively. All sizes of RRIM600 seedling started wilting at moisture contents 4.9-5.9 percent and then showed permanent wilting at 3.30-3.39 percent w/w. Clay minerals used as basal application under field experiment significantly increased drought tolerance of young RRIM600 to be 158 days after planting whereas no application on the rubber tree could stand by the age of 92-135 days or averagely 111 days after planting. Increasing 15-15-15 concentration as basal fertilizer by the rates 100, 200, 400, and 600 g/plant significantly accelerated the termination of rubber tree. According to this, the rubber tree died at the age of 166, 149, 107, and 102 days after planting. Chemical fertilizer associated with clay mineral as basal application showed a trend of extending rubber age.

Key words soil improvement materials, bentonite, rubber, drought tolerance

INTRODUCTION

Since 2007 under the government policy, rubber plantation area in Northeast Thailand has been extended to 450,000 hectares. However, large land area of the Northeast contains various and complicated soil types and soil properties that will directly affect the success of this policy, particularly rubber tree younger than 5 years which should be intensively cultivated due to unsustainable root system during this growth stage (Office of Agricultural Economics, 2009). Naturally, 85 percent of roots are in deep zone whereas effective roots for nutrients absorption, 15 percent, are spreading in topsoil (Rubber Research Institute of Thailand, 2004). A preliminary data from survey research revealed that clay mineral used in substrate culture for seedling stage can

improve drought tolerance of rubber plant. This research aimed at applying some types of organic material associated with bentonite clay mineral to improve drought tolerance of young rubber tree.

METHODOLOGY

There were 3 main methods used in this study as follows:

1. Effect of organic materials and clay mineral on soil water holding capacity

Five types of organic materials were used: sugarcane bagasse, coconut fluff, peanut husk, black-burned rice husk, and fresh rice husk. A 5x7 factorial arrangement in completely randomized design (CRD) with 3 replications was performed. Factor A was the ratio of mixing between organic materials and bentonite 0, 2, 4, 8, and 16 percent w/w, while factor B was the period of water deficit 2, 4, 6, 8, 10, 12, and 14 days, respectively.

2. Effect of bentonite on drought tolerance

Both rubber varieties RRIM 600 and RRIT251 were used as experimental materials. A 4x3 factorial arrangement in CRD with 3 replications was performed. Factor A were bentonite 0, 2, 4, and 8 percent w/w of loamy sand. Factor B were rubber sizes, small, medium, and large. Survival rate after water deficit was investigated.

3. Effect of mixed bentonite and basal fertilizers applied under field condition on drought tolerance

RRIM 600 was used as experimental material. A 2x5 factorial arrangement in CRD with 3 replications was performed. Factor A were bentonite mixed with organic matterials 0, and 10 percent w/w. Factor B were basal chemical fertilizer 15-15-15 at the rates of 0, 100, 200, 400, and 600 g/plant. Period of drought tolerance was collected.

RESULTS AND DISCUSSION

The research findings are as follows:

1. Water holding capacity

After 2 days from watering at saturated moisture content, bentonite mixed with coconut fluff showed the highest water holding capacity and then black-burned rice husk, sugarcane bagasse, peanut husk, and fresh rice husk. The remaining moisture contents were 134-205, 130-154, 72-94, 31-64, and 23-61 percent. At the day of 14th, they were 46.8-100.8, 86.0-96.3, 41.6-57.2, 10.2-20.4, and 3.6-19.4 percent, respectively (Table 1).

Table 1 Effect of bentonite mixed with organic materials on water holding capacity (percentage of moisture contents)

Organic materials used for mixing with bentonite 0-16 percent w/w	Remaining moisture contents at the days after saturation (percent)		CV (%)
	2 Days	14 Days	
Sugarcane bagasse	72.0-98.1	41.5-58.8	3.30
Coconut fluff	132.9-207.7	44.3-105.0	4.74
Peanut husk	30.4-62.9	9.1-20.4	10.24
Black-burned rice husk	128.6-154.2	89.3-106.1	4.12
Fresh rice husk	20.6-65.6	3.1-21.3	2.70

2. Effect of bentonite on drought tolerance

Applying bentonite, 0, 2, 4, and 8 percent w/w on loamy sand increased drought tolerance of both RRIM600 and RRIT251 rubbers averagely from 31 to 55 days after water deficit for RRIM600 and 29 to 47 days for RRIT251. Small and medium sizes of rubber seedling showed better drought tolerance than large size. The period of surviving could last until 40-48 days for RRIM600 and 38-43 days for RRIT251 (Table 2). Increasing the amount of clay mineral can increase soil micropores and then reduce bulk density. This will increase available water capacity (Russell, 1973; Brady and Well, 2002).

Table 2 Number of the days that rubber died after water deficit among rubber varieties and sizes, and bentonite application rates

Rubber sizes of RRIM600	Bentonite application rates				Average*
	0%	2%	4%	8%	
Small	31.67	41.67	46.67	55.00	43.75b
Medium	35.00	43.33	51.67	61.67	47.92a
Large	28.33	38.33	45.00	48.33	40.00c
Average*	31.67d	41.11c	47.78b	55.00a	43.89
CV = 9.30%	LSD bentonite rates = 3.972, LSD rubber sizes = 3.440 at 95% level				
Rubber sizes of RRIT251	Bentonite application rates				Average*
	0%	2%	4%	8%	
Small	33.33	43.33	48.33	46.67	42.92a
Medium	28.33	43.33	48.33	48.33	42.08a
Large	26.67	38.33	43.33	45.00	38.33b
Average*	29.44c	41.67b	46.67a	46.67a	41.11
CV = 7.58%	LSD bentonite rates = 3.033, LSD rubber sizes = 2.627 at 95% level				

**Means in the same column/row followed by the same letter are not significant difference (p<0.05) under DMRT (Duncan's New Multiple Range Test)*

3. Effect of mixed bentonite and basal fertilizers applied under field condition on drought tolerance

In case of applying bentonite mixed with organic materials and basal fertilizer applied under field condition on drought tolerance of rubber, it was found that RRIM600 significantly increased survival period for all sizes (small, medium, and large) of young rubber tree, particularly the small size could last until 158 days comparing with no application that could last for only 92-135 days or averagely 111 days (Table 3).

Table 3 Number of the days that rubber (RRIM600) died after planting among rubber sizes, application rates of bentonite mixed with organic materials, and basal fertilizer rates of 15-15-15

Small size	15-15-15 (g/plant)					Average*
	0	100	200	400	600	
No application	134.7	128.7	115.0	84.7	91.7	110.9b
Mixed bentonite	162.7	202.3	182.3	129.0	113.0	157.9a
CV = 23.71%	148.7a	165.5a	148.7a	106.8b	102.3b	134.4
Medium size	15-15-15 (g/plant)					Average*
	0	100	200	400	600	
No application	131.0	140.0	119.3	96.7	72.0	111.8b
Mixed bentonite	214.0	208.7	169.7	112.0	112.0	163.3a
CV = 18.47%	172.5a	174.3a	144.5a	104.3b	92.0b	137.5
Large size	15-15-15 (g/plant)					Average*
	0	100	200	400	600	
No application	135.0	144.0	132.0	89.0	72.0	114.4b
Mixed bentonite	168.7	202.7	167.7	101.0	94.0	146.8a
CV = 28.61%	151.8ab	173.3a	149.8a	95.0bc	83.0c	130.6

**Means in the same column/row followed by the same letter are not significant difference (p<0.05) under DMRT (Duncan's New Multiple Range Test)*

Because of high specific surface areas, clay mineral as inorganic colloid generally increases cation exchange capacity (CEC); therefore, it induces the sustainability of soil fertility. Plant nutrient retention and availability are increased (Brady and Well, 2002). When organic materials are decayed, cementing agent will increase soil aggregation process and then increase soil water holding capacity (Tester, 1990; Asher et al., 2002). Applying 15-15-15 as basal fertilizer at the rate of over 200 g/plant increased the termination of RRIM600 at 92-102 days after planting. Medium

size seedling could stand for drought tolerance better than the other small and large sizes. Averagely, rubber died within 138, 134, and 131 days for medium, small, and large sizes, respectively.

CONCLUSION

Bentonite 0-16 percent w/w mixed with coconut fluff showed the highest water holding capacity and then black-burned rice husk, sugarcane bagasse, peanut husk, and fresh rice husk. The remaining moisture contents were 46.8-100.8, 86.0-96.3, 41.6-57.2, 10.2-20.4, and 3.6-19.4 percent, respectively. Bentonite 2-8 percent w/w increased drought tolerance 29.81-50.86 percent for RRIM600 and 41.54-58.52 percent for RRIT251. Small and medium sizes of rubber seedling showed better drought tolerance than large size. They were 42.9-43.3, 42.1-45.0, and 38.3-39.1 days, respectively. RRIM600 was better than RRIT251 in terms of drought tolerance. They were 31.6 days, and 29.4 days, respectively. Applying bentonite mixed with organic materials and basal fertilizers under field condition increased survival period for all sizes (small, medium, and large) of young rubber tree. Applying over 200 g/plant of 15-15-15 as basal fertilizer increased the termination of seedlings. Averagely 88-100 days or 3 months after planting with no rainfall, rubber died.

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Research article

Potential of Sunflower Varieties Grown under Different Input Levels

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Abstract This experiment was aimed to investigate the potential of sunflower varieties (*Helianthus annuus* L.) grown under different levels of inputs. Sunflower varieties consisted of two hybrids (Pacific 77 and Olison 3) and two synthetic varieties (Suranaree (S) 471 and Suranaree (S) 473). Input levels were low, medium and high packages which were obtained from the combination of levels of weed control and fertilizer applications. The study was conducted in a strip-plot design in the dry season of 2010 and 2011 at Chaipattana-Mae Fah Luang Reforestation Project, Prachuap Khiri Khan, Thailand. The results showed that both synthetic varieties outyielded the two hybrids. S471 produced the highest yield of 2,269 kg ha^{-1}. However, the oil content of Pacific 77 was the highest, with 42 percent. The responses of sunflower varieties to levels of input were not significant almost for all characters except for oil content. Seed yields were 1,931, 2,025 and 2,375 kg ha^{-1} for low, medium and high input packages, respectively. Seed size showed positive association with the levels of input. However, the oil content did not increase with the increase of input levels. The net income of all varieties grown under different levels of input were estimated by using the farm gate price. The highest net income of 21,500 baht ha^{-1} was obtained from S471 grown under the lowest input level. For this study where the soil is quite fertile, the lowest input levels should be used for all varieties of sunflower.

Keywords Sunflower, *Helianthus annuus*, synthetic varieties, packages of input

INTRODUCTION

Sunflower (*Helianthus annuus* L.) has been grown widely in the central part of Thailand for oil, seed meal and tourist attraction. Hybrid varieties have been used mostly by farmers as they found that these varieties produced well and give uniform performance for most characters. However, the cost of seed is high because it has to be imported. To reduce this problem in Thailand, many synthetic varieties were developed to be used as stop gap varieties (Kaewmeechai et al., 1989; Laosuwan, 1997). High yield is usually favorable regardless the levels of inputs in terms of chemicals and labor. However, what farmers should need most is the highest net income. Therefore, certain measures for crop production were called package of input by Laosuwan and Macartney in 1992, which were tested in many crops; especially peanut (Laosuwan and Macartney, 1992). This also should be used to evaluate the potential of sunflower production on-farm. The objectives of this study were to evaluate the potential of hybrid and synthetic varieties of sunflower for yield and other characters. They were also evaluated for net income due to the application of different levels of input.

