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Infrastructural Systems:

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

Contents

Research article

The Influence of Earthworm and Rice Stubble on Soil Aggregate, Carbon Sequestration and Soil Fertility in Sandy Loam Paddy Soil in Northeast Thailand

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Abstract The objective of this study was to investigate the effect of epigeic earthworm (*Eudrillus eugeniae*) and rice stubble on soil aggregate, SOC, soil fertility and greenhouse gases (CO_2) emission in sandy loam paddy soils in Northeast Thailand. Experimental design was a completely randomized design. There were four treatments of incubation using Thai soil (Roi-et series) Sandy loam were: (I) soil control (no additions), (II) soil + rice stubble, (III) soil + earthworms (these added after 8 days incubation) and (IV) soil + rice stubble + earthworms (these added after 8 days' incubation), and then incubated for 20 days. During the experiment, soil respiration (CO_2), the aggregate size, SOC and soil fertility (N, P and K) were measured. The results suggest that the treatment with adding earthworms and rice stubble had significantly changed on soil aggregate than those without earthworm and added rice stubble only. Earthworm increased SOC and soil fertility (N, P and K) in paddy soil (sandy loam) than other treatment. The effect of earthworm on the decomposition of rice stubble in paddy sandy loam may influence the CO_2 emission from paddy soil.

Keywords sandy loam paddy soil, rice stubble, earthworm, carbon sequestration, soil fertility

INTRODUCTION

Earthworms, one of the most important macroinvertebrates in the terrestrial ecosystems of the temperate zone, exert important influences on soil functions (Fonte et al., 2007). Their activities play an important role in improving and changing the physical, biological, and chemical properties of soil (Coq et al., 2007). Earthworms improve the soil and increase water retention (Bossuyt et al., 2005). Additionally, the biomass and activity of soil microbial diversity (Doube and Beown, 1998) encourage earthworm activity, and allow fungi to perform better. Such activities are the main factors influencing the transformation of organic matter and are important for the dynamics of carbon in the soil. Thus, the experimental results of Don et al. (2008) reported that earthworms have a significant impact on the turnover of carbon in soil. They assist nutrient cycling in soil (Edwards and Bohlen, 1996).

Most of soil in Northeast Thailand is classified as sandy textured soil, which has relatively low fertility (Patama et al., 2004). The change of land use from forest to agriculture causes soil deterioration. Returning organic materials into the soil is one of the most effective approaches to restoring soil fertility (Patama et al., 2004). In Thailand, the main crop is rice. This contributes to a high amount of stubble and straw, while the rest of rice plant materials are retained in the paddy

field. The rice residue produced is equal to 38.22 million tons/year (Rice Department, 2006). There are several beneficial uses of rice residue, such as incorporating the residue into soil, which may enhance soil fertility. Results of long-term research have shown that the carbon content of soil treated with rice residue was low, while simultaneously, CO_2 evolution increased (Samahadthai et al., 2010; Puttaso et al., 2011). There remains a critical need for research on the effects and interactions (soil carbon dynamics and nutrient turnover) of earthworms with rice residue in agro-ecosystems (paddy fields).

OBJECTIVES

The objectives of this study were to investigate the activities of earthworms and added rice stubble on soil properties; chemical, biological and physical; dynamics of organic carbon in soil and to improve the properties of soil and increase carbon sequestration in soil.

METHODOLOGY

Soil samples were collected (0-15 cm depth) from paddy fields in Khon Kaen province, Northeast Thailand. The soil textural class was sandy loam (62.40% sand, 36.60% silt, and 1% clay), organic C 4.55 g kg^{-1}, total N 0.28 g kg^{-1}, available P 6.29 mg kg^{-1} and exchangeable K 38.51 mg kg^{-1}. After collection, the soil was air-dried and sieved to pass 2 mm. Residue, stones, and sand larger than 2 mm. were discarded. Soil incubation consisted of 12 subsamples with four treatments, and three replicates each. Treatments consisted of four categories: 1) non rice stubble with no earthworms 2) soil with added rice stubble 3) soil with added earthworms and 4) soil with added rice stubble and earthworms. The earthworm species was *Eudrilus eugeniae*. The treatment added rice stubble 1.15 g (2-3 cm) was mixed in 200 g soil and put in glass jars with lids. Moisture levels in all treatments were appropriate (≈ 70%) and incubated at 30 ^{o}C. After seven days of incubation, eight adult earthworms were added in the designated earthworm treatments. Soil respirations were measured at days: 0, 3, 7, 10, 14 and 18. At 20 days; earthworms were removed from the jars, residues were discarded form soil, and the soil was air-dried. Soil was separated into two parts: one part aggregately measured (sieving shaker), another part chemically measured. Organic carbon was measured by the partial-oxidation method (Walkley and Black, 1934). Total nitrogen was measured by micro Kjeldahl method (Jackson, 1975). Extractable phosphorous was determined by following Olson's sodium bicarbonate extraction method (Olsen et al., 1954).

Exchangeable K was determined after extracting the sample using the ammonium acetate extractable method, and analyzed using the Perkin Elmer model 3110 double beam atomic absorption spectrophotometer (AAS) (Simard, 1993).

Analysis of variance pertaining to a complete random block design (CRD) and related statistical analysis were performed employing Statistics 8.0 (Analytical Software, 2003). Mean comparisons of different treatments were done by least significant difference (LSD) and standard error of the difference (SED).

RESULTS AND DISCUSSION

Soil aggregate formation

The results of short term experimentation show the influence of earthworm activity on soil aggregate formation in micro and macro aggregates (Table 1). The results clearly show that the earthworm significantly helped form new macroaggregates ($p<0.01$) on earthworm treatments compared with added earthworms and no earthworms, or added rice stubble only. On the other hand, activity of earthworm treatments decreased in the microaggregate. This is compatible with the hierarchical theory of aggregate formation (Samahadthai et al., 2010; Tisdall and Oades, 1982). In this experiment, added rice stubble had no effect on soil aggregate formation. Added earthworms

had positive effects on soil aggregation. Earthworms contributed to soil aggregation mainly through cast production and burrowing activities. Earthworm gut transit involved contamination and mixing of soil, fragmentation of plant litter, and the addition of large amounts of water soluble mucus (Edwards and Bohlen, 1996).

Table 1 Chang of soil aggregate after 20 days of incubation with rice stubble and earthworm

Land use system	Microaggregate (<1 mm.)	Macroaggregate (≤ 2-1 mm.)
Control (soil)	89.86 a	9.63 c
Soil + Rice stubble	83.13 a	16.55 c
Soil + Earthworm	72.33 b	26.84 b
Soil + Rice stubble + Earthworm	57.31 c	41.82 a
f – test	**	**
CV %	5.41	16.43

Mean (n=3) in the same column followed by the same lower case letters are not significantly different at |p| *≤0.01 (LSD).*

Carbon sequestration in soil

Carbon storage was increased in all soils compared to the initial, by about 2-27% in all treatments (Table 2). Concentrations of total C in soil between added rice stubble with earthworm and added rice stubble only were significantly ($p<0.01$) difference in soil organic C (SOC) than added earthworm only (Table 2). Newly added of rice stubble residues was improved SOC. This results were consistent with Naklang et al. (1999) which studied the management of chemical fertilizer and rice straw and leaves in rain fed paddy fields of Northeast Thailand (in both the dry and rainy season). They reported that in the first year's newly added residue (1994), the incorporation of rice stubble produced a higher level of organic carbon in soil (3.40 mg/g) than treatments without the incorporation of rice straw (3.10 mg/g). Interaction between earthworm activity and rice stubble increased SOC 27.22% higher than the control. Earthworm activities on macroaggregate dynamics are also important for C stabilization processes (Elliott, 1986; Six et al., 1998, 2002; Fonte et al., 2007). Due to rapid occlusion of organic materials, microbial communities associated with microaggregates within macroaggregates formed during or shortly after passage through the earthworm gut are relatively inactive, and therefore change relatively little over time compared to macro aggregate populations as a whole (Mummey et al., 2006). Earthworm gut mixing with soil was previously inaccessible as physically protected organic matter from microbial attack (Edwards and Bohlen, 1996).

Table 2 Quantities of carbon in soil after 20 days of incubation with rice stubble and earthworm

Treatment	Total C ($g\ kg^{-1}$)	Changes in quantities relative to the control (%)
Control (soil)	0.380 b	
Soil + Rice stubble	0.450 a	18.55
Soil + Earthworm	0.389 b	2.56
Soil + Rice stubble + Earthworm	0.483 a	27.22
f – test	**	
CV %	6.28	

Mean (n=3) in the same column followed by the same lower case letters are not significantly different at |p| *≤0.01 (LSD).*

Soil respiration

In this study, CO_2 evolution was the highest in added rice stubble with earthworm treatment (Fig. 1). This demonstrates that rice stubble with earthworms could lead to a metabolically active

microbial biomass efficient in utilizing carbon resources. A greater proportion of substrate carbon is lost in the form of CO_2 through respiratory activity (Pang et al., 2012). Rice residues were categorized as low quality organic material since they comprise a high content of carbon (367-423 g kg^{-1}) and cellulose (353-507 g kg^{-1}), and a low content of nitrogen (4.7–8.5 g kg^{-1}) and lignin (19-45 g kg^{-1}). Incorporated into soils with optimum conditions, rice residues rapidly decomposed (Samahadthai et al., 2010; Puttaso et al., 2011) and led to an increase in CO_2 evolution.