METHODOLOGY

This experiment was conducted at the Chaipattana Mae-Fah Luang Reforestation Project at Prachuap Khiri Khan in 2010-2011. Four varieties of sunflower including two hybrid varieties (Pacific 77 and Olison 3) and two synthetic varieties (Suranaree (S) 471 and Suranaree (S) 473) were used. Three input levels were formulated to explore the response of sunflower and to estimate the net income. These input levels were (1) low input level: no fertilizer was applied and weed control was made only once, (2) medium input level: 187.5 kg ha^{-1} of 15-15-15 NPK fertilizer was applied only once at planting and the weed control was made only once, and (3) high input level: 250 kg ha^{-1} NPK fertilizer was applied at planting and 1,250 kg ha^{-1} of organic fertilizer was applied before the flowering stage. In this treatment package, the weed control was continuously made to provide a weed free condition.

The study was conducted in a strip-plot design with four replications. Six rows each 5 m long were used for each plot with spacing of 0.75 m between rows and 0.25 m between hills. The data were recorded for seed yield and seed size. The seed sample was taken from each treatment to analyze for oil contents.

RESULT AND DISCUSSION

Data for seed yield, seed size and oil contents are shown in Tables 1 and 2. Although the results were not statistically different, S471 tended to give the highest yield, S473 ranked second, Pacific 77 ranked third and Olison 3 gave the lowest yield (Table 1). This study showed that synthetic varieties tended to give higher seed yield than hybrids or at least similar. However, other experiments showed that synthetic varieties usually yielded lower than hybrids (Kaewmeechai et al., 1989; Laosuwan, 1997; Satjawattana, 2001).

Table 1 Seed yield of 4 varieties of sunflower grown under 3 input levels in 2010-2011 at Chaipattana-Mae Fah Luang Reforestation Project, Prachuap Khiri Khan, Thailand

Variety	Input levels			Mean (kg ha^{-1})
	Low	Medium	High	
Pacific 77	1,988	2,138	2,294	2,150
Olison 3	1,506	1,506	2,231	1,775
Suranaree (S)471	2,231	2,262	2,319	2,269
Suranaree (S)473	1,981	2,075	2,675	2,238
Mean (kg ha^{-1})	1,931	2,025	2,375	
Environment (E)	*ns*	*V x I*	*ns*	
Varieties (V)	*ns*	*V x E*	*ns*	
Input levels (I)	*ns*	*I x E*	*ns*	
		V x I x E	*ns*	

Table 2 Seed size (1,000 seeds weight; g) and oil content (%) (in parentheses) of 4 varieties of sunflower grown under 3 input levels in 2010-2011 at Chaipattana-Mae Fah Luang Reforestation Project, Prachuap Khiri Khan, Thailand.

Variety	Input levels			Mean
	Low	Medium	High	
Pacific 77	46 (42 ab)	50 (44 a)	59 (40 ab)	52 b (42 a)
Olison 3	43 (38 ab)	50 (35 ab)	50 (41 ab)	47 c (38 b)
Suranaree (S)471	56 (40 ab)	60 (39 ab)	61 (33 ab)	59 a (37 c)
Suranaree (S)473	50 (32 b)	57 (35 ab)	54 (32 b)	53 b (33 d)
Mean	49 b (38 a)	54 a (38 a)	56 a (36 b)	
Environment (E)	*** (**)*	*V x I*	*ns (**)*	
Varieties (V)	*** (**)*	*V x E*	*ns (**)*	
Input levels (I)	*** (**)*	*I x E*	*ns (**)*	
		V x I x E	*ns (**)*	

Data for seed size (Table 2) showed that S471 gave the largest seed and the smallest seed was found for Olison 3. However, both synthetic varieties gave lower oil content than hybrids, while the highest oil content was given by Pacific 77 and the lowest by S473.

Responses to levels of input were found for all characters observed in the study except seed yield. However, the high input level gave the highest seed yield and the low input gave the lowest. The same responses were found for seed size where the character increased due to the increase of input levels. However, the low and medium input levels gave higher oil contents than the high input level, indicating that a negative response was obtained for this character.

The cost of input levels were roughly estimated for this experiment and many details may have not been considered (Table 3). However, it was considered that input levels are important for economic yield of all crop production by subsistent farmers.

Table 3 Cost of different input levels used in the experiment at Chaipattana-Mae Fah Luang Reforestation Project, Prachuap Khiri Khan, Thailand

Input cost	Low input	Medium input	High input
Fertilizer input	0	3,125	5,000
Fertilizer	0	1,875	3,125
Labor	0	1,250	1,850
Weed control	1,250	2,500	3,750
Others [1]	10,125	10,125	10,125
Total	11,375	15,750	18,875

[1] *Cost due to land preparation, disease and pest controls; labors for planting, harvesting, threshing, etc.*

Table 4 Net income for all varieties of sunflower grown under different levels of input estimated by using the farm gate price

Variety	Cost-income	Input levels		
		Low	Medium	High
Pacific 77	Yield (kg ha^{-1})	1,988	2,138	2,294
	Farm gate price (baht kg^{-1})	15	15	15
	Gross income (baht ha^{-1}) [1]	29,820	32,070	34,410
	Production cost (baht ha^{-1})	11,375	15,750	18,875
	Seed cost (baht ha^{-1})	2,125	2,125	2,125
	Net income (baht ha^{-1}) [2]	16,320	14,195	13,410
Olison 3	Yield (kg ha^{-1})	1,500	1,588	2,231
	Farm gate price (baht kg^{-1})	15	15	15
	Gross income (baht ha^{-1})	22,500	23,820	33,465
	Production cost (baht ha^{-1})	11,375	15,750	18,875
	Seed cost (baht ha^{-1})	2,125	2,125	2,125
	Net income (baht ha^{-1})	9,000	5,945	12,465
S471	Yield (kg ha^{-1})	2,225	2,262	2,319
	Farm gate price (baht kg^{-1})	15	15	15
	Gross income (baht ha^{-1})	33,375	33,930	34,785
	Production cost (baht ha^{-1})	11,375	15,750	18,875
	Seed cost (baht ha^{-1})	500	500	500
	Net income (baht ha^{-1})	21,500	17,680	15,410
S473	Yield (kg ha^{-1})	1,975	2,075	2,675
	Farm gate price (baht kg^{-1})	15	15	15
	Gross income (baht ha^{-1})	29,625	31,125	40,125
	Production cost (baht ha^{-1})	11,375	15,750	18,875
	Seed cost (baht ha^{-1})	500	500	500
	Net income (baht ha^{-1})	17,750	14,875	20,750

[1] *Gross income = Yield x farm gate price* *(1)*

[2] *Net income = Gross income - production cost - seed cost* *(2)*

The net income for all varieties of sunflower due to the applications of all input levels are shown in Table 4. The highest net income of 21,500 bath ha^{-1} was obtained from S471 grown under the low input level followed by 20,750 bath ha^{-1} from S473 grown under the high input level. The

net incomes obtained for hybrid varieties were lower than those of synthetic varieties for all input levels. This partly due to the high seed cost which was about four times higher than that of synthetic varieties.

CONCLUSION

This experiment showed that sunflower can have a good production at the location where farmers may grow sunflower for seeds and tourist attraction. In this study, synthetic varieties gave comparable seed yield as hybrid varieties but their oil contents were lower. However, the advantages of synthetic varieties are that farmers can continuously produce their own seeds for the next planting without having to buy expensive imported hybrid seeds. This experiment showed that S471 can be used for further planting, although it is too early to recommend at this stage. The responses of sunflower to input levels were found for all characters. All characters, except oil content, increase when increasing input level. However, the high net income may be obtained from certain varieties grown under the low input level.

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Research article

Biocontrol of Phytopathogen by *Pseudomonas fluorescens* R21, Isolated from Rice Rhizosphere in Thailand

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Abstract Secondary metabolites produced by fluorescent *Pseudomonas* play key roles in the suppression of various soilborne plant pathogens. However, the performance of this biocontrol agent varies depending on the environment and host plant species. In this study, *In vitro* antagonistic activity against phytopathogens by *Pseudomonas fluorescens* R21, which was isolated from rice rhizosphere in Thailand, was investigated in comparison to *Pseudomonas fluorescens* F113, which was isolated from sugar beet rhizosphere in Ireland. The result of *in vitro* antagonistic activity showed that *Pythium* spp. was suppressed by strains R21 and F113. Then, strain R21 that has the ability to produce IAA and to control plant pathogen was investigated for *in vivo* antagonistic activity and also was screened for the production of secondary metabolites such as pyoluteorin, pyrrolnitrin, hydrogen cyanide and 2,4-diacetylphloroglucinol (DAPG). The result of *in vivo* antagonistic activity confirmed that *Pythium* spp. was suppressed by strains R21 and F113. In addition, the application of strain R21 to rice seeds significantly increased plant height, shoots dry weight and roots dry weight of rice while the application of strain F113 to rice seeds showed no significant difference when compared to control.

Keywords *Pseudomonas*, rice, *Pythium* spp.

INTRODUCTION

Agriculture over the past few decades is heavily dependent on the application of chemical inputs. However, many chemical pesticides are very toxic and thus result in contamination of environment. Biological control is thus being considered as an alternative or a supplemental way of reducing the use of chemicals in agriculture (Compant et al., 2005; Welbaum et al., 2004).

The introduction of *P. fluorescens* as a biocontrol agent offers a promising alternative to manage soilborne plant pathogens. However, the production of an antimicrobial compound varies among cultivars of the same species, and this has hampered the commercialization (Notz et al., 2001). The studies of the ability to produce antibiotic secondary metabolites and their plant growth promoting potential are important not only for understanding their ecological roles in the rhizosphere and their interaction with plants, but also for any biotechnological applications.

In this study, *P. fluorescens* R21, isolated from rice (*Oryza sativa*) rhizosphere in Thailand, that has the ability to produce indole-3-acetic acid (IAA) was selected (Lawongsa et al., 2008). Strain R21 was investigated for *in vitro* and *in vivo* antagonistic activity of pathogenic fungi and also screened for secondary metabolites production. These results will facilitate overcoming

existing limitations in the understanding of plant-microbe interactions of strain R21. In this work, *P. fluorescens* F113 isolated from sugar beet (*Beta vulgaris*) rhizosphere in Ireland was used as the reference strain to compare with strain R21.

MEHODOLOGY

Bacterial strains and culture conditions

Isolation of rice rhizosphere strain R21 was carried out by serial dilution. Nutrient agar and *Pseudomonas* isolation agar (Sigma-Aldrich) were used. Strain R21 was identified on the basis of growth characteristic, microscopy and biochemical tests. The strains of *Pseudomonas fluorescens* were maintained on Luria-Bertani (LB) agar at 4°C and grown at 28°C overnight, shaking at 150 rpm.

In vitro biological control assay

An inhibition of phytopathogen by the *Pseudomonas* strains on Potato dextrose agar (PDA) plates was performed as detailed in previous study (Lawongsa et al., 2008). Bacterial suspension of strains F113 and R21 was spotted 2 cm from the edge of the plate, and 0.1-0.3 cm square plug from a culture of *Pythium* spp. was placed at the center of the plate. The results were assessed after 3 days by measuring the distance between the edges of the bacterial colony and the fungal mycelium.

Rice and soil preparation for the assay of *in vivo* antagonistic activity

The cultivated rice (*Oryza sativa* cultivar Pathum Thani 1) was obtained from Pathum Thani Rice Research Center, Pathum Thani, Thailand. The rice seeds were surface-sterilized with 70% ethanol for 1 min and shaken in 10% (w/v) NaOCl solution for 30 min. Seeds were then washed three times with sterilized distilled water by shaking (15 min each) (Prakamhang et al., 2009). Surface sterilized seeds were gnotobiotically germinated on sterilized wet tissue paper. After 3 days, rice seedlings in each treatment were transferred into pots (cm in diameter, 60 cm high) containing autoclaved soil. Three rice seeds were planted to a depth of 1 cm in each pot. Three replications for each treatment were done. Rice pots were placed in growth chambers maintained at 25 °C (± 1 °C) with 12 hours of light and 12 hours of darkness (Kato-Noguchi and Kanesawa, 2003).