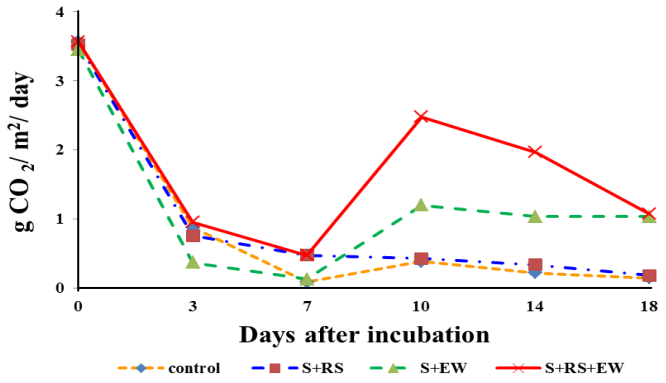

Fig. 1 Temporal pattern of CO_2 evolution (g CO_2 m^2 day) as affected by rice stubble and earthworm

Earthworm influence on N, P, K

In this experiment, the results have shown that the effect of earthworms and rice stubble increase soil nutrients such as N, P and K. Ponnamperuma (1984) reported that rice straw added to soil increases nitrogen, phosphorus, potassium and beneficial nutrients. Furthermore, rice straw helps increase the amount of organic matter and nitrogen in the soil (IRRI, 1976). Utilization of rice straw is possible through the incorporation of rice straw residue. Through cultivation into soil, rice straw proves to be an important source of plant nutrients and improves soil fertility (Azam, 1990).

Concentration of total N, though not significant, increased through earthworm treatments (Table 3). Earthworms increase nitrogen mineralization *via* the biological processes or physical changes they bring about in the environment (Costello and Lamberti, 2012). Earthworm feeding increases the rate at which organic N is mineralized into inorganic forms as earthworms primarily excrete NH_4^+ (Scheu, 1987; Whalen et al., 2000; Costello and Lamberti, 2012). Concentration of available P and exchangeable K were higher in rice stubble with earthworm treatment. Lui et al., (2005) reported that during 100-day incubation periods, earthworm inoculation combined with organic materials (rice straw, peanut residue and rape residue) increased significantly the content of soil available phosphorus. Basker et al., (1992) reported upon the incubation experiment of Tokomaru soil (silt loam) inoculated with the common pasture earthworm species *Aporrectodea caliginosa* for a period of 21 days. The resulting content of exchangeable K increased significantly due to earthworm activity.

Table 3 Chemical compositions of soil after 20 days incubation with rice stubble and earthworm

Treatment	Total N (mg kg^{-1})	Available P (mg kg^{-1})	Exchangeable K (mg kg^{-1})
Control (soil)	0.28	6.83 c	42.39 d
Soil + Rice stubble	0.29	7.81 b	118.74 b
Soil + Earthworm	0.42	7.11 bc	69.55 c
Soil + Rice stubble + Earthworm	0.45	11.78 a	143.19 a
f – test	ns	**	**
CV %	51.62	4.67	2.46

Mean (n=3) in the same column followed by the same lower case letters are not significantly different at $|p| \leq 0.01$ (LSD).

CONCLUSION

This study suggests that the effect of earthworm and rice stubble increase soil fertility N, P and K in paddy sandy loam. As, interaction between earthworm and rice stubble helped form new macroaggregate; they are increased carbon storage compared to the initial, by about 2-27%. And increase metabolically active microbial biomass and influence the CO_2 emission from paddy soil. Earthworms have an important in soil carbon sequestration. However, more studies need to be conduct to investigate other factors may influence such as type of earthworm, soil and rice stubble between agroclimatic zones.

ACKNOWLEDGEMENTS

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Research article

One Way of Expressing Bio-diversity based on Simpson and Fisher Indexes

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Abstract For making out soil lives in upland field and field properties clearly, micro-arthropods living in farmland soils were picked up, and population, genera, diversity index of Simpson (1/λ) and that of Fisher (α+1) were employed for evaluating soil micro-arthropods under different management were investigated in this study. Also soil physical and chemical properties were measured. Soil samples were gathered from the fields at Hachioji, Tama and Machida in Tokyo, Japan. Planting and fertilized types were collected. And for making out of relationships in diversity of soil micro-arthropods and soil moisture conditions, soil micro-arthropods in some types of drip irrigation fields and tube irrigation fields in green house were observed. The fields in this study were categorized into two groups based on the history of dressing or land degradation. There was no certain difference in population, number of genera and two types of diversity indices between decollated and not-decollated fields. Fisher's diversity index seemed to be larger than Simpson's in soil dressed fields, while Simpson's diversity index seemed to be larger than Fisher's in non-dressed fields. The difference in types of diversity may be caused by years of cultivation in those fields. Also, based on the results of multiple regression analysis, population, number of genera and Simpson's diversity index were related with macro porosity. So, it was concluded that those two types of diversity indices are useful for making clear difference of bio-diversities in upland field's soils.

Keywords soil micro arthropods, bio-diversities, soil physical property

INTRODUCTION

Bio-diversities in farmlands are important for sustainable land use. Soil conditions in agricultural fields are hard for lives. That limits richness of lives of soils. And low application of organic fertilizers caused declining the richness of soil lives is said. But in Japan, ecosystems in upland fields were less interested than that in paddy fields. So there are few surveys on upland field's bio-diversity and its effects on their soils in Japan. One cause is that farmers avoid their fields disturbing many places for research, especially in farming season. It is need that solve that problem will be solved for evaluating farming fields in biological diversity.

Micro-arthropods are kinds of group of soil lives, sort of insects and mites. And micro-arthropods are known to have large population and high species richness, especially in high content of organic matters. That fits 'good' soil. Effects of their density or species richness on soil chemical properties were investigated in Europe (Cole et al., 2004). Enough population is need for evaluating bio-diversity, so there is some possibility of evaluating farmland with bio-diversity disturbing minimum space.

OBJECTIVES

Surveys on upland field's micro-arthropods in Japan were mainly in just biological. Cropping or harvesting methods in their surveys were limited 2 or 3 types, and soil physical properties were not discussed. So making out some relationship between upland field's micro-arthropods diversity and its soils, and suggesting method of the evaluating the farming fields with the biological diversity are objectives in this study.

METHODOLOGY

Field survey

Soil samples were gathered from the farmers' fields at Hachioji, Tama and Machida in Tokyo, Japan. The fields were located in west hill side of Tokyo, there are called Tama hills. There are mixed residential area and farm fields. Some of farm fields were dressing or land degradation for making residential area. So the fields in this study were categorized into two groups based on dressing or land degradation affected or not. We use "decollated fields" for the fields that dressing or land degradation affected in this study.

Soil sampling carried out Aug. 2003 to Nov. 2003 and Aug. 2005 to Nov. 2005. Autumn is the season that micro-arthropods' population is the most. All of the fields were for vegetables, but a few sampling had the same plant. Fertilizing is independent in each field. And no herbicides nor pesticides were used. 5 cm depth, total 400 ml surface soil was sampled for gathering soil micro-arthropods. Physical properties of soils and amounts of fertilizers were collected. Total 22 fields' samples were measured.

Experimental survey

For making out of relationships in diversity of soil micro-arthropods and soil moisture conditions, soil micro-arthropods in some types of drip irrigation fields and tube irrigation fields in green house were observed. Drip irrigation plots were typed with water mass (standard, less and little), and interval were 2 or 3 days, irrigated 3-5 mm/day in standard plot. Less irrigation plot was 0.75 times, little irrigation plot was 0.5 times less than the standard plot. Tube irrigation field was there were micro-pored tube on the ground base with minimum pressured and irrigated full of soil water pore volume within the plant growth. Soil sampling carried out Jun. 2006 to Oct. 2006. 5 cm depth (same as field survey), 200ml soil was sampled from each plots in each 2 weeks within irrigating for plants.

This green house is built in Setagaya, Tokyo, about 20 km far from field survey area. And soil category of this field is same as decollated fields in field survey. The green house of this survey was also used test at supplying gathered rain water falling on top of green house. So the tanked rain water was used for irrigation in this survey.

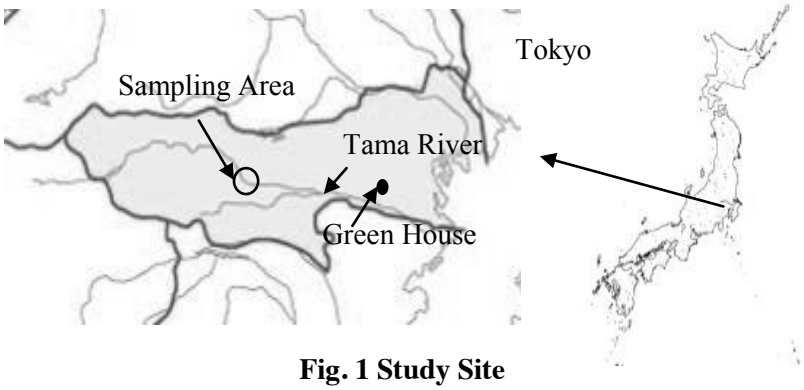

Fig. 1 Study Site

Gathering soil micro-arthropods

Micro-Arthropods in this study are mainly in collembola and mites. They are called soil animals or soil meso-fauna in Japan (Fig.2). Soil macro-fauna are larger than 2 mm, include earth worms and insects. Soil micro-fauna are smaller than 0.2 mm, lives in soil water.

Tullgren's apparatuses (Fig. 3) were used for gathering soil fauna. Apparatus was made from 2 mm opening sieve, stain-less funnel and 40 W heating light stand. Soil samples for investigating micro-arthropods were put on stainless sieve set on funnel under the heating light for 48 hours. Glass beaker with 70% alcohol was set for catching arthropods dropped through funnels. Then micro-arthropods were classified into genera, and then each species' population was counted with a microscope. Pictorial Keys to Soil Animals of Japan (Edited by Aoki, 1999) was used for classifying.