Preparation of bacterial inocula and seed treatment for the assay of *in vivo* antagonistic activity

Cells of antagonistic bacteria for use in the assay of *in vivo* antagonistic activity were grown in King's Medium B broth (KMB) into a late exponential phase at 28°C with shaking at 150 rpm overnight. Cells were then harvest by centrifugation (5000 rpm/min for 5 min), washed twice and resuspended in 0.5% sterile NaCl solution. The rice seeds were soaked with bacterial suspension that was adjusted to about 10^8 colony forming units (CFU/ml) for each experiment and applied with *Pythium* spp. (1×10^6 spores/ml) (Timms-Wilson et al., 2000). Control treatments were inoculated in sterile distilled water and seedling with disease symptoms were recorded 4 weeks after planting. Plants were arranged in a randomized completed block design with three replications. Percentage of disease incidence was assessed 4 weeks after planting. Rice plants were sampled 4 weeks after planting to measure plant height, shoot and root dry weight.

Statistical analysis

Statistical analysis was performed using one way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at 5 % level using the statistical package of the social sciences (SPSS) version 17.0. The data presented are means standard deviation (SD) of three replicates.

Detection of pyoluteorin and pyrrolnitrin biosynthetic loci

Primers PltBf2 and PltBr were used for detection of the pyoluteorin biosynthetic locus of *pltB*. Primers PrnCf and PrnCr were used for detection of the pyrrolnitrin biosynthetic locus of *prn*C. PCR amplification was carried out in 25 µl reaction mixture containing 1× *Taq* DNA polymerase buffer, 200 µM each of dATP, dTTP, dGTP, and dCTP, 20 pmol of each primer, 1.5 mM MgCl2, and 0.06 units of Go*Taq* DNA polymerase (Promega). The PCR cycling program consisted of initial denaturation at 94°C for 2 min followed by 29 cycles of 94°C for 1 min, 58°C for 45 s, and 72°C for 1 min. The amplification products were electrophoresed in 1% agarose gels in 1× TAE buffer for 40 min at 100 Volt at room temperature, stained with ethidium bromide, and photographed under UV light (Mavrodi et al., 2001).

Detection of hydrogen cyanide production

The production of hydrogen cyanide (HCN) was measured as described by Castric, 1975. Whatman 3MM paper was soaked in a chloroform solution containing copper (II) ethyl acetoacetate (5 mg/ml) and 4,4'-methylene-bis-(N,N-dimethylaniline) (5 mg/ml), and subsequently dried and stored in the dark. A piece of paper was placed in the lid of a Petri dish in which bacteria had been placed on SA agar. The Petri dish was incubated overnight at 28 °C. Production of HCN by the bacteria was indicated by blue coloration of the paper (Castric, 1975).

Detection of genes involved with DAPG production by PCR

Standard PCR mixtures and PCR conditions were employed: typically, an initial denaturation step at 96°C for 3 min followed by 30 cycles of denaturation at 94°C for 30 s, then 30 s of primer annealing with temperatures dependent on the primer pairs used, and an extension of 1 kb per min at 72°C. DAPG genes were determined using *phlD* gene specific primers, Phl2a and Phl2b (Raaijmakers et al., 1997), and *phlA* gene specific primer, phlA-1f and PhlA-1r (Rezzonico et al., 2003).

RESULTS AND DISCUSSION

***In vitro* antagonistic activity**

The antagonistic activity from both strains R21 and F113 was summarized in Table 1.

Table 1 Measurement of diameter of fungal inhibition ring (cm) of *P. fluorescens* R21 against *Pythium* spp.

Pathogen	Diameter of fungal inhibition ring (cm)	
	R21	F113
Pythium spp.	1.4 ± 0.05	1.4 ± 0.05

The *in vitro* antagonism experiments with *Pythium* spp. (Figure 1) revealed that strain F113 showed the same level of antagonistic activity when compared to strain R21.

Assay of *in vivo* antagonistic activity

After two weeks, rice seedling inoculated with strains R21 and F113 showed damping-off symptoms. An initial symptom was developed as lesions on sheaths of lower leaves near the water line. After 4 weeks, the disease intensity in the treatment inoculated with *Pythium* spp. and strain R21 was 58.3 % while the disease intensity in strain F113 was 66.7 %. However, there is no significant difference in the disease intensity between applications of strain R21 and strain F113 against *Pythium* symptom (Fig. 2 and Table 2). These results indicated and confirmed the result of

in vitro antagonistic activity that the colonization of roots by *Pythium* spp. was suppressed by both strains R21 and F113. Additionally, there is no significant difference in plant height, shoots dry weight and roots dry weight of rice between applications of strain R21 and strain F113 against *Pythium* spp. Interestingly, the application of strain R21 to rice seeds showed significantly increased plant height, shoots dry weight and roots dry weight of rice when compared with control while the application of strain F113 to rice seeds showed no significant difference when compared to control.

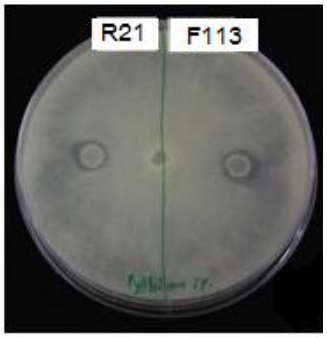

Fig. 1 *In vitro* antagonistic activity against *Pythium* spp. by strain R21 and strain F113

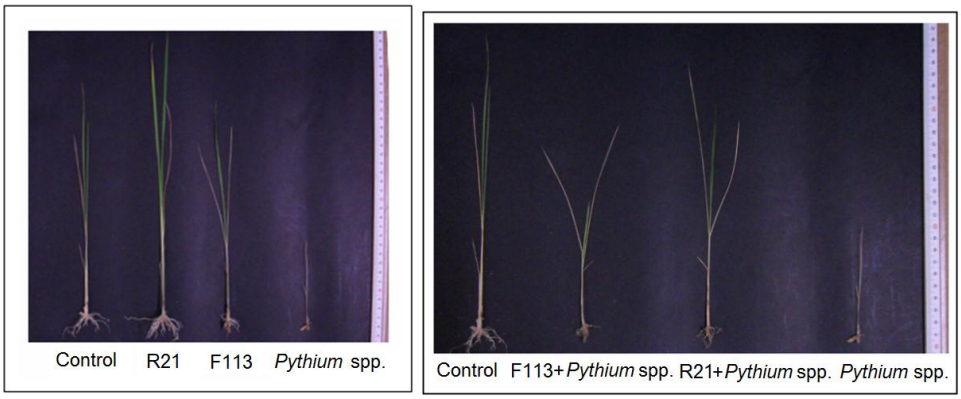

Fig. 2 *In vivo* antagonistic activity of strain R21 and strain F113 against *Pythium* spp.

Table 2 Disease incidence, plant height, and dry weight of shoots and roots of rice inoculated with strain R21 grown in the presence of *Pythium* spp.

Sample	% incidence	Plant height (cm)	Shoot dry mass (mg)	Root dry mass (mg)
Control	0^{c}	21.70 ± 1.57^{bc}	32.47 ± 2.50^{b}	11.44 ± 0.30^{b}
R21	0^{c}	28.77 ± 2.81^{b}	56.57 ± 6.14^{b}	22.22 ± 3.89^{b}
F113	0^{c}	22.40 ± 1.44^{b}	33.00 ± 7.05^{b}	10.15 ± 3.21^{b}
Pythium spp.	100 ± 0.00^{a}	9.40 ± 3.65^{d}	7.90 ± 0.98^{d}	2.17 ± 0.75^{c}
R21+*Pythium* spp.	58.3 ± 14.43^{b}	18.77 ± 2.85^{bc}	23.57 ± 5.95^{c}	5.56 ± 0.70^{c}
F1113+*Pythium* spp.	66.7 ± 14.43^{b}	17.67 ± 1.59^{c}	22.57 ± 1.05^{c}	5.82 ± 0.98^{c}
%CV	22.22	12.46	15.94	20.36

Means in columns followed by different letters are significantly different at 5 % level according to the Duncan's Multiple Range Test (DMRT)

Detection of secondary metabolites

Most biocontrol strains of *Pseudomonas* spp. with a proven effect in plant bioassays produce one or several antibiotic compounds. Pyoluteorin is composed of a resorcinol ring, derived through

polyketide biosynthesis (Nowak-Thompson et al., 1997). It is an antibiotic that inhibits oomycete fungi, including the plant pathogen *Pythium ultimum*, and suppresses plant diseases caused by this fungus (Howell and Stipanovic, 1980). The pyoluteorin biosynthetic gene cluster *pltLABCDEFG* is required for pyoluteorin biosynthesis (Nowak-Thompson et al., 1999). In this experiment, strain R21 was screened for the presence of pyoluteorin. *P. fluorescens* Pf-5 and CHA0 were used to be the positive control. The PCR result showed no PCR product was amplified from strain R21 with the PltBf2 and PltBr primers that amplified the predicted 773-bp fragment for detection of the pyoluteorin biosynthetic locus of *pltB* (Fig. 3). Pyrrolnitrin is a secondary metabolite derived from tryptophan and has strong antifungal activity (Zhou et al., 1992). DNA region confers the ability to produce pyrrolnitrin that contains four genes, *prnABCD*, each of which is required for pyrrolnitrin production. Pyrrolnitrin has been described as an inhibitor of fungal respiratory chains (Tripathi and Gottlieb, 1969) and synthetic analogues of pyrrolnitrin have been developed for use as agricultural fungicides (Ligon et al., 2000). In this experiment, strain R21 was screened for the presence of pyrrolnitrin. *P. fluorescens* Pf-5 and CHA0 were used to be the positive control. The PCR result showed no PCR product was amplified from strain R21 with the PrnCf and PrnCr primers that amplified the predicted 719-bp fragment of *prnC* (Fig. 3).

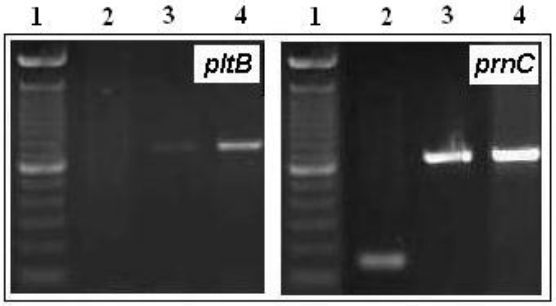

Fig. 3 PCR analysis of genes involved in pyoluteorin (*pltB*) and pyrrolnitrin (*prnC*) production. Lane 1, 100 bp ladder (Invitrogen); lane 2, R21; lane 3, Pf-5; lane 4, CHA0

HCN is a volatile compound which plays a role in biological control of some soilborne diseases (Haas and Defago, 2005). The cyanide ion derived from HCN is a potent inhibitor of many metalloenzymes, especially copper-containing cytochrome *c* oxidases (Blumer and Haas, 2000). In this experiment, strain R21 was screened for the presence of HCN. *P. fluorescens* Pf-5 and F113 were used to be the positive control for HCN detection. Strain R21 showed a negative result of hydrogen cyanide production (Fig. 4).

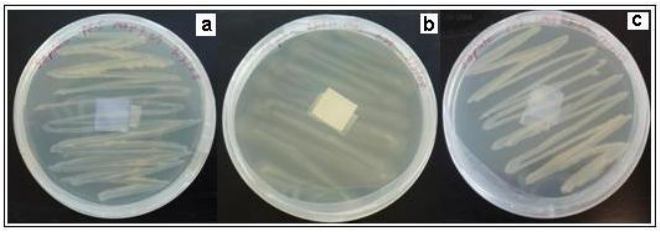

Fig. 4 Hydrogen cyanide production assay of strains Pf-5 (a), R21 (b) and F113 (c)

DAPG is the best-known phloroglucinol compound in a family of related molecules that includes MAPG and uncharacterized condensation products of DAPG and MAPG (Heeb et al., 2002). DAPG causes membrane damage to *Pythium* spp. and is particularly inhibitory to zoospores of this oomycete (de Souza et al., 2003). In this experiment, strain R21 was screened for the presence of DAPG. *P. fluorescens* Pf-5, CHA0, and F113 were used to be the positive control. The result showed that the positive amplification PCR product was revealed by strain R21 using

primers Phl2a and Phl2b that amplified the predicted 745-bp fragment of *phlD* (Fig. 5) and primers phlA-1f and phlA-1r that amplified the predicted 418-bp fragment (Fig. 5).