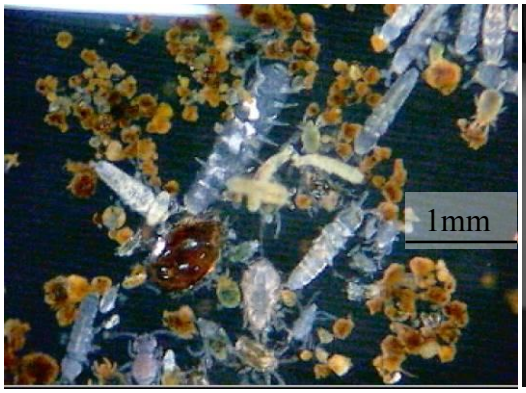

Fig.2 Soil micro-arthropods

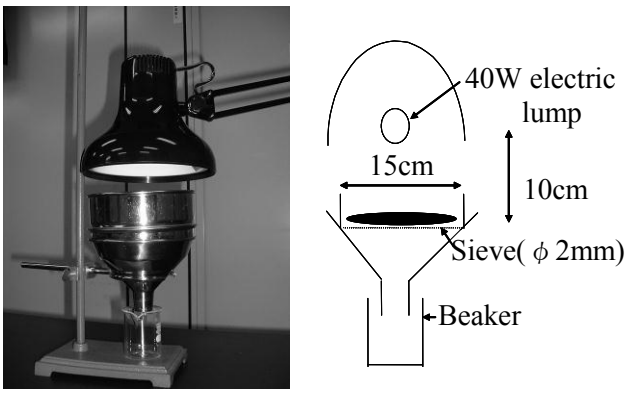

Fig.3 Tullgren's apparatuses

Diversity indices

If their species' richness (one of the diversity index) was discussed, it is not compared in other situation. Because of the environment of every field is different. It needs some standard that the bio-diversity can use evaluation of farming fields.

Two types of diversity indexes were employed for evaluating soil micro-arthropods under different management were investigated in this study. Fisher et al. (1943) suggested that some of number of species and number of individuals in random sample fitting logarithmic distribution. α is fixed and calculated from Eq. (1) as uses total population (N) and total species (S). Simpson suggested λ as the index which independent of sample size (Simpson, 1949). λ is calculated in Eq.(2). Simpson also said, we obtain Eq. (3) when the individuals of population are under the logarithmic population. This is the point that the Fisher's diversity index (α+1) is the expectation of the Simpson's diversity index (1/λ) at the identified total population (N) and total species (S). An expectation can use the one kind of standard. So 1/λ and α+1 are used as diversity index in this study.

$$S = \alpha(\ln N/\alpha + 1) \tag{1}$$

$$\lambda = \frac{\Sigma Ni(Ni-1)}{N(N-1)} \tag{2}$$

$$1/\lambda = \alpha + 1 \tag{3}$$

RESULTS AND DISCUSSION

Field survey

Population, number of genera and two types of diversity indices are shown in Table 1. Total population and total genera in non-decollated fields were larger than those in decollated fields. It would depend on the difference of land use around the sampling fields. There are many houses and asphalt pavement roads around the decollated fields, and woods and bamboo forest around non-decollated field. But there was no certain difference in population, number of genera and two types of diversity indices between decollated and not-decollated fields. those are suggests that the severe impact for soil micro-arthropods from farming activity (cultivating, tillage, weed control, etc.) .

But in relationships between two types of diversity indices (Fig. 4), Fisher's diversity index seemed to be larger than Simpson's in soil decollated fields, while Simpson's diversity index seemed to be larger than Fisher's in non-decollated fields. The difference in types of diversity may be caused by years of cultivation in those fields.

Based on the results of multiple regression analysis (Table 2), population, number of genera and Simpson's diversity index were related with macro porosity ($d > 0.3$mm, measured water suction by 10 cm high capillary rise) and water content (dry base) at the sampling day. The macro porosity was almost same space as air phase 6-12 hour after rain or irrigation. That air space in soils limits the micro-arthropods' population.

Experimental survey

Results of averages and medians of population, genera and two types of diversity indices in each sampling in experimental survey are shown in Table 3. Tube irrigation plot had the least population and number of genera. Those results can be express as same as in field survey, the air phase in tube irrigation plot was lowest in experimental survey. But there was no certain difference in population, number of genera and two types of diversity indices between each plot.

But in relationships between two types of diversity indices (Fig. 5), both standard irrigated plot in drip irrigation and underground water irrigation plot were stable conditions of diversity indices. Because standard irrigated plot was the most stable soil moisture conditions in drip irrigated fields, there were same tendency that both standard irrigation plot and tube irrigation had similar expanse of the distribution. And high correlation coefficient of tube irrigation plot was caused by stabilized soil moisture in their field. This result suggests that soil moisture condition is the most important factor for sampling times minimized.

Table 1 Population, number of genera and two types of diversity indices in field survey

Decollated fields					Non-Decollated fields				
No.	Pop.	Gen.	$1/\lambda$	α+1	No.	Pop.	Gen.	$1/\lambda$	α+1
No.1	6	5	15.0	15.1	No.12	52	18	11.5	10.8
No.2	82	18	10.6	8.1	No.13	360	15	1.3	4.2
No.3	235	24	8.5	7.7	No.14	53	16	8.2	8.8
No.4	100	12	5.5	4.6	No.15	369	21	4.1	5.8
No.5	53	15	11.9	8.0	No.16	281	29	3.8	9.1
No.6	67	16	5.0	7.7	No.17	211	13	3.2	4.1
No.7	88	18	7.3	7.8	No.18	43	12	8.9	6.5
No.8	12	6	6.6	5.8	No.19	65	15	5.2	7.1
No.9	170	19	6.7	6.5	No.20	10	4	2.1	3.5
No.10	135	14	5.2	4.9	No.21	77	23	11.7	12.1
No.11	205	11	2.4	3.5	No.22	135	13	3.3	4.5
Ave.	104.8	14.4	7.7	7.2	Ave.	150.5	16.3	5.8	7.0
Med.	88.0	15.0	6.7	7.7	Med.	77.0	15.0	4.1	6.5
Total	1153	46	11.4	10.6	Total	1656	53	5.9	11.5

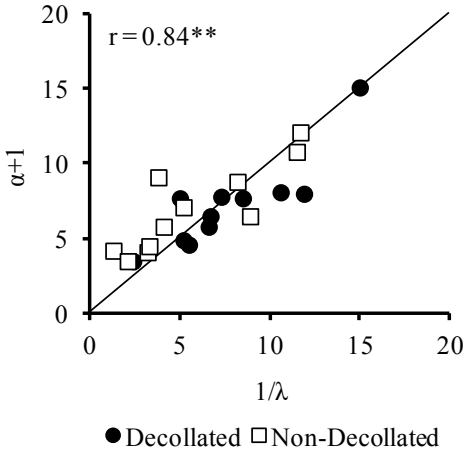

Fig. 4 Relationship between two types of diversity indexes in decollated and non-decollated fields

Table 2 Results of multiple regression analysis between bio-indexes and soil physical properties in field survey

Criterion variable	Predictor variable	Partial regression coefficient	F factor	Partial correlation coefficient	Correlation coefficient	Multiple correlation coefficient
Population* (log)	Macro porosity*	0.588	8.481	0.589	0.391	0.597
	Water content*	0.561	7.719	0.570	0.354	
Genera*	Water content**	0.685	11.334	0.644	0.568	0.589
	Macro porosity	0.332	2.669	0.378	0.091	
1/λ	Macro porosity	-0.431	3.870	-0.431	-0.431	0.371
α+1	-	-	-	-	-	-

** p<0.05, **p<0.01*

Table 3 Results of averages and medians of population, genera and two types of diversity indexes in each sampling in experimental survey

		Drip irrigation field			Tube irrigation field
		Standard (×1.0)	Little (×0.75)	Less (×0.5)	
Population	Average	41.9	41.2	35.1	26.3
	S.D.	28.7	28.2	27.3	18.7
	Median	44	34	26	19
Genera	Average	7.3	8.6	9.1	7.3
	S.D.	3.2	3.3	3.3	4.2
	Median	8	9	9	6
1/λ	Average	4.1	5.4	6.5	4.4
	S.D.	1.4	3.1	2.9	1.4
	Median	4	4.6	7.2	4.35
α+1	Average	4	5.1	5.8	4.8
	S.D.	1.0	2.4	1.7	1.7
	Median	4.2	4.3	5.9	4.95

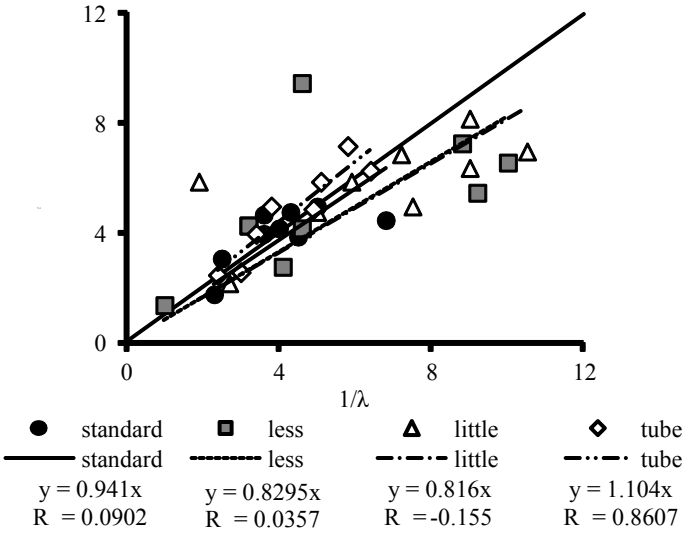

Fig. 5 Relationship between two types of diversity indexes in irrigated plot

CONCLUSION

Using Fisher's diversity index as the expectation of Simpson's diversity index, it makes clearly that the difference in types of diversity may be caused by years of cultivation in those fields. Field survey shows that the soil macro porosity (sometimes same as gas phase) is important for soil micro-arthropods. And through the field survey and the experimental survey, soil moisture condition is most important factor for soil sampling minimum.