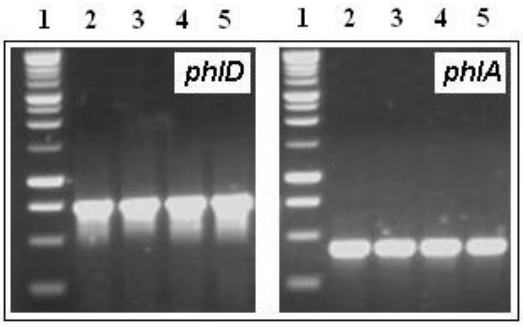

Fig. 5 PCR analysis of genes involved in DAPG production (*phlD* and *phlA*). Lane 1, 1 kb ladder (Promega); lane 2, R21; lane 3, Pf-5; lane 4, CHA0; lane 5, F113

CONCLUSION

Among biocontrol agents, *P. fluorescens* producing the polyketide antibiotic DAPG are important groups of plant growth promoting rhizobacteria (PGPR) that suppress root and seedling diseases on a variety of crops. In this study, the results of *in vitro* and *in vivo* antagonistic activity showed that *Pythium* spp. that caused damping-off and root rot was suppressed by strain R21 and F113. Interestingly, the application of strain R21 to rice seeds showed a significantly increased of plant height, shoots dry weight and roots dry weight of rice when compared with control while the application of strain F113 to rice seeds showed no significant difference when compared to control. This information indicated that the ability to colonize rice roots is variable between rhizobacteria, being these characteristics a reflection for their ability to compete for ecological niches in the rhizosphere. Moreover, the exertion an appropriate biological control of soil borne fungi relies on their ability to colonize roots efficiently; otherwise, their biocontrol character would be unusable. Thus, introduction of biocontrol agent to agriculture requires appropriate and compatible PGPR for the goal of making agriculture more sustainable. Moreover, an understanding of how biocontrol bacteria regulate the inhibition of pathogens is important for predicting the optimum environmental conditions of the bacteria to produce antagonistic compounds.

ACKNOWLEDGEMENT

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Research article

Assessment of the Groundwater Quantity Resulting from Artificial Recharge by Ponds at Ban Nong Na, Phitsanulok Province, Thailand

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Abstract Ban Nong Na Phitsanulok Province, has been facing continuous groundwater level decreases, from 1-2 m below ground surface in the past 25 years to 7-8 m in the present due to overexploitation for irrigation. This area was selected as a pilot site to construct and conduct the recharge experiment. The objective of this research is to quantify groundwater mound resulting from the recharge experiment using MODFLOW2000. Two recharge ponds A and B, which have an area of 660 and 600 m^2, respectively, were constructed in the selected site of the study area. The experiment duration was July to November, 2010 using raw water with turbidity less than 100 NTU. The total recharge amount is 25,797 m^3. The results showed that under the experiment conditions the designed recharge pond can provide a moderately good analysis of the recharge water. The mounding results of the simulations were compared with the field observation; both were found to be compatible. After 5 days of the fifth test, the maximum rise of the mound was 3.33 m and covers an area of approximately 6,000 m^2.

Keywords artificial recharge, groundwater mound, Phitsanulok

INTRODUCTION

The Groundwater Research Center (GWRC), Khon Kaen University, was invited by the Department of Groundwater Resources (DGR), Ministry of Natural Resources and Environment, to conduct the research on "Pilot Study and Experiment on Managed Aquifer Recharge Using Ponding System in the Lower North Region River Basin, Phitsanulok, Sukhothai, and Pichit Provinces" to test the feasibility of using artificial groundwater recharge to reverse the declining trend. The project duration was between April 2009 and April 2011. The project area was identified from the Lower North Region River Basin areas of about 21,300 km^2 covering the areas of Phitsanulok, Sukhothai, and Pichit Provinces using a zooming-in technique ultimately focusing in on the Ban Nong Na pilot area of approximately 4.12 km^2, and a construction site for the artificial recharge pond system of about 0.01 km^2. Ban Nong Na pilot project area is suitable for the construction site of recharge pond system because it fits various suitability indices such as; (i) hydrogeological suitability, which include thin top clay layer of less than 3 m thick, thick shallow strata (10-15 m) of sands and gravels with good continuity of strata; (ii) there are about 100 agricultural wells for target water user; (iii) suitable distance from raw surface water source; (iv) availability of electricity and access road; and (v) availability of land and good cooperation from

local people and local organization (DGR, 2011). Uppasit et al (2011) described the site characterization for the ponding recharge system at Ban Nong Na and used the finite difference groundwater flow model, MODFLOW2000, (Harbergh et al, 2000) in order to assess the groundwater flow and groundwater balance.

The objective of this study is to quantify the groundwater mound resulting from the recharge experiment using numerical modeling technique in the study area.

STUDY AREA

General description

The study area covers Ban Nong Na, Tambon Nong Kula, Amphoe Bang Rakham, Phitsanulok Province. Topographic elevations range between 43-50 meters above mean sea level (m amsl). Low elevations are found in the central and northern part and to the southeast of the study area which are mainly dominated by paddy fields. High elevations are found in the southwestern part, where landuse is mainly dominated by villages and sugarcane fields. Soil types of the study area consist of loamy sand, clay, and loamy clay (Fig. 1). Important sources of surface water are Klong Lan Ba and a drainage canal. Klong Lan Ba is located in the northern part of the study area and flows from West to East with a total catchment area of 30.38 km^2. The canal is used to drain water from paddy fields. It flows from west through the central part, and drains into Klong Lan Ba in northern part with a catchment area of 6.54 km^2. Average runoff of the drainage canal is about 0.75 million (M) m^3/y. Surface water quality is good and with no contamination of chemical fertilizers under the standard of notification of the national environmental board No. 8. Surface water turbidity frequently exceeded the "recharging waste water into groundwater wells regulation" of 50 NTU established by the Ministry of Industry, Thailand. Manganese concentration ranges from 5-8 mg/L (the standard is 1 mg/L; DGR, 2011). The water of the canal is used to recharge the aquifer using the pond system.

Hydrogeology

Detailed hydrogeological characteristics of the study area were obtained from the field investigation. Forty seven wells were drilled and installed in the main directions of groundwater flow since June, 2009 to explore geology, and monitor the groundwater level and quality. These include 32 wells for shallow depths of less than 15 m and 15 wells for depths greater than 15 m. Uppasit et al (2011) described the hydrogeology of the study area, underlain by alluvial fan deposits (Qaf) consisting of sand, gravel and clay; and flood plain deposits (Qff) composed of sand and gravel (Fig. 2). The area is overlain with clay layer of varying thickness of 0-3 m. Shallow aquifers deposited at the depth of 6 to 20 m below ground level. Thin clay layer of 2 to 7 m separates the shallow and deeper aquifers. The deep aquifer consists of gravelly sand and is found at 17-27 m depth (Fig. 3). The shallow aquifer has a transmissivity (T), hydraulic conductivity (K), and storativity (S) of 2,000-3,400 m^2/d, $2.43x10^{-3}$ - $3.90x10^{-3}$ m/s, and 0.001-0.090, respectively. The deep aquifer has T and S values of 30-150 m^2/d, and 0.001-0.040, respectively. The main groundwater moves from the southern part area with a head of 38.5-39 m amsl to the northern part area with a head of 36-36.50 m amsl (Fig.2). Shallow groundwater depths range from 7-9 m below the ground surface. The groundwater recharge of the study area is about 6 to 21% of annual rainfall (1,300 mm). The groundwater balance study using mathematical groundwater model simulations in the study area showed that the total groundwater recharge rates, use and deficit are about 1.2, 1.5 and 0.23 Mm^3/y, respectively. Groundwater level in the current condition showed a declination of 0.25 m/y.