So we concluded that those two types of diversity indexes are useful for making clear difference of bio-diversities in upland fields soils.

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Research article

Predictive Model for Biochemical Component of Phytoplankton in the River and Estuarine Systems of the Mae Klong River, Thailand

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Abstract As one of the four major rivers of Thailand, the Mae Klong River flows in the west of the Kingdom and exits into the Gulf of Thailand. This research study was conducted during February 2006 through May 2008 and found the increased levels of NH_4^+, NO_2^-+NO_3^-, and PO_4^{3-} in the lower river and estuary areas of the Mae Klong River, which led to the phytoplankton blooming phenomenon in such areas. Three phyta and 63 genera of phytoplanktons were discovered in the river. The dominant groups were diatoms (*Plurosigma* or *Gyrosigma*), cyanobacteria (*Trichodesmium*), and dinoflagellates (*Peridinium* and *Gonyaulax*). In this study, generalized linear modeling (GLM) was applied to examine the factors influencing phytoplankton abundance in the river systems. The results showed that phytoplankton abundance varied according to the dissolved inorganic nutrient (DIN), zone, and season. Thus, the predictive model should be established to facilitate determination of phytoplankton abundance, assessment of water quality, and thereby more efficient management of water resources for sustainable use.

Keywords dissolved inorganic nitrogen, phytoplankton, GLM analysis, Mae Klong River

INTRODUCTION

The Mae Klong River is the most important river in the west of Thailand, with an approximate length of 140 km and a catchment covering 22,075 km^2. The river runs from Kanchanaburi province and flows toward the lower plain through Ratchaburi province before discharging into the Gulf of Thailand in Samut Songkhram province (Thongdonphum et al., 2010). It has long been known that changes of river flow could impact biochemical composition, including nutrient loading, in the river and thereby phytoplankton abundance. Nutrient loading restriction is the cornerstone of aquatic eutrophication control (Smith et al., 1999) and is readily available monitoring data of red tide/harmful algal bloom (Zhou et al., 2008). Regional Environmental Office 8 (REO8, 2004) reported that utilization of land along the Mae Klong River for agriculture was estimated at 83%, 58%, and 32% in Samut Songkhram, Ratchaburi, and Kanchanaburi

provinces, respectively. According to REO8 (2007), the deterioration of water quality induced mainly by sewage, domestic discharges, and agriculture use has contributed to phytoplankton blooming phenomena in the estuarine and coastal zones.

OBJECTIVE

This study aims to assess the impacts of aquatic environmental factors on the variation or abundance of phytoplankton. The findings could subsequently be used to establish a biochemical predictive model that enables better management of water resources and thereby sustainable utilization of the river and estuarine systems as well as the ecosystem.

METHODOLOGY

Sampling sites and survey plan

The surveys were conducted at 27 sampling stations (stn.) along the Mae Klong River, the stations of which were grouped into 3 zones: the estuarine zone in Samut Songkhram province (stn.1-stn.8), the middle zone in Ratchaburi province (stn.9-stn.18), and the upper zone in Kanchanaburi province (stn.19-stn.27), spanning from February 2006 to May 2008 (Fig. 1). According to the rainfall patterns, Thailand is under the influence of monsoon winds (TMD, 2012). The seasons can thus be divided into rainy season (May- September), winter season (October-February), and dry season (March-April). In addition, large amounts of water typically flow into the lower river basin between September and February. Water samples from the 27 stations were collected during the three seasonal periods for the 2-year interval such that all possible loading periods were taken into consideration, hence giving rise to a total 6 sampling times: May 2006 and May 2008 (early-loading period), November 2006 and September 2007 (mid-loading period), and February 2006 and December 2007 (late-loading period).

Sample collection and analysis

The general water quality factors, namely temperature, dissolved oxygen (DO), salinity and pH, were measured with a multi-parameter probe (YSI-6600 Sonde instrument) at the sampling sites. Samples of surface water (30 cm deep) were pre-filtered through GF/F (Whatman) and then stored at 4^{o}C before transporting to the laboratory for analysis of nutrients, including ammonium (NH_4^+), nitrite and nitrate (NO_2^-+NO_3^-), silicate ($Si(OH)_4$), and ortho-phosphate (PO_4^{3-}), with a SKALAR segmented flow analyzer. The samples for chlorophyll *a* (Chl *a*) and total suspended solids (TSS) measurement were analyzed by the spectrophotometric method and the freeze-dried technique, respectively. Phytoplankton samples were collected and preserved in formaldehyde buffered solution before being classified and enumerated with a Sedgewick-Rafter counting chamber under a light microscope.

Data analysis

Comparisons of water quality in terms of temperature, salinity, DO, pH, Chl *a*, and TSS among the sampling periods and zones were performed using average levels and distribution characteristics. Least Significant Differences (LSD) or Tamhane's T2 of Post Hoc test of the one-way analysis of variance (ANOVA) was used for the environmental variation comparison, and the level of confidence greater than 95% ($p < 0.05$) was considered to indicate a statistically significant impact. The Mann-Whitney test was used where a normal distribution was not observed. Based on the work of Zuur et al. (2007), GLM analysis was applied to the proposed predictive model for phytoplankton assessment, with attention given to the goodness of fit of the model.

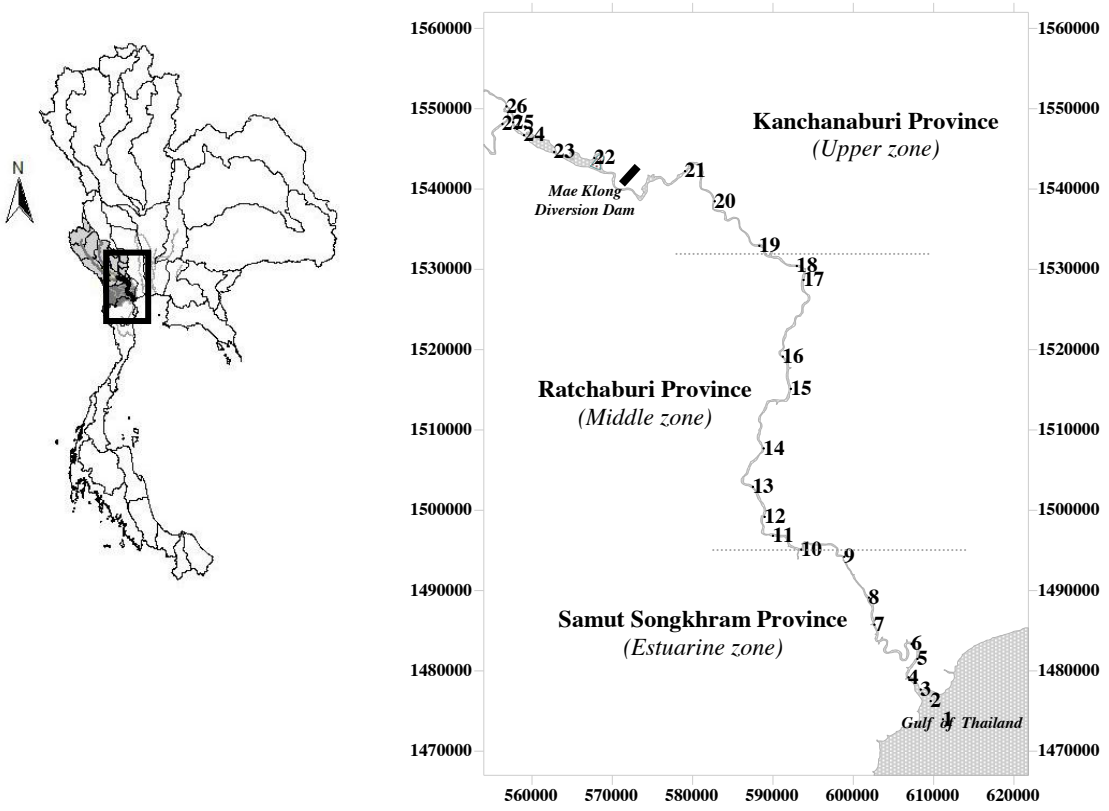

Fig. 1 Sampling stations (Stn. 1–27) from the estuarine to the upper zone of the Mae Klong River

RESULTS AND DISCUSSION

Environmental factors

The results indicated that the Mae Klong River was influenced by freshwater runoffs, which in turn contributed to varying water quality by loading periods. Water temperatures slightly decreased with seasons ($p < 0.05$), and low level of salinity was detected during the early-loading period for which large quantity of water flows into the river. The pH level was found to be relatively constant for the entire study area, while DO varied and markedly decreased to unsuitable levels (<4 mg/l) in the estuarine zone during the early-loading period. The levels of TSS were between 2.40 and 187.50 mg/L with higher TSS levels found in the lower and estuarine zones. The Chl *a* concentration ranged between 1.34 - 14.69 µg/l with high concentration levels mostly found in the estuarine zone. Chl *a* of approximately 10 µg/l has been regarded as the initial level for eutrophication in the estuarine zone. In addition, this study has found that the level of Chl *a* in the upper zone was 4.24 µg/L, which far exceeded the natural base-line level of Chl *a* of approximately 3.3 µg/L (Thongdonphum et al., 2011).

The levels of NH_4^+ and NO_2^-+NO_3^- varied significantly ($p < 0.05$) with seasons. The concentrations of NH_4^+ and NO_2^-+NO_3^- varied from 0.63 to 74.47 µM and 0.40 to 24.75 µM, respectively. Higher concentration levels were found in the lower and estuarine zones with land utilization for agriculture, of which rice fields and aquaculture areas accounted for 108.2 and 29.1 square kilometer, respectively (NSO, 2010). The highest population density was reported at 496 people per square kilometer in Samut Songkhram province (REO8, 2008). $Si(OH)_4$ concentrations ranged from 30.13 to 148.35 µM with the concentration level apparently decreasing around the estuarine stations near the river mouth. The results show that the nutrients induced by rainfalls during the early-loading period in the three zones under the study were significantly different ($p <$

0.05). PO_4^{3-} levels ranged from undetectable to 8.07 μM with noticeably high levels in the estuarine zone where population density and land use were high. Of concern is that PO_4^{3-} concentration in the Mae Klong estuary was much higher than the recommended level of 0.48 μM for the ASEAN marine water quality (Chongprasith et al., 1999).

Table 1 The quality of water (mean±SD) along the Mae Klong River during the study period

Parameters	Early-loading period			Mid-loading period			Late-loading period		
	Upper	Middle	Estuarine	Upper	Middle	Estuarine	Upper	Middle	Estuarine
Temp (°C)	29.3±0.7	30.3±0.3	30.5±0.5	28.4±0.7	29.4±0.7	29.5±1.2	27.1±1.1	27.8±1.3	27.6±0.9
Salinity (psu)	0.1±0.0	0.1±0.0	2.5±4.7	0.1±0.0	0.1±0.0	9.1±10.5	0.1±0.0	0.1±0.0	10.5±9.6
DO (mg/L)	6.0±1.6	6.2±1.4	4.8±0.8	7.7±1.3	6.5±1.0	5.7±1.8	6.8±2.0	7.4±1.3	6.2±1.0
pH	7.7±0.7	8.6±0.2	8.0±0.7	8.5±1.0	8.7±0.2	8.2±0.6	8.5±0.6	7.8±0.5	8.1±0.4
Chl *a* (μg/L)	3.7±1.5	3.8±1.1	4.5±2.0	4.8±1.9	3.1±1.2	5.4±3.0	4.1±1.5	3.4±0.9	6.8±3.9
TSS (mg/L)	17.5±7.9	25.6±17.9	32.8±23.0	21.1±15.8	20.9±10.0	30.7±19.1	11.7±5.1	16.5±6.0	27.2±43.9
NH_4^+ (μM)	3.4±2.0	9.6±4.3	12.8±5.3	2.9±2.1	7.8±3.3	19.4±9.4	2.1±1.1	11.4±9.2	22.4±17.9
NO_2^- +NO_3^- (μM)	4.9±2.28	8.7±4.4	13.4±4.9	6.4±2.8	9.0±2.0	10.8±6.3	6.0±1.4	9.2±2.8	11.0±5.2
$Si(OH)_4$ (μM)	98.9±49.2	99.6±48.7	95.8±44.8	73.6±5.7	73.66±5.8	69.1±8.1	64.6±7.3	66.5±4.8	54.5±13.6
PO_4^{3-} (μM)	0.2±0.1	0.7±0.4	2.2±0.8	0.2±0.1	0.8±0.4	4.4±2.4	0.2±0.1	0.5±0.3	1.8±1.1

Phytoplankton distribution

The phytoplankton community during the study period consisted of 63 genera, namely 7 Cyanophyceae, 19 Chlorophyceae, 26 Bacillariophyceae (diatoms), 10 Dinophyceae (dinoflagellates), and 1 Chrysophyceae. The amount of phytoplankton varied from 125 to $1.86x10^5$ unit cells/L with the highest density found around the stations in the estuarine zone. The results showed that diatoms were the most dominant group with highest phytoplankton abundance (1.86×10^5 cells/L). Other species, such as *Trichodesmium* sp., *Gymnodinium* sp., *Noctiluca* sp., *Ceratium* sp., *Gonyaulax* sp., *Peridinium* sp. and *Protoperidinium* sp., were also found in the estuarine zone and markedly increased in the late-loading period.

Predictive model for phytoplankton

The results of GLM analysis in Table 2 show that M2 is the optimal model (Adj.R^2 = 0.400). The model indicates that phytoplankton abundance depends on the dissolved inorganic nitrogen (DIN; NH_4^++NO_2^-+NO_3^-), zone, and loading period (Load). Moreover, an interaction effect exists between Load and DIN.

Table 2 Predictive model of phytoplankton density for the Mae Klong River

Model	Adj.R^2	MSE	Goodness of Fit
M1: Total_Phyto1 = Zone1 + Zone2 + DIN	0.254	239183423	p = 0.913
M2: Total_Phyto2 = Zone1 + Zone2 + DIN + Load + Load*DIN	0.400	192354102	p = 0.963
M3: Total_Phyto3 = Zone1 +Zone2 +DIN + Load + Load*Zone	0.283	229810498	p = 0.925

A numerical example of phytoplankton abundance estimation in the estuarine zone is shown below:

$$\begin{aligned}\text{Total\_Phyto2} &= \text{Intercept} + \text{zone} + \text{DIN} + \text{Load} + \text{Load*DIN} \\ &= 4{,}843.427 - 5{,}475.341(\text{Zone1}) - 7{,}211.332(\text{Zone2}) + 226.213(\text{DIN}) - \\ &\quad 16{,}936.047(\text{Load1}) + 194.040(\text{Load2}) + 1{,}060.511(\text{Load1})(\text{DIN}) - \\ &\quad 115.320(\text{Load2})(\text{DIN}) \\ &= 4{,}843.427 - 5{,}475.341(1) - 7{,}211.332(0) + 226.213\text{DIN} - 16{,}936.047(1) \\ &\quad + 194.040(0) + 1{,}060.511(1)(\text{DIN}) - 115.320(0)(\text{DIN}) \qquad (1)\end{aligned}$$

From Eq. (1) and as shown in Table 3, the estimated values of phytoplankton or phytoplankton density is dependent upon the levels of DIN.

Table 3 Predicted phytoplankton density in the estuarine zone during the study periods

Study period	Predicted phytoplankton density	Phytoplankton density (unit cells/l)		
		Median	Min	Max
Early-loading period (DIN* = 23.30)	4,739	1,600	325	63,750
Mid-loading period (DIN* = 27.06)	2,663	2,150	550	7,900
Late-loading period (DIN* = 26.77)	16,977	3,350	200	186,400

** median values*

CONCLUSION

This study has revealed the ability of the proposed predictive model to identify dissolved inorganic nitrogen (DIN) as the crucial influencing factor of phytoplankton growth. DIN has greatly influenced the phytoplankton density of the Mae Klong River and the estuary. The predictive model could be employed to monitor and manage eutrophication sites. In addition, the levels of chlorophyll *a* well in excess of the natural base-line level (3.3 μg/L) point to the fact that the nutrient loading is impacted by the anthropogenic and natural activities in the area. The study results could be applied to estimate the level of phytoplankton density for more efficient management of water resources and thereby sustainable utilization.

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Research article

Reducing Deforestation and Forest Degradation in Phnom Tbeng Forests

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Abstract Carbon emissions are the source of global climate change. Tropical deforestation was responsible for up to 25% of the global carbon emissions. Foreseeing the danger of losing tropical forests and impacts on local people and global climate change, world leaders have adopted the Copenhagen and Cancun Accords to fully recognize the REDD+ (Reducing Emissions from Deforestation and forest Degradation, Conservation of Carbon Stocks, Sustainable Management of Forests and the Enhancement of Forest Carbon Stocks) scheme of the United Nations Framework Convention on Climate Change. The REDD+ scheme provides financial incentives for any verified activities that result in reducing carbon emissions or increasing carbon stocks. Compensation can be made possible only when the amount of reduced emissions or increased carbon stocks is estimated. This study focuses on estimating the reduced emissions from deforestation and forest degradation and discusses the benefit sharing for local people. Phnom Tbeng forest in the Preah Vihear province was selected as a study site. There are four types of forests, namely evergreen forest, semi-evergreen forest, deciduous and others forests covering 41,530 ha. Our results suggest that a carbon project in this site is likely to result in reduced carbon emissions of about 3.7 million tCO_2 over 30-year project. Depending on carbon price, carbon revenues would be US$ 19 million or US$ 0.6 million annually for a 30-year REDD+ project cycle. In addition to carbon revenues, there are other ecosystem benefits that well-protected forests will provide to local people. Designing appropriate policies and measures to reduce the drivers of deforestation and forest degradation along with law enforcement mechanism is essential for success of the forestry carbon project.

Keywords REDD+, carbon emissions, climate change, carbon stocks, tropical deforestation

INTRODUCTION

Since the adoption of the Bali Action Plan in 2007 at the 13th Conference of Parties (COP13) of the United Nations Framework Convention on Climate Change (UNFCCC), renewed interests have rapidly increased in achieving carbon and sustainable development benefits by implementing activities that result in reducing emissions from deforestation and forest degradation, conservation of carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks (REDD+). The REDD+ scheme had become the common terms referring to a scheme that provides financial compensation to developing countries for reducing carbon emissions. Accounting for up to 25% of the global emissions (Houghton, 2003), carbon emissions from deforestation and forest degradation in developing countries contribute significantly to global warming. Such emissions could be reduced at a relatively low cost compared to the reduction costs in energy sector (Stern 2006; Kinderman et al., 2007). Obviously, huge carbon emission reductions could be achieved with

the appropriate compensation mechanisms. However, financial compensation could only be possible if the amount of reduced emissions and/or removals through enrichment planting is quantifiable. Until recently, there is no agreed global carbon accounting system that is applicable for estimating carbon stock changes and related emissions or removals (Angelsen, 2008). Particularly, no study of carbon accounting system for forest management at local level was conducted in Cambodia, except a handful of few general studies on carbon emissions in the whole Cambodia (Sasaki, 2006) and the opportunity costs for tropical forest management in Cambodia (Sasaki and Yoshimoto, 2010). As REDD+ projects are commonly implemented at the local level (project level), there is an urgent need to develop carbon accounting system, based upon which carbon emission reductions and related financial compensation could be estimated.