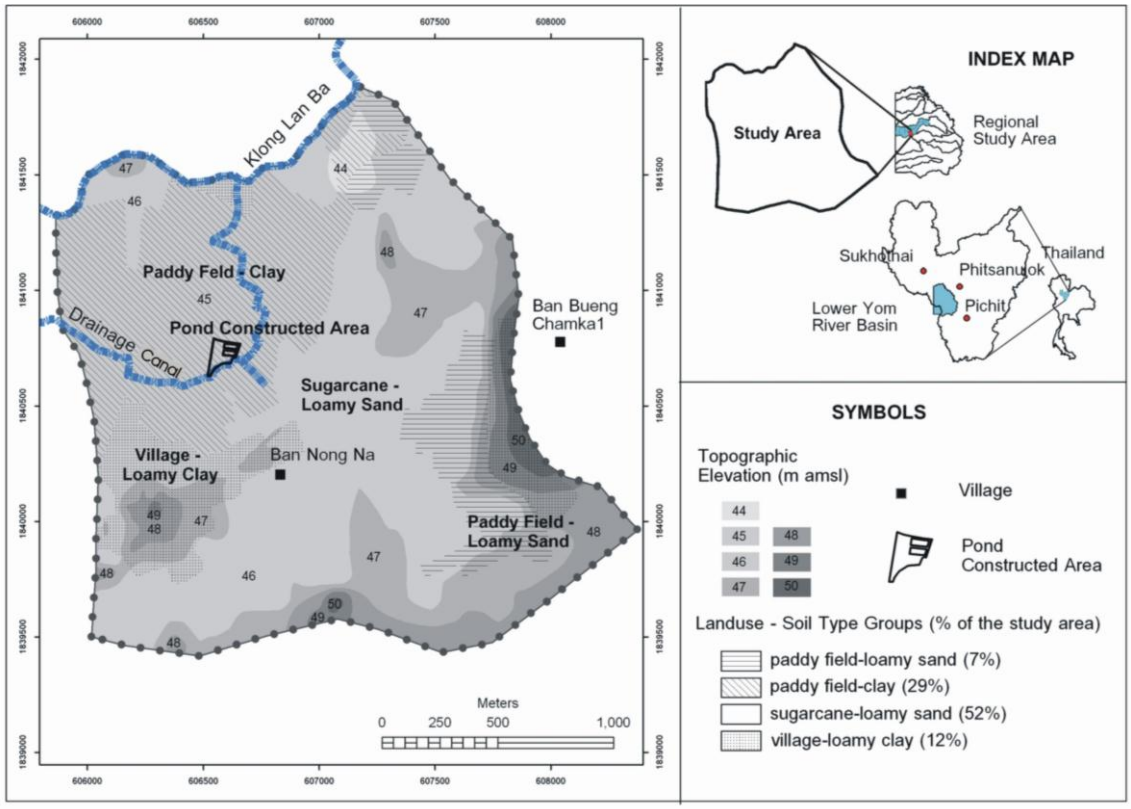


Fig. 1 Map of the study area showing topography and landuse

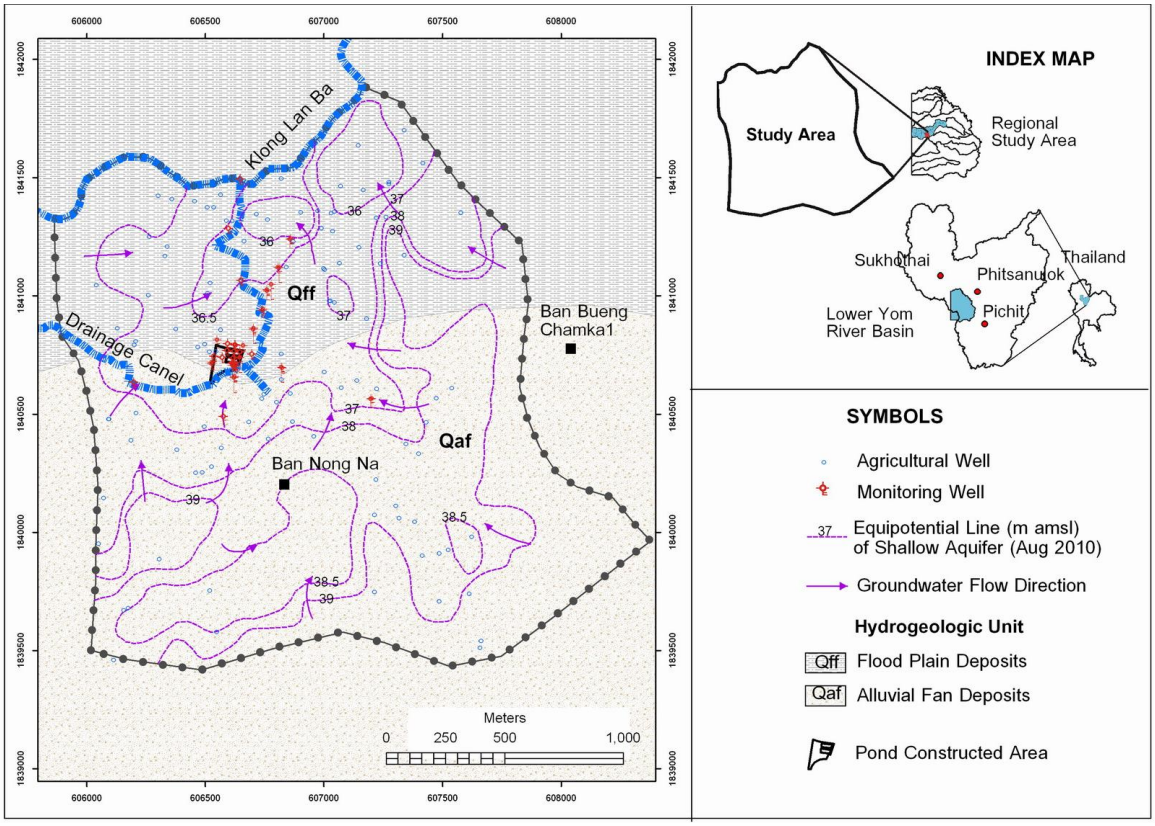


Fig. 2 Hydrogeological map of the study area

The thirty nine groundwater samples from the groundwater wells were monitored prior and during the recharge experiments and analyzed for physicals, chemicals, and toxic elements following the standard of characteristics discharged into deep wells of the Notification of the Ministry of Industry, No. 5 B.E. 2521 (1978) and analyzed for volatile organic compounds, heavy metals, and pesticides following the groundwater quality standards of the Notification of the National Environmental Board No. 20, B.E. 2543 (2000). It was indicated that the samples are of good quality and do not show signs of contamination from fertilizers or pesticides (DGR, 2011).

METHODOLOGY

The methods used in this paper consist of (1) data compilation including climate, physiography, hydrology and hydrogeology from the literature review and field investigation of DGR (2011) and Uppasit et al (2011); (2) recharge pond experiment, groundwater level and quality monitoring; and (3) numerical modeling of groundwater flow, balance and mound prior and resulting from the recharge experiment.

Recharge pond system and experiments

The recharge pond system was constructed in the central part of the study area closely to the drainage canal (Fig. 3). The construction site consists of two main systems; four constructed wetlands for raw water quality treatment, and two recharge ponds. The constructed recharge ponds A and B have ground surface areas of 1,250 and 1,160 m^2 and the bottom floor areas of 660 and 600 m^2, respectively. The depths of the ponds A and B are 2.66 and 2.75 m with the maximum storage capacity at the storage level of 2 m of 1,830 and 1,690 m^3, respectively. The side slope of the ponds was designed at 1.5:1 to ensure slope stability. The bottom floor of the ponds were covered with filter sand layer of 0.5 m thick and the side walls and bottom floors were lined with synthetic filtering blankets for sediments filtering and protection of erosion (DGR, 2011).

The twenty two shallow groundwater wells situated along the major groundwater flow direction were installed to monitor the water level fluctuation during experimental of artificial recharge. The recharge pond experiment was made 5 times for 55 days during July to November 2010, the recharge vary from 3,953-4,439 m^3 using surface water with the average turbidities varying from 27.2 to 89.9 NTU. The total recharged water is 25,797 m^3 as shown in Table 1 (DGR, 2011). During the longest experiment of 30 days in the fifth test, the groundwater level underneath the recharge ponds rises to the highest level of 3.33 m from normal immediately after 5 days of artificial recharge operation and after that gradually lowers to normal level (Fig. 3). The groundwater flows from the recharge pond area to the surrounding region and the north with average flow velocity of 0.07 m/day. The results of the physical, chemical and biochemical groundwater quality monitoring show no indications of groundwater quality changes (DGR, 2011).

Groundwater numerical modeling

The simulation area is 2.6 km in width and 2.7 km in length. The size of the grid cells increase from 5 m x 5 m at the recharge pond area to 20 m x 20 m at the remainder of the model. The model height ranges from 0-50 m amsl. Model was divided into three layers; shallow aquifer, deep aquifer, and confining layer. For the shallow aquifer, the southern side was selected as groundwater divided boundary, eastern and western boundaries as parallel with groundwater flow line, and northern side set as river boundary. For the deep aquifer, western and eastern sides are designed as prescribed flux, and southern and northern boundaries as parallel with groundwater flow line. Ponds A and B were assigned as recharge boundaries.

The recharge from rainfall and the pilot experiment was assigned using recharge boundary. Groundwater usage was simulated by the well package. The hydraulic property values are assigned based on the range of field hydrogeological testing results. The model was calibrated with the water level data both in prior and during the recharge experiment. In current condition, the water level data of 59 monitoring wells observed during monthly basis since December 2009 to November

2010. During the recharge test, water level data in daily basis of 22 monitoring wells were calibrated.

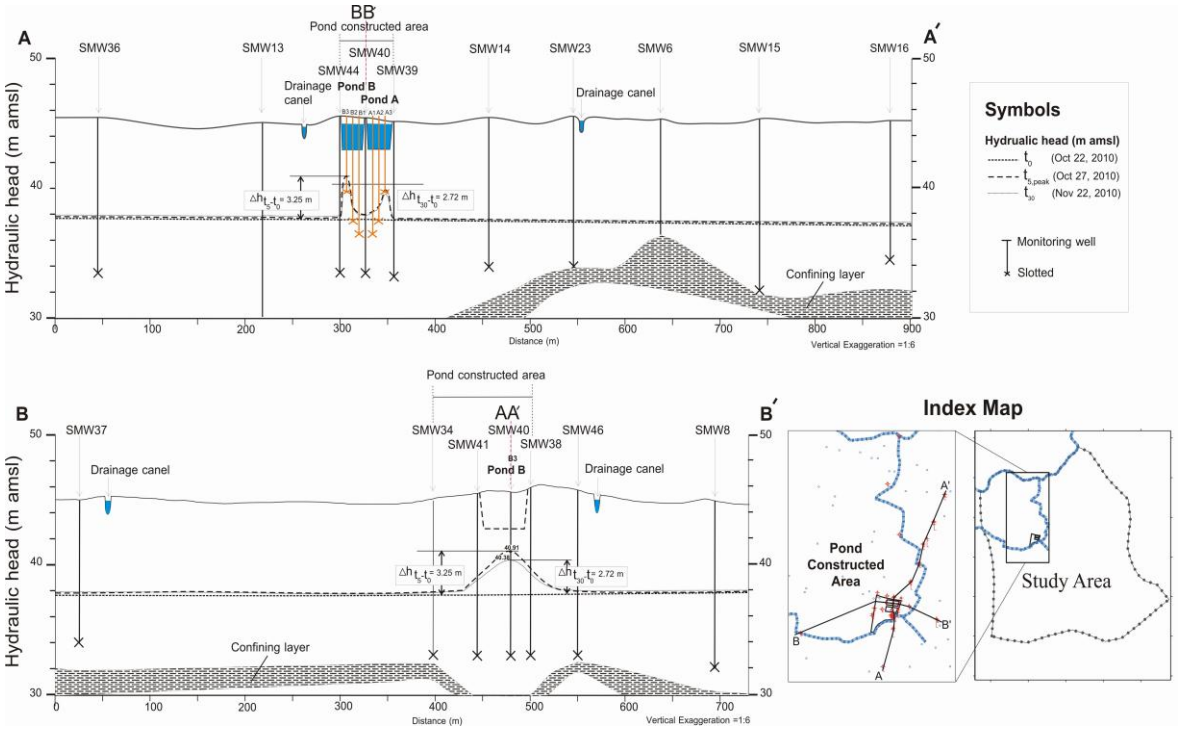


Fig. 3 Cross sections showing groundwater mound during the fifth experiment.

Table 1 Field data of the recharge pond experiment

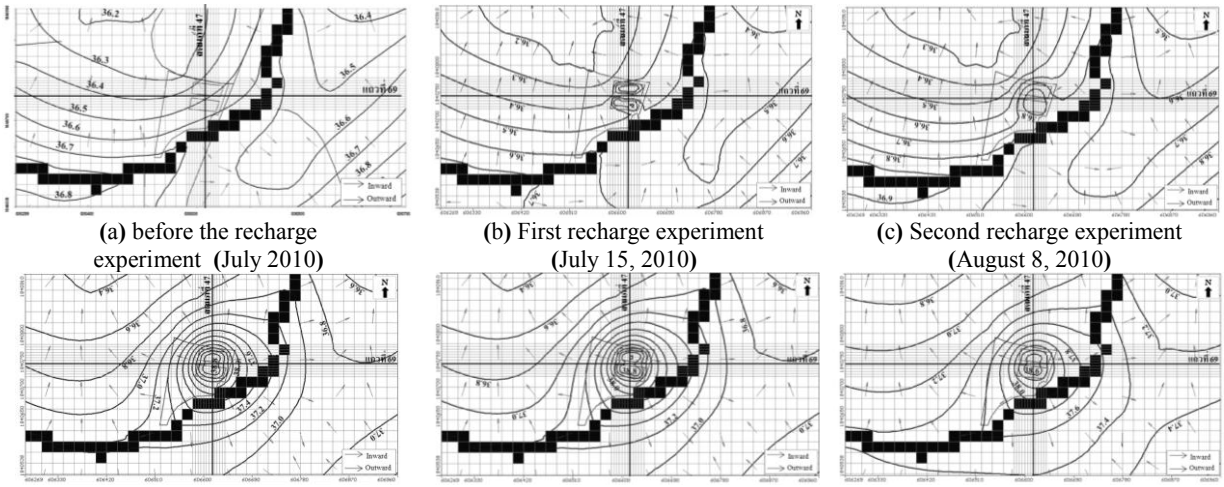
No.	Pond	Duration (days)	Recharged water Turbidity (NTU)	Artificial recharge (m^3)
1	B	Jul 13-15, 2010 (2)	52.6	814
2	A	Aug 3-8, 2010 (5)	27.2	4,439
	B			896
3	A	Aug 25-Sep 8, 2010 (14)	71.9	1,918
	B			4,157
4	A	Sep 19-23, 2010 (4)	65.5	2,835
	B			1,901
5	A	Oct 23-Nov 22, 2010 (30)	89.9	4,884
	B			3,953
Total		Jul 13-Nov 22, 2010 (55)		25,797

RESULTS AND DISSCUSSION

Groundwater flow pattern in natural condition shown that groundwater flows from the southern part of the study area or at Ban Nong Na with recharge rates of 6 to 21% of rainfall to the cone of depression area in the northern region nearby Klong Lan Ba and is characterized by low recharge rates of 3 to 5%. Groundwater heads surrounding the recharge ponds A and B were 36.70-36.30 m amsl (Fig. 4a). Groundwater balance during the recharge experiment can be summarized as the followings: the total recharges to the study area were 1.37 Mm^3 including the total of artificial recharge of 25,735 m^3, and seepage from the river was 0.17 Mm^3. The total annual draft through pumpage was 1.40 Mm^3. The subsurface horizontal inflows and outflows were 0.17 Mm^3. The result shows a deficit balance of 0.20 Mm^3. A continuous trend of groundwater decline of 0.22 m/y can be found for the study area. The mounding results of the numerical model simulations were compared with the field observation; both were found to be compatible with the Root Mean Square (RMS) of 0.48 m.