OBJECTIVE

The objectives of this study are to provide assessments of carbon emissions and emission reductions from protecting forests under the REDD+ scheme at Phnom Tbeng forests in Cambodia and to discusses the benefit sharing for local people

METHODOLOGY

Study Site and Forest Resources: In 2011, the Ministry of Economy, Trade and Industry of Japan initiated grants for feasibility study (FS) on potential new mechanisms including REDD+ scheme in developing countries. This study is continuous part of this FS on developing REDD+ project in Phnom Tbeng forests in the Preah Vihear Province, Cambodia. The study site administratively includes four districts and one municipality of Preah Vihear province. Field surveys revealed that there were more than 30 villages in 11 communes around this site (Fig. 1). Approximately 75% of rural population depends on forest and non-timber forest products such as for energy use and food particularly during drought or war time (FA, 2010).

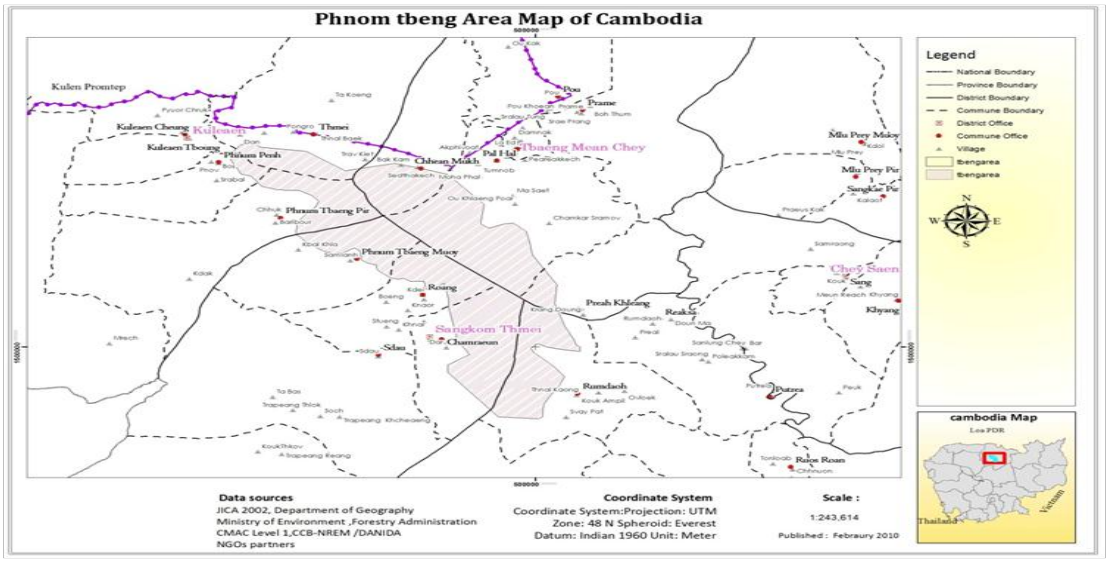

Fig. 1 Location map of the Phnom Tbeng study site

Local communities living in and around Phnom Tbeng forests depend on forests for daily subsistence, energy, and rice cultivation. Due to increasing population and fast economic growth, these forests are increasingly threatened by the clearing of forests for land speculation, the clearing of forests for industrial crop cultivation, land encroachment, and illegal logging. During the fieldwork in 2011 and with collaboration with FA's local authority of Cambodia, Japan Forest Technology Association (JAFTA) classified forests in this study site to four types, namely

evergreen, mixed, deciduous, and other forests. According to JAFTA's forest land cover analysis, total forest area was 41,530 ha in 2004 and decreased to 41,038 ha in 2009 with an overall annual decrease rate of 0.24% (JAFTA's unpublished data). More specifically, evergreen forest decreased 2.71%, semi-evergreen forest 2.09%, other forests 1.53% while deciduous forest increased 5.58% annually between 2004 and 2009 (Table 1).

Table 1 Forest cover changes by type in Phnom Tbeng forest

Forest type	2004		2009		Decreasing rate/year
	Area (ha)	Percent %	Area (ha)	Percent %	2004-2009
Evergreen	14,784	34.3%	12,778	29.7%	-2.71%
Semi-evergreen	12,075	28.1%	10,816	25.1%	-2.09%
Deciduous	10,954	25.5%	14,013	32.6%	5.58%
Other forest	3,717	8.6%	3,431	8.0%	-1.53%
Total forest	41,530	96.5%	41,038	95.3%	-0.24%
None forest	1,511	3.5%	2,003	4.7%	6.51%
Total Area	43,041	100.0%	43,041	100.0%	-

Source: JAFTA's unpublished data

Based on data from 45 sample plots, mean of carbon stocks for each forest type are 102 MgC ha^{-1}, 117 MgC ha^{-1}, and 61 MgC ha^{-1}, respectively for evergreen, semi-evergreen, and deciduous forests. We assumed that carbon stocks in deciduous and other forest are equivalent. Upper confidence interval with 90% reliability (CI90%) is 111 MgC ha^{-1}, 128 MgC ha^{-1}, 69 MgC ha^{-1}, and 69 MgC $ha^{-1}$and lower CI90% is 93 MgC ha^{-1}, 105 MgC ha^{-1}, 54 MgC ha^{-1}, and 54 MgC ha^{-1} corresponding to 9%, 10%, 12% and 12% of the means, respectively for evergreen, semi-evergreen, deciduous and other forest (Table 2).

Table 2 Carbon stock of each forest (MgC ha^{-1})

Variables	Evergreen	Semi-evergreen	Deciduous	Other forest
Mean	102	117	61	61
Upper Confidence Interval with 90% Reliability	111	128	69	69
Lower Confidence Interval with 90% Reliability	93	105	54	54

Source: Result of 45 sample plots in Phnom Tbeng forest

Equations of Estimating Forest Cover Change and Carbon Emission Reductions

Change in area of forest cover by type in the study site can be estimated by

For change rate smaller than zero (a<0)

$$FA(t) = FA(0) \times e^{a \times t} \quad (1)$$

For change rate greater than zero (a>0)

$$FA(t) = FA(0) \times t^{a} \quad (2)$$

If no change in forest cover (a=0)

$$FA(t) = FA(0) \quad (3)$$

where

FA(t): area (ha) of each forest type at time t

$FA_i(0)$: area (ha) of each forest type at time t=0 (i.e. area in 2012)

a: Change rate of forest cover for each forest type

t: is time step (year)

Baseline deforestation (BD) and project deforestation (PD) can be derived by

$$BD(t) = FA(t2) - F(t1) \quad (4)$$

$$PD(t) = RPI(t) \times BD(t) \quad (5)$$

where

RPI(t): Relatives impact of all project activities on drivers of deforestation at time t. RPI(t) is taken from Ty et al. (2011)
CS: Carbon stocks of forest type (MgC ha^{-1})
Baseline and project emissions (CE) can be derived by

$$CE_{baseline}(t) = BD(t) \times CS \times 3.67 \quad (6)$$

$$CE_{project}(t) = PD(t) \times CS \times 3.67 \quad (7)$$

$$CC(t) = [CE_{baseline}(t) - CE_{project}(t)] \times (1 - Leakage) + Carbon\ Sinks \quad (8)$$

where
3.67 is the conversion factor from carbon to carbon dioxide (CO_2)
CC(t): carbon credits
Unit for CE and CC is $MgCO_2$
Leakage: carbon emissions outside project boundary. It is assumed here at 20% (or 0.2)
Carbon Sinks: are the increases of carbon stocks ($MgCO_2$ ha^{-1})

RESULTS AND DISCUSSION

Modeling timeframe for this study is a 30-year period between 2012 and 2042. During the 30-year period, baseline deforestation was estimated at 224 ha, 160 ha and 41 ha $year^{-1}$ corresponding to carbon emissions of 83,811 $MgCO_2$, 68,582 $MgCO_2$ and 9,171 $MgCO_2$ $year^{-1}$, respectively for evergreen, semi-evergreen and other forests. Over the same period, area of deciduous forest increased about 39 ha $year^{-1}$ corresponding to the increase of forest carbon stocks of 8,792 $MgCO_2$ $year^{-1}$(Fig. 2).

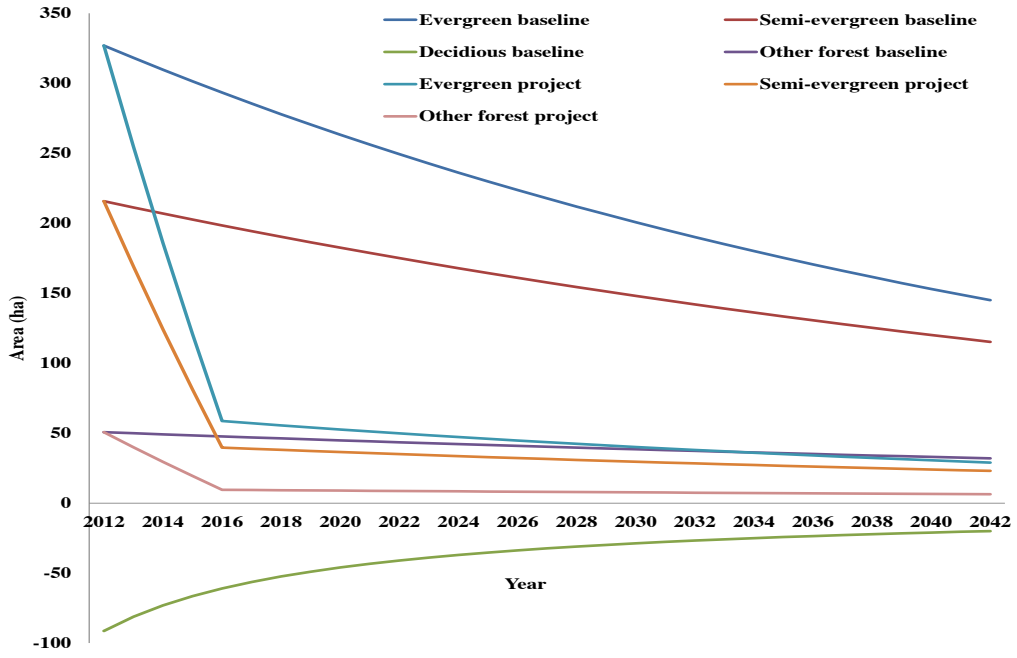

Fig. 2 Forest area loses under baseline and project line

Totally for evergreen, semi-evergreen, and other forests, baseline emissions were estimated at 5,008,487 $MgCO_2$ for the modeling period or 166,950 $MgCO_2$ $year^{-1}$. If REDD+ project is implemented (project scenario), project emissions were estimated at 1,442,867 $MgCO_2$ or 48,096 $MgCO_2$ $year^{-1}$. Our results suggest that a 30-year REDD+ project in Phnom Tbeng forests could lead to emission reductions of 3,565,6621 $MgCO_2$ or 118,854 $MgCO_2$ $year^{-1}$. Increasing in area of deciduous forest could lead to carbon sinks up to 272,541 $MgCO_2$ or 9,085 $MgCO_2$ $year^{-1}$ (Fig. 3).

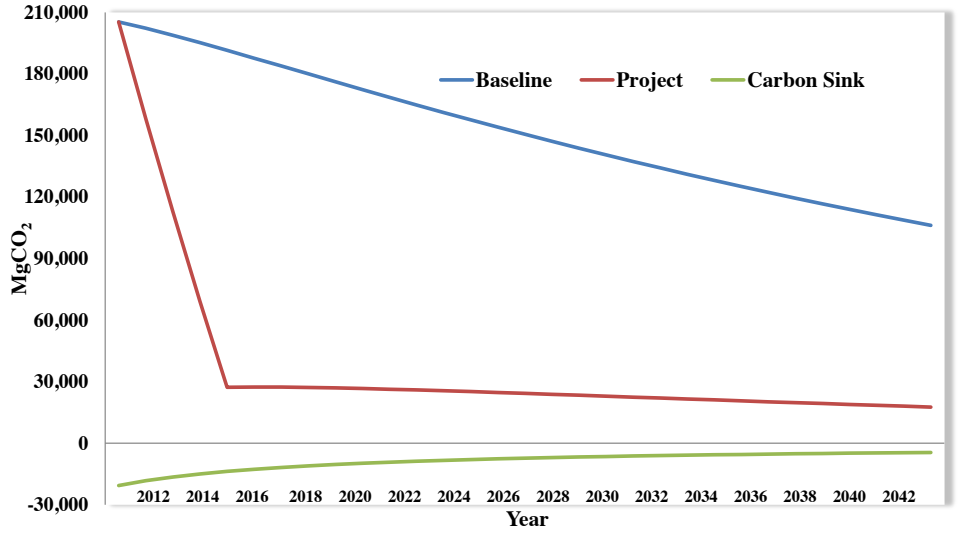

Fig. 3 Carbon emissions under baseline and project scenarios

Therefore, protecting Phnom Tbeng forests under the REDD+ scheme would result in carbon emission reductions of about 3.7 million $MgCO_2$ or US$19 million if carbon is traded at US$6 (mean carbon price at the voluntary carbon market was $7.88 per $MgCO_2$ reported by Hamilton et al., (2011)). Revenues from carbon sales will protect and improve the ecosystem functions of forests, benefit to local communities and government as resource manager and owner. A transparent benefit sharing system is required so as to make sure that carbon benefits will directly reach local communities.

Estimation of carbon emissions and emission reductions is affected by the change rate of forest cover, initial carbon stocks, and the assumptions of the effectiveness of the future project implementation. In addition, actual emissions may also be affected by other factors such as forest fires, rise of opportunity costs and the political stability.

CONCLUSION

This study has attempted to estimate carbon emissions and emission reductions from protecting forests in Phnom Tbeng in the Preah Vihear province. The methods developed in our study could be useful tool for better informed-decision making and the developed methods may be applicable to other locations in Cambodia. Our findings suggest that there are huge emissions from reducing deforestation and forest degradation. Achievement of such emissions will provide more benefits to local people and the Cambodian government through financial support from the international agreements, carbon trading, and other ecosystem related benefits (i.e. improve agricultural land productivity). Protecting forests will also results in biodiversity conservation and protection of traditional rights and culture of forest-dependent communities. Government should be committed to protecting forests for multiple benefits under the REDD+ scheme or similar international agreements that aim to provide financial support for managing forests.

ACKNOWLEDGEMENTS

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Research article

Factors Affecting Rice Production in Northeastern Thailand: The Relationship between Soil Salinity and Vegetative Cover

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Abstract Saline soil is typically found in lower elevation terrain which is also used for rice cultivation. Deforestation in recharge areas can accelerate soil salinity due to increased capillary action. This study examined the relationship between saline soil distribution and vegetative cover at Nong Due Village, Khon Kaen, Thailand. It also identified some social factors and farm management practices which affected rice production in saline paddies. A field survey was conducted in April, 2012 to determine soil property analysis, combined with a questionnaire on rice production, farm management, and farmer's household socioeconomic conditions. In total, 34 paddy fields were surveyed with 68 soil samples collected from non-saline and saline plots. Elevations of the sampled plots were 146-178 m with electrical conductivity (ECe) 0.19-16.58 dS/m. Soil salinity did not show a significant correlation from the sampled paddies to the closest vegetation, but high salinity did occur in lower elevations and farther away from the nearest forest. Forty household representatives answered the questionnaire, of which 34 had encountered some problems with soil salinity (average 0.89 ha/household). Average rice yields from saline paddies were 1.9 tons/ha, lower than those from non-saline paddies (mean difference -113.39 kg/ha). Rice production costs associated with soil salinity were estimated 10,770 Baht/ha, of which the highest amount was spent on crop maintenance. In contrast, costs from non-saline farming systems were 9,791 Baht/ha (39.75% also spent on farm maintenance). Household income and labor did not show a significant correlation with farm management practices. Fertilizer application is dependent on the availability of on-farm resources and word-of-mouth. Farmers often use cattle manure, compost and green manure to reduce soil salinity. Moreover, farmers raised the height of paddy borders, so that more rainwater could be stored, thus ensuring that the rice paddies were continuously submerged.

Keywords soil salinity, saline paddies, vegetative cover, rice production, Nong Due village

INTRODUCTION

Soil salinity is a major problem in semi-arid or arid regions around the world. For example, Arunin (1996) reported 17.81 million ha of salt-affected areas in northeastern Thailand (approximately 17% of the region). According to Yuvaniyama (2003), two important factors that cause saline soil distribution are: 1) the presence of salt rock in Maha Sarakham geological formation which induces salt-dissolved water to the topsoil through capillary action; and 2) land use activities, such as deforestation in recharge areas, that accelerate dissolved salt transfer to the surface (Land Development Department, 2009). Soil salinity reaches a steady state when the amount of salt intruding into the soil profile is equaled by the amount leaving the soil surface via stream flow. This phenomenon is widespread in rice paddy fields where salt accumulates easily and gradually

deteriorates over time (Barrett-Lennard, 2002). Sayok et al. (1993) reported that soil EC measures for specific clear-cut areas in the Davy Crockett National Forest near Apple Springs, Texas were higher than adjacent, undisturbed forest land.

Economically speaking, rice (*Oryza sativa* L.) is Thailand's most important cash crop. During 2009-2011, Thailand exported about 9.42 million tons of rice annually, estimated at USD 5.18 million per year (Office of Agriculture Economics of Thailand, 2012). In 2011, the total harvested paddies were estimated at 8.91 million ha, of which about 5.55 million ha (62.22%) were from the Northeast (12.01 million tons accounted for 51.60% of Thailand's total rice production). Although the region's total rice production is relatively high, the yield per unit area is only 2.02 tons/ha as compared to the national average yield of 2.38 tons/ha (Office of Agriculture Economics of Thailand, 2012). This is due to several factors, including the region's climatic conditions, poor soil fertility, low inputs (Wijnhoud et al., 2003) and soil salinity (Quantin et al., 2008). Rice yields and economic returns are about one third less in saline soil as compared with nearby unaffected areas (Hall et al., 2004).

Salinity has a harmful impact on soils and crop production. Excessive amounts of salt adversely affect the physical and chemical properties of soil, as well as microbiological processes (Lakhdar et al., 2009). Salinity and sodicity also affect crop yields because of osmotic effects and sodium toxicity (Marschner, 1995). If nutrient up-take efficiency decreases, then plants will suffer. For example, nitrogen deficiency expresses itself in older leaves of rice – those having a pale and dry leaf apex. Prolonged nitrogen deficiency causes severe plant stunting, reduced tillering, and yield reduction. Additionally, increased levels of salt can result in soil compaction, thus reducing water infiltration and causing difficulty in plowing. Wijnhoud et al. (2003) stated that farming decisions often favor rice paddies with higher income potential, thus shifting management priorities to socioeconomic factors. Family income can also affect farm management practices, including fertilizer application.