During the recharge experiment, it was found that groundwater mounded underneath the recharge ponds as shown in Fig. 4b and Fig. 4f. Groundwater flows from the central part of the

mound to the surrounding area. The mound geometry that develops in the unconfined aquifer beneath the recharge ponds depends on several factors including the aquifer hydraulic properties, aquifer thickness, duration and quantity of the artificial recharge.



(a) before the recharge experiment (July 2010) (b) First recharge experiment (July 15, 2010) (c) Second recharge experiment (August 8, 2010)

(d) Third recharge experiment (September 7, 2010) (e) Fourth recharge experiment (September 22, 2010) (f) Fifth recharge experiment (November 22, 2010)

Fig. 4 Simulations of groundwater levels before and during the recharge pond experiment

CONCLUSIONS AND RECOMMENDATIONS

Groundwater recharge mound from the recharge experiment can be quantified using numerical modeling technique. It can provide a clarification of recharge mechanism, water balance, and mounding characteristics. Results from the simulations indicated that groundwater deficit in Ban Nong Na could be controlled by constructing an artificial recharge system in the highly abstraction of groundwater areas. Based on the results of pilot experiments, to keep the water table in Ban Nong Na area as the current condition, the volume of artificial recharge in this area have to be increased to not lower than 0.23 Mm^3/y, which indicated that more than 6 six recharge systems need to be implemented in this area.

ACKNOWLEDGEMENTS

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Research article

Effects of Transplanting Methods on Yield of Different Rice Varieties under Sandy Soil Conditions

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Abstract Rice is a staple food for Cambodians and it is also a main source of income for farmers' livelihood in rural areas. However, rice yield is low so it is vitally important to increase rice yield through promoting new rice varieties and cultivation methods. To promote new knowledge for famers, an experiment regarding the effect of transplanting methods on rice yield of different varieties was conducted in experimental station. The experiment investigated the interaction of different transplanting methods on rice varieties and identified the best variety and transplanting methods for rice cultivation. The experimental design was based on Randomize Complete Block Design (RCBD) which had six treatments: Riang Chey variety with straight-row transplanting, Riang Chey variety with conventional transplanting, Phkar Rumduol variety with straight-row transplanting, Phkar Rumduol variety with conventional transplanting, IR66 variety with straight-row transplanting, IR66 variety with conventional transplanting and three replications. Hill spaces were 25 cm x 25 cm for straight-row transplanting method, and 15 cm to 25 cm for conventional transplanting method. The result of the experiment showed that yield component, panicle number per hill, percent of filled grains per panicle and total yield of three varieties transplanted straight–row transplanting method had significant difference with conventional transplanting method. However, the yield components, panicle length and 1000-grain weight of three varieties transplanted by using straight–row transplanting method had no significant difference from conventional transplanting. Also, the rice yield components had no interaction with the three varieties and the transplanting methods. IR 66 variety with straight–row transplanting method had the highest yield with 6.145 t/ha in average compared to conventional transplanting method with only 5.630 t/ha in average. In conclusion, among three varieties and two transplanting methods, the potential and highest yield was IR66 variety transplanted by using straight-row transplanting method.

Keywords cultivated method, conventional transplanting, straight-row transplanting, yield component

INTRODUCTION

Cambodian agriculture sector has played a vital role in increasing national economy as it has provided many jobs for 85% of people in rural areas, and contributed with 34.4% of GDP (Sarun, 2007; MAFF, 2009). Rice is a main stable crop which ensures food security and is a main source of income for Cambodian people in rural areas (Helmer, 1997).

In rainfed lowland rice, 70% of farmers cultivate rice with traditional methods and use traditional varieties. They also transplant rice seedlings that were 40 to 80 day olds and 4 to 5 seedlings per hill, and transplant too much of rice seedling hills in paddy field that reached 800,000 hill/h (Rickman et al., 1997). Rice yield is low comparing to other Asian countries because 91% of total rice productivity depends on rainfall, damage from pests, and decreasing soil fertility (Javier, 1997).

Makara et al. (2001) reported that to increase rice yield, it is necessary to develop new varieties which produce high yield, are resistant to climate stress and pests along with new cultivation techniques which are suitable for each rice agro-ecosystem. More importantly, the new varieties and the new cultivated techniques should be promoted and taught to local farmers. In 2000, system of rice intensification (SRI) was introduced to farmers by CEDAC, Cambodian NGO, and in 2005 SRI technique was promoted widely to local farmers by MAFF and other NGOs. However, some principles of SRI were not applied by farmers, and there are few farmers who have applied SRI techniques (Sarun, 2007; Sothy and Rattana, 2008).

The objectives of this research are to determine the interaction of different transplanting methods on rice varieties and to identify the best variety and transplanting methods for rice cultivation.

MATERIALS AND METHODS

Site description

Soil condition: This study was carried out at the crop experimental station of the Royal University of Agriculture, Cambodia. The soil condition of experimental site is Prateash Lang soil type (85% is sandy soil). Prateash Lang soil has low fertility so it needs be applied with organic fertilizer combined with chemical fertilizer. The properties of this soil are detailed in Table 1.

Climatic conditions: In 2009 annual average temperature at experimental site was 28.40 ^{o}C. Minimum average temperature was 26 ^{o}C in December and maximum average temperature was 30.50 ^{o}C in May. For rainfall, 2009 annual average rainfall was 137.06 mm, and higher average rainfalls were recorded in August and September, 290 mm and 289.60 mm respectively (Fig. 1)

Table 1 Soil properties in experimental site

Soil property	Prateah Lang soil (Red yellow podzol)
Organic matter (OM) %	0.26
C %	0.156
N %	0.035
P (ppm)	113
K (meq/100g soil)	0.12
Mg (meq/100g soil)	1.25
Ca (meq/100g soil)	2.5
Na (meq/100g soil)	0.86
pH	5.5-7.5
C:N Ratio	5

Source: Soil result analysis, department of Agronomy and soil improvement, 2005

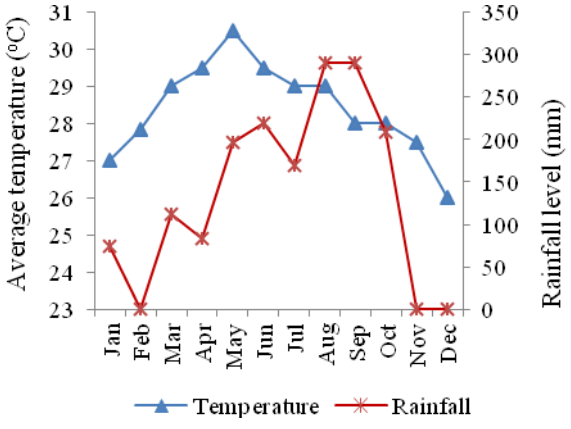


Fig. 1 Average temperature and rainfall level during 2009

Experimental design

Three common rice varieties including Riang Chey, Phkar Rumduol and IR6 developed by CARDI were selected to conduct the experiment in the station in 2009, and these rice varieties were cultivated with two different transplanting methods: straight-row transplanting method with hill

space of 25 cm x 25 cm and conventional transplanting method with variable hill space from 15 cm to 25 cm. The experimental plots (9 m^2) were organized based on randomized complete block design (RCBD) with 6 treatments and 3 replications set up at the crop station. Each plot was applied with 10 t/ha of compost manure before transplanting.

Data analysis

Parameters for data collection of rice yield components including panicle, panicle length, filled grain, 1,000-grain weight and grain yield were calculated for means and significant difference determined between treatments by analysis of variance (ANOVA) at 5% and 1% of significant level. In addition, multiple comparison of the treatment was tested for high significant difference by Muncan's Multiple Range Test (DMRT) at 5% of significant level. Also, simple linear regression was performed to determine relationships of yield component and grain yield by using Microsoft Excel.

RESULTS AND DISCUSSION

The result of statistical analysis indicated that the yield components of three rice varieties had significant difference at 1%. Also, the two transplanting methods had effect on panicle per hill, filled grain and grain yield of the three varieties. However, panicle length and 1,000 - grain weight of each variety had no significant difference between the two transplanting methods; and there was no interaction between three varieties and two transplanting methods on rice yield component (Table 2).

Table 2 Summary of statistical analysis of rice yield component

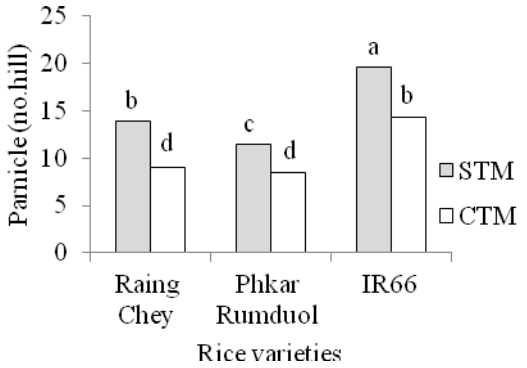
Rice Varieties	Transplanting methods	Yield components				
		Panicle (no./hill)	Panicle length(cm)	Filled grain (no./panicle)	1,000-grain weight(g)	Grain yield (t/ha)
Raing Chey	STM	13.84^{b}	23.83^{b}	164.80^{a}	23.37^{b}	4.872^{c}
	CTM	8.95^{d}	23.73^{b}	134.60^{b}	22.99^{b}	4.427^{d}
Phkar Rumduol	STM	11.48^{c}	24.90^{a}	110.86^{c}	27.22^{a}	3.654^{e}
	CTM	8.49^{d}	24.43^{a}	82.27^{d}	26.86^{a}	3.347^{f}
IR66	STM	19.51^{a}	23.01^{c}	118.40^{c}	21.59^{c}	6.145^{a}
	CTM	14.25^{b}	22.88^{c}	93.03^{d}	21.42^{c}	5.630^{b}
F-test	Variety	**	**	**	**	**
	Method	*	ns	*	ns	*
	Variety* Method	ns	ns	ns	ns	ns
C.V (%)		6.92	2.18	5.64	1.70	5.60

** = Significant at 5%, **= Significant at 1%, ns = Non significant difference*
Different letters were DMRT test by significant difference at 5%
STM: Straight-transplanting method, CTM: Conventional transplanting method

The results of the experiment showed that IR 66 variety had more panicles per hill than Raing Chey and Phkar Rumduol varieties, and for straight-transplanting method IR 66 had more panicles per hill than when it is transplanted by using conventional transplanting method (Fig. 2). Raing Chey variety had more filled grain per panicle than Phkar Rumduol and IR 66 variety, and with straight-transplanting method, Raing Chey variety got more filled grain than when it is transplanted by using conventional transplanting method (Fig. 3).

Fig. 4 shows that IR 66 variety (average grain yield was 6.145 t/ha) cultivated by using straight-transplanting method got higher grain yield than Raing Chey and Phkar Rumduol variety, by using conventional transplanting method which was only 5.630 t/ha in average.

Straight-transplanting method made rice to produce more panicles per hill than rice transplanted by using conventional method. The relationship between panicles per hill and grain yield showed that increasing IR 66 yield was correlated highly with panicle per hill. Furthermore, grain yield of Raing Chey and Phkar Rumdoul variety did not only depend on panicle per hill but also on filled grain (Fig. 5 and Fig. 6).



*STM: Straight- transplanting method,
CTM: Conventional transplanting method

Fig. 2 Panicle number per hill of each variety with different methods of transplanting

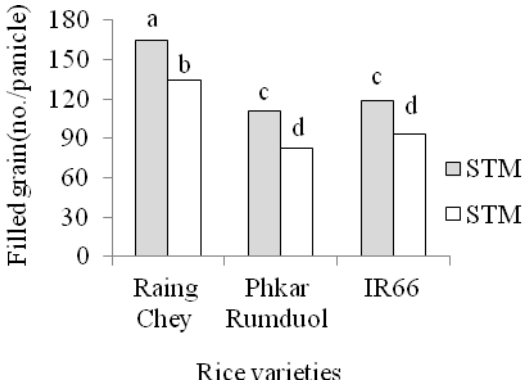


Fig. 3 Number of filled grain per panicle of each variety with different methods of transplanting

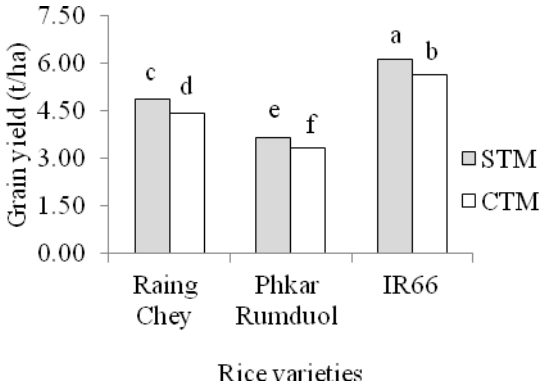


Fig. 4 Grain yield of each variety with different methods of transplanting

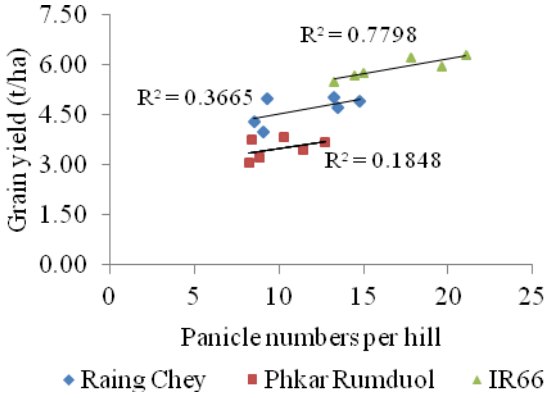


Fig. 5 Relationship between panicle number perhill and grain yield

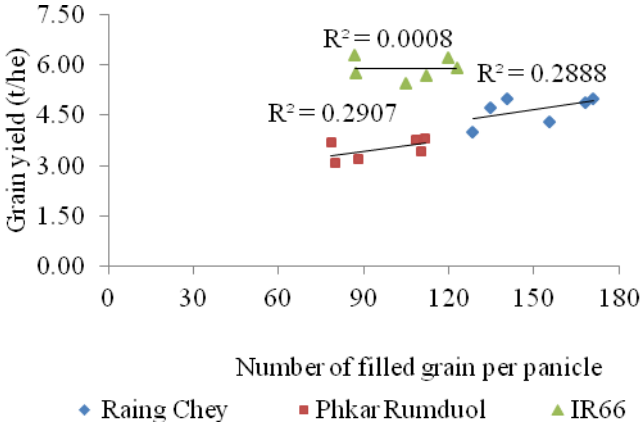


Fig. 6 Relationship between filled grain per hill and grain yield

Cultivation of rice by using straight-transplanting method provides the potential for rice to absorb nutrients from the soil, and sunlight to make photosynthesis higher; it also increased rice

yields from 25% to 39%, higher than conventional transplanting. Contrastingly, conventional transplanting can cause rice yield to decrease from 20% to 30% (IRRI, 1987; Men Sarom, 2007). Takan and Kiyochika (1993) reported that shade affects filled grain and weight of grain, and yield component will decrease if sunlight intensity decreased. Shouichi (1981) also reported that sunlight intensity is vitally important in dough grain stage and mature grain stage. Rice will grow well when intensity of sunlight is higher than 250 cal/cm^2, and if light intensities reached 300 cal/cm^{2,} rice yields will increase to 5 t/ha.

CONCLUSION

This study has indicated that the yield component of each variety is significantly different. Panicle per hill, filled grain and grain yield of the three varieties were significantly different between straight-transplanting and conventional transplanting. However, panicle length and 1,000- grain weight were not significantly different between the two transplanting methods. Also, there was no interaction between these varieties and two transplanting methods. Therefore, IR66 variety transplanted by using straight-transplanting method got yields in average 6.145 t/ha higher than those of IR66 transplanted by using conventional transplanting method. As a result, among the three varieties, IR66 variety has the potential for producing higher yields than Raing Chey and Phkar Rumdoul variety. The best method for transplanting rice is straight-transplanting methods.

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Research article

Comparison of System of Rice Intensification (SRI) Practices in Irrigated and Rainfed Areas of Cambodia

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Abstract Based on principles of the System of Rice Intensification (SRI) practices, farmers need to manage properly the water level in the paddy fields to get higher yields. It is only in the irrigated area where farmers can control the water level. However, the practice of SRI has been disseminated to farmers also in rain-fed areas in Cambodia. Therefore, the study aimed to compare the SRI results done so far by farmers in irrigated and rain-fed areas and explain the SRI practices in both areas. Irrigated and rain-fed areas in Kampong Speu Province of Cambodia were selected as study areas. In irrigated areas, five farmers from upstream and downstream were selected. In rain-fed areas, five SRI farmers were also chosen. In-depth interview was conducted with field observation. The results showed that farmers at upstream can grow rice twice (late ripening variety-LRV and early ripening variety-ERV) per year. Farmers at downstream and in rain-fed areas can grow rice only one time (ERV) per year. There is an irrigation system at downstream area, but farmers cannot grow rice twice due to the lack of irrigation facilities, poor water distribution, and geographic condition. In rain-fed area, drought occurs in some years; so water availability is a big concern. In both areas, LRV conventionally provides the yield from 2.31 to 2.36t/ha. SRI way can improve the yield up to 3.30t/ha to 3.70t/ha. Besides same provided yields, farmers have applied almost same SRI principles such as reducing seeds for sowing (up to 50%) and chemical fertilizers (20% to 40%), raising nursery bed, and transplanting with fewer seedlings. So, the study concludes that SRI practices in rain-fed areas are similar with ones in irrigated area. Although irrigation system is a big advantage, controlling water in paddy fields in both areas is still a problem since irrigated facilities are poor.

Keywords system of rice intensification (SRI), irrigated area, rain-fed area, early ripening variety, late ripening variety

INTRODUCTION

In spite of the fact that several big NGOs such as Oxfam/GB and GTZ have played an important role in supporting local NGOs to implement and disseminate SRI in several provinces in Cambodia (CEDAC, 2004), most Cambodian farmers cannot practice SRI well due to inadequate irrigation systems and other inputs. Proper management of water level in paddy fields is one of the fundamental practices of SRI that produces higher yield. Today only 16% of total cultivated areas have been irrigated, revealing that Cambodia is using only 1% of its total water resources in Agriculture (Ngin, 2010). However, currently, SRI techniques are being promoted in rain-fed areas (Tsurui, 2010). This is surprising since it is hard for farmers in rain-fed areas to practice SRI without proper irrigation systems. Thus, it is worthwhile to know how much farmers in rain-fed areas earn after applying SRI techniques since only irrigated farmers can benefit from these

techniques before. Therefore, this study aimed to compare the SRI results produced by farmers in both irrigated and rain-fed areas, and to explain the SRI practices in both areas.

MEHODOLOGY

The study was conducted in Kampong Speu province in Cambodia. Two types of SRI farmers in Chbar Mon City were selected as key informants for irrigated areas. Five Farmers in Srae Thnal village (upstream) are represented as Farmers A1-A5, and five Romleang village farmers (downstream) are represented as Farmers B1-B5. The other five SRI farmers in Samraong Tong District were selected as key informants for rain-fed areas. They are represented as Farmers C1-C5. Qualitative and quantitative approaches were mainly used. Primary and secondary data collections were utilized to get needed information from various existing sources and field works.

Primary Data: The research employed the following data collection to get the needed data:

In-Depth-Interview: Fifteen classified farmers (A1-5, B1-5, and C1-5) were thoroughly questioned about SRI results, performances, perceptions and willingness to continue SRI.

Village observation: Village resources, farming land and the status of agricultural practices in the village can be noticed in order to create real images for the research.

Secondary data: Documents related to the concept of SRI are reviewed. Those documents can be reached by accessing the websites, libraries, reports, or research journals, etc.

Data analysis is done by using both descriptive and statistical analysis. Data are condensed and critically analyzed in order to respond to the above-mentioned objectives.

RESULTS AND DISCUSSION

Comparison of rice yield between SRI and Conventional ways

Before following the SRI techniques, farmers were told that SRI can provide higher yields. This established a reason for farmers in study areas to decide to apply these techniques. Based on the interviews with SRI selected farmers, some have made comparisons of SRI to conventional methods by applying these techniques in different plots. Without conducting experiments, a researcher simply asked farmers to compare the yields of conventional plots and SRI plots during 2009-2010.

Table 1 Comparison of average rice yield between SRI and Conventional ways

Area (t/ha)	Farmers	Seasons	Varieties	Methods	Average Yield
Irrigated Upstream	A1-A5	Dry (2009)	ERV	Conventional	**2.25**
				SRI	***3.51***
		Rainy (2009, 2010)	LRV	Conventional	**2.31**
				SRI	***3.70***
Irrigated Downstream	B1-B5	Rainy (2009, 2010)	LRV	Conventional	**2.36**
				SRI	***3.20***
Rain-fed	C1-C5	Rainy (2009, 2010)	LRV	Conventional	**2.31**
				SRI	***3.30***

As shown in Table 1, in the upstream portions of the irrigated areas, the average yield for Late Ripening Variety (LRV) conventionally is 2.31 t/ha; while SRI way can improve the yield up to 3.70 t/ha. For the downstream and rain-fed areas, the average yield of conventional methods is almost the same as upstream yields, approximately 2.31 to 2.36 t/ha. SRI method yields are slightly less compared to those of upstream, at roughly 3.20 to 3.30 t/ha. However, the difference was not as much as expected. It can therefore be concluded that SRI practices in both areas provide nearly

the same results because they have not applied all the SRI techniques. Moreover, irrigation systems in irrigated area do not greatly help improve the SRI results. Although there are irrigated facilities, good water distribution and the functions of facilities remain poor. It can be said that irrigation systems in Cambodia are not on big scale but of a small farming scale. Therefore, it is hard for farmers to use the irrigated facilities to full capacity because they have a limited knowledge in operating those facilities.

Rice cultivation practices in irrigated area and rain-fed area

In irrigated areas, most farmers are able to perform rice cultivation two times per year for the early ripening variety (ERV) and late ripening variety (LRV); especially in upstream villages because of the water availability through canals and rainfall. Some farmers still practice conventional farming; while some farmers have practiced SRI. In the case of the selected upstream farmers (A1-A5), some of them apply both conventional and SRI methods in different plots to be compared. The others have already applied SRI method for all of the plots. On the other hand, upstream farmers are likely to use water inefficiently. Although there are irrigation facilities, water is not distributed properly because farmers have limited knowledge on operation of these facilities. This makes downstream farmers suffer from water shortage. Then downstream farmers including selected farmers (B1-B5) do their farming one time per year for LRV only. As with upstream farmers, downstream farmers apply both conventional and SRI methods in separated plots or two-part divided plots.

In rain-fed areas, the majority of farmers are able to perform rice cultivation only once per year for LRV due to insufficient water or less rain. The main water storage for rain-fed area is a big reservoir. In case that there is no enough rain, farmers need to save water in the reservoir for other works such as daily life use, animal raising and vegetable watering. Under the support from NGOs on the SRI dissemination, farmers in the rain-fed areas have learnt what SRI is. According to the conducted interviews, some of the selected farmers (C1-C5) have applied both conventional and SRI methods in different plots for comparison. Nevertheless, some farmers have fully applied SRI to all the plots. Again the interviews with farmers reveal that in some years with little rain, rice plants are in tiller and panicle initiation stages. This significantly worsens the yield. However, if there is enough rain from early in the cultivation season, the rice plants will grow well and provide a high yield. But some farmers hesitate to drain water out when there is too much water in the paddy field because they are afraid of facing water shortages. This is one reason that SRI farmers in rain-fed areas face difficulty controlling water in the paddy field since the water availability is unpredictable.

Degree of Adoption of SRI principles by selected farmers in study areas

Under the past support from CEDAC (Cambodian Center for Study and Development in Agriculture), selected farmers started to practice SRI techniques since 2006. CEDAC introduced SRI with 12 principles and strongly recommended farmers to follow them (JICA, 2008). However, according to the interviews with the 15 selected farmers about their farming practices during 2009 and 2010, once CEDAC was removed, farmers became unable to follow all the principles. In irrigated areas as well as in rain-fed areas, farmers cannot apply all the 12 SRI principles (Table 2). In irrigated areas, roughly 76% of upstream farmers can adopt the SRI principles; compared with only 62% of downstream farmers. In addition, in rain-fed area, 68% of farmers can adopt SRI principles. Two principles stood out as being adopted by rain-fed and downstream farmers but not by upstream farmers. Those include the principle to "transplant seedlings younger than 15 days" adopted at level of 40%, 10% and 0%; and the principle to "transplant seedlings 25-40 cm apart" adopted at level of 60%, 80% and 0% by rain-fed farmers, downstream farmers and upstream farmers respectively. Nevertheless, there is one principle adopted only by upstream farmers. It is that which says to "weed at least 2-4 times a season" with adoption rate 40%. For the rest, the average rates of adoption are somehow the same. Therefore, it can be said that rain-fed farmers have stronger commitments towards following SRI principles. On the other hand, most farmers

generally have difficulty in keeping less water in their paddy fields. Even in the irrigated area, the act of keeping less water in paddy fields is still a big problem for farmers. This is because of insufficient irrigation facilities and geographic conditions. In rain-fed areas, water is not fully available all the time, so even though there is abundant water in the paddy fields, farmers do not dare to drain it out because they are afraid of future water shortage.

Table 2 Degree of SRI principles adoption by selected farmers (2009-2010)

SRI Principles	Farmer A1-A5		Farmer B1-B5		Farmer C1-C5	
	No.	%	No.	%	No.	%
Level the paddy field and provide drainage	4	80	4	80	5	100
Keep less water in the paddy field	3	60	2	40	3	60
Raise nursery beds or use dry nursery beds	5	100	3	60	5	100
Select purified and dense seedlings for sowing	5	100	4	80	5	100
Transplant seedlings younger than 15 days	0	0	1	10	2	40
Transplant big seedlings immediately	4	80	4	80	4	80
Transplant one plant per hill	3	60	3	60	2	40
Transplant seedlings shallowly with horizontal roots	5	100	5	100	5	100
Transplant seedlings with square pattern or in line	4	80	2	40	2	40
Transplant seedlings 25-40cm apart	0	0	4	80	3	60
Apply natural fertilizer as much as possible	5	100	5	100	5	100
Weed at least 2-4 times a season	2	40	1	10	0	0
Average of adoption		**67**		**62**		**68**

Change in using seeds

Revealed in the interviews with selected farmers, it seems that all farmers do feel positive about the decrease of seeds used for sowing and transplanting. They said that applying SRI in their fields can help reduce a large amount of seeds per year. Saving seeds can help them use the remaining seeds for food and for storage in the following year (save space for storing seeds).

Table 3 Change in use of seed on average during 2009-2010

Seed (kg/ha)	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
Before SRI	100	250	80	50	230	65	60	162	108	114	90	80	200	175	75
After SRI	36	83	50	25	110	35	30	50	50	71	30	40	80	50	38
Ratio (%)	***64***	***67***	***38***	***50***	***52***	***46***	***50***	***69***	***54***	***38***	***67***	***50***	***60***	***71***	***49***

A decreased weight of seeds is what farmers can notice quickly when they start to apply SRI. It is also another reason why they decide to apply SRI. Table 3 shows that farmers can reduce the weight of seeds from 38% up to 71%. The majority of farmers can also decrease the weight of seeds up to 50%. This is because most farmers know how to select full-inside seeds, to raise nursery beds for sowing and to select big healthy seedlings for transplanting.

Change in application of chemical and natural fertilizers

The effect on environmental understanding is noticeable since farmers have changed their habits, started to reduce the weight of chemical fertilizers and increase the use of natural fertilizers. During

interviews with selected farmers, they were asked to reveal the weight of the chemical and natural fertilizers they used before and after practicing SRI. These changes are shown below:

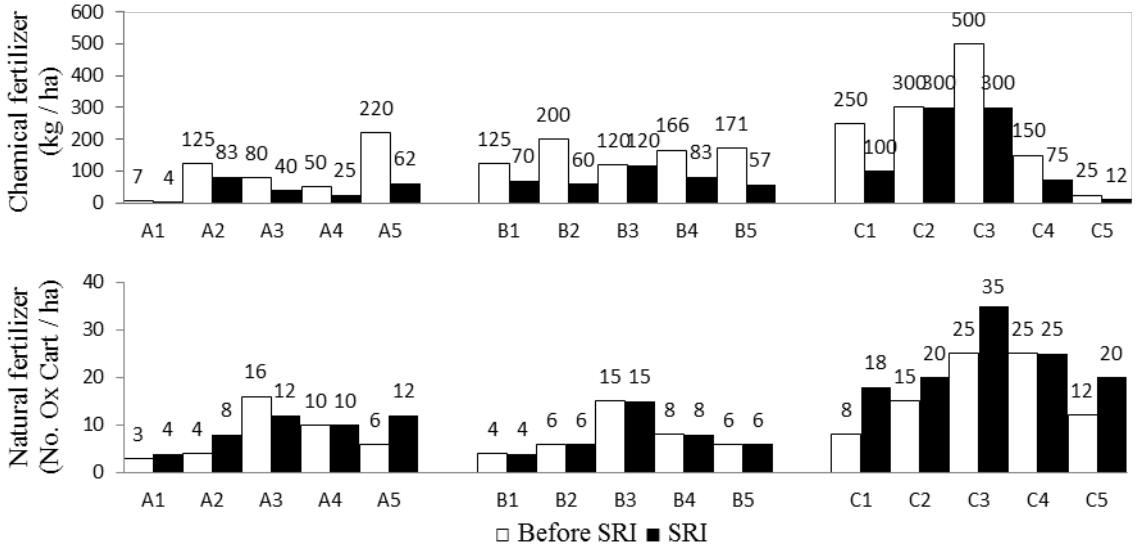

Fig. 1 Change in application of chemical and natural fertilizers

According to Fig.1, the weight of chemical fertilizers decreased remarkably. Previously, farmers had used chemical fertilizers from 7 kg/ha up to 500 kg/ha for conventional farming, but afterwards farmers reduced this amount to 4 kg/ha to 120 kg/ha for SRI practice. This results in almost 20% to 40% decrease from previously used conventional practices. This shows that farmers have understood the impact of chemical fertilizers on soil fertility, health, expenditure and environment.

In contrast, there is also a noticeable increase in the weight of natural fertilizers as shown in Fig. 1 as well. On average, conventionally farmers used 3 ox carts of natural fertilizers per ha up to 25 ox carts. However, for SRI practices, farmers can increase from 4 ox carts of natural fertilizers to 35 ox carts. Although there is not much improvement in the use of natural fertilizers, it is evident that some farmers are still making attempts to increase the use of natural fertilizers. Moreover, it can be said that farmers have used the resources available near their living areas on the fields in order to reduce the expenses of chemical fertilizers. Therefore, farmers have gained a better understanding since SRI techniques require farmers to use natural fertilizers in order to sustain and enrich the soil quality over a long period.

Benefits and difficulties in Practicing SRI

According to interviews with selected farmers, there are various key benefits from practicing SRI. These include increased yields, saving of seeds, decreased amount of chemical fertilizer, reduction of labors, and time saving. Among these benefits, saving seeds is the most popular answers from SRI farmers. 15 farmers out of 15 (100%) said that they can save a lot of seeds after applying SRI. 14 farmers of 15 farmers (93%) also said that their yields increased after practicing SRI compared to previous practices. The other three popular answers about the benefits of practicing SRI are the reduction of labors, decreased amount of chemical fertilizer, and time saving with the percentage of answers 66%, 46% and 20% respectively. Nevertheless, some difficulties arise while practicing SRI. 53% of the responses from 15 SRI farmers complained about transplantation in a line. They faced difficulties in making a line, or did not have the equipment to make a line in their paddy fields. In addition, other reported difficulties included water management (53%), weeding (26%), preparation of nursery beds (6%), and plowing (6%). The percentage of weeding is very low because farmers do not have weeding tools and they need to do it by hand. That is why farmers do not care much about weeding, which requires intensive labor.

CONCLUSION

Although SRI techniques are believed to provide higher yields than conventional methods, most farmers still cannot apply all 12 SRI principles due to insufficient irrigation systems, labor shortages, and time consuming activities. It can be said that farmers` behaviors toward SRI technique are somehow positive and that they will be able to apply all principles if all those inconvenient things mentioned above can be resolved.

Upstream farmers can grow rice twice per year for LRV and ERV; while downstream and rain-fed farmers can grow only once per year for LRV. In comparison with conventional methods, all selected farmers can get the average LRV yield of 2.31 to 2.36 t/ha. The SRI method for LRV is around 3.30 to 3.70 t/ha. The differences of yield between the SRI method and the conventional method are roughly the same for irrigated and rain-fed areas. This means that in both irrigated and rain-fed areas, SRI results are higher than the conventional method by around 1 to 1.5t/ha. In addition to the SRI method providing the same yields in irrigated and rain-fed areas, farmers also applied nearly identical SRI principles such as reducing seeds for sowing (up to 50%) and chemical fertilizers (20% to 40%), raising nursery bed, and transplanting with fewer seedlings. Therefore, this study concludes that SRI practices in rain-fed areas are similar with those in irrigated areas. Although irrigation systems provide big advantages, controlling water in paddy fields in both areas is still a problem since irrigation facilities are poor. Nevertheless, all selected farmers have also faced the same problems in practicing SRI such as transplanting in line, doing weeding, and managing water. Finally, some farmers still have strong intentions to continue SRI, and also have willingness to share these techniques with other farmers. However, others have given up due to a lack of external supports.

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International Society of Environmental and Rural Development

Philosophy of ISERD:

Recently, in developing countries, subsistence agriculture is being converted to export-oriented mono-culture, and the amounts of agricultural chemicals applied to the farmland are increasing every year. The applied chemicals in farmland cause serious environmental problems downstream such as eutrophication, unusual growth of aquatic plants, decrease in dissolved oxygen and accumulation of bottom mud in water resources. Also, there seem to be many cases in which people apply agricultural chemicals without understanding its impact to health and food safety. Therefore, it is necessary to promote and enhance understanding of sustainable rural development among local stakeholders including farmers.

Sustainable rural development aims to meet human needs while preserving the natural environment. As it should cover not only social and economic development but also natural environment conservation, no single organization can achieve sufficiently the aspirations of sustainable rural development. Collaboration among international, governmental and non-governmental organizations, together with the academe and scientific sector, is indispensable.

The knowledge and intelligence accumulated in universities and research institutions are also expected to make the programs facilitated by the international, governmental and non-governmental organizations more adequately implemented and meaningful to societal development. However, these cases especially those implemented locally have been scattered without having been summarized well or recorded in annals academic or scientific societies.

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