OBJECTIVE

Soil salinity tends to increase when vegetative cover decreases. This can exacerbate land limitation problems, especially on rice production which takes place in areas where soil salinity typically occurs. Subsequently, ecological factors, such as the availability of nutrients (N-P-K) can affect rice production. Furthermore, farm management practices (e.g., fertilizer application, manure input and irrigation) play key roles in productivity, but success is heavily dependent upon the farmer's socio-economic condition. This study examined several factors affecting rice production at Nong Due Village, Nong Song Hong district, Khon Kaen province, including the relationship between saline soil distribution and vegetative cover. Better understanding of soil salinity and rice production problems will help farmers to more effectively adapt, thus to a certain extent help improve their productivity and benefits gained.

METHODOLOGY

Two data collection activities were done. Firstly, soil samples from both saline and non-saline rice paddies were collected in April, 2012 using a composite sampling method for soil property analysis, including ECe, organic matter (titration method, modified from Walkley and Black, 1934), N (calculation derived from OM values), P (Bray no. II method), K (Flam photometry method), soil pH, texture and color. Sampled paddy coordinates and elevations were recorded on a GPS receiver (Garmin etrex). The distance between each sampled plot to the closest forest was estimated using a Google Earth map. Correlations between soil sample ECe values and distances to the closest forest, as well as elevations, were calculated to determine the extent of salinity distribution.

Secondly, a questionnaire was administered to villagers in July, 2012 to measure rice production, farm management practices, and household socioeconomic factors. Most of the quantitative data such as rice yields, nutrient inputs, and residue management were provided by

farmers during oral interviews. Units were standardized, which involved conversion of volumes to weights. This conversion was checked through direct observations of rice containers and/or sacks. Descriptive statistics, t-tests and correlations were performed to examine potential factors affecting rice production.

RESULTS AND DISCUSSION

Nong Due (UTM 48P 263316mE 1733847mN) is a village in Dong Keng sub-district, Nong Song Hong district, Khon Kaen province, Thailand. Patches of soil salinity can be observed in rice paddies, especially during the dry season. Rice paddies were primarily located northeast of the village adjacent to a dry Dipterocarp forest called Kok Nongjan (KNJ) community forest (UTM 48P 265044mE 1735511mN). The southern side of the village was surrounded by a forest patch with trees scattered throughout the rice paddies (Fig.1).

Fig. 1 Nong Due Village (A): rice paddies and surrounding forests - KNJ (B)
(*Source: Google Earth, 2012*)

Soil salinity distribution

A total of 68 soil samples from both saline and non-saline rice paddies were collected. The sampled point elevations ranged from 146 m to 178 m with the lowest estimated soil ECe 0.19 dS/m up to 16.58 dS/m. The average distance from non-saline rice paddies to the closest vegetation was 0.28 ± 0.10 km, while high salinity sampled plots were found farther away from the forests (Table 1). Although soil salinity distribution did not show significant correlations with distance, high salinity areas tended to occur in lower elevations and farther away from vegetative cover.

Table 1 Salinity distribution: sampled point elevation, distance to the closest forest and ECe

Salinity level	ECe (dS/m)		Elevation (m)	Distance (km) to the closest vegetation	No. of sampled points (%)
	Criterion *	Range			
Non saline	<2	0.19- 1.99	161.95 ± 7.60	0.28 ± 0.10	41 (60.29)
Slightly saline soil	2-4	2.33- 3.83	159.89 ± 5.37	0.29 ± 0.09	9 (13.24)
Moderately saline soil	4-8	4.09- 7.49	162.43 ± 4.65	0.30 ± 0.11	7 (10.29)
Highly saline soil	8-16	8.49-14.63	159.20 ± 5.81	0.32 ± 0.12	10 (14.71)
Severely saline soil	>16	16.58	161	0.30	1 (1.47)

*Source: *U.S. Salinity Laboratory Staff (1954)*

Soil properties

Soil samples consisted of loamy sand with high variability of pH (3.64-9.93, median=7.28). Takuhito et al. (2006) found that soil pH can be affected by water drainage during fallow periods

and rice straw inputs to the soil. Water drainage during the fallow season increases soil pH, which might explain higher pH readings in the sampled plots since it rained the night before sampling occurred. Furthermore, the application of rice straw decreases soil pH, partly due to the decomposition of organic matter. Since organic materials serve as an electron donor for soil reduction, the soil pH decreases because of increased pressure from CO_2 (Ponnamperuma et al., 1966; Takuhito et al., 2006).

Soil coloration from the saline samples ranged from reddish yellow to strong brown, while samples from non-saline paddies were reddish yellow to pinkish gray. The majority of soil samples (60.29%) were classified as non-saline, except for one location (Table 1). Furthermore, the majority of soil samples had low nutrient contents (Tabel 2), including OM and N (less than 1%). This finding is typical for soils in Northeast Thailand (Tulaphitak, 2002), partly due to loamy sand texture, erosion, and land use activities. Only a few samples yielded moderate to high contents of K. The independent samples t-tests showed significant differences of OM and total N contents between non-saline soil and saline sites (mean difference = 0.127 and 0.006; p-value < 0.05, respectively). Although no significant difference was detected, available K contents of saline soil samples were higher than non-saline soils (Table 3). This may result from poor nutrient uptake caused by dehydration since the rice plants were growing in saline soil (Patel et al., 2009).

Table 2 Soil properties: Total OM, Total N, Available P and K

Soil salinity	Parameters	Soil fertility					
		Low*		Moderate*		High*	
		Mean ± S.D.	No. of samples (%)	Mean ± S.D.	No. of samples (%)	Mean ± S.D.	No. of samples (%)
Non-saline soil	OM (%)	0.44 ± 0.29	41 (100)	-	0 (0)	-	0 (0)
	N (%)	0.02 ± 0.01	41 (100)	-	0 (0)	-	0 (0)
	P (ppm)	0.11 ± 0.05	41 (100)	-	0 (0)	-	0 (0)
	K (ppm)	28.75±13.69	29 (71)	70.22 ± 12.38	8 (20)	98.43 ± 6.81	4 (10)
Saline soil	OM (%)	0.31 ± 0.22	27 (100)	-	0 (0)	-	0 (0)
	N (%)	0.02 ± 0.01	27 (100)	-	0 (0)	-	0 (0)
	P (ppm)	0.08 ± 0.08	27 (100)	-	0 (0)	-	0 (0)
	K (ppm)	19.79±10.87	22 (81)	83.40 ± 0.44	3 (11)	255.55 ± 127.07	2 (7)

*Note: *Standards: Total OM (%): Low <1.5, Moderate 1.5-3.5, High >3.5; Total N (%): Low <0.3, Moderate 0.3-0.6, High >0.6; Available P (ppm): Low <10, Moderate 10-25, High >25; and Available K (ppm): Low <60, Moderate 60-90, High >90*

Source: Soil Survey Division, Land Development Department (1980)

Table 3 Comparison of soil nutrient contents between non-saline and saline soil samples

	Group	N	Mean ± S.D.	Mean Difference	t-test (p-value)	95% Confidence Interval of the Difference	
						Lower	Upper
OM (%)	NS	41	0.437 ± 0.209	0.127	2.354 (0.022)	0.021	0.233
	SS	27	0.310 ± 0.223			0.019	0.235
N (%)	NS	41	0.022 ± 0.0104	0.006	2.349 (0.023)	0.001	0.012
	SS	27	0.016 ± 0.0112			0.001	0.012
P (ppm)	NS	41	0.111 ± 0.054	0.030	1.943 (0.056)	-0.001	0.062
	SS	27	0.080 ± 0.075			-0.0031	0.064
K (ppm)	NS	41	43.638 ± 27.634	-0.686	ns	-24.761	23.389
	SS	27	44.324 ± 69.526			-29.343	27.970

Note: NS = non-saline soil sample and SS = saline soil sample

Rice production and farm management in saline soil farming systems

Rain-fed rice cultivation is the primary occupation of Nong Due villagers. A total of 40 household

representatives (out of 70) participated in the survey. A majority of the households (n=34) had encountered soil salinity issues (the averaged size was 0.89 ha/household which accounted for 34% of their total paddy area). Primarily, farmers grow two rice cultivars including a glutinous mutant of jasmine rice—RD6 and jasmine rice—KDLM-105. The average rice yield from farmers who experienced soil salinity was 1.9 tons/ha, lower than the average production from non-saline paddies (mean difference –113.39 kg/ha). Moreover, the size of saline paddies showed a negative correlation with rice production ($R^2 = 0.120$, p-value = 0.029).

The average household annual income derived from a four-person labor force was approximately 112,000 Baht (USD1 ~ 30.64 Baht as of December 14, 2012). These figures were not significantly different between households that experienced soil salinity and those who did not. Moreover, the household income and labor force did not show significant correlations with farm management practices. Fertilizer application is likely dependent upon the availability of on-farm resources and word-of-mouth. Nonetheless, the total paddy field per household significantly correlated with rice yields ($R^2 = 0.275$, p-value = 0.001). Although this finding implies that the labor force may not differ across samples, it does limit household production and management abilities.

Rice production costs of farming systems which experienced soil salinity were estimated at 10,770 Baht/ha. The highest spending was associated with farm maintenance, especially from farmers using chemical fertilizers. The costs from non-saline farming locations were 9,791 Baht/ha, with 39.75% also spent on farm maintenance (Table 4). Seemingly, farmers have adapted to soil salinity by using on-farm resources, such as cow manure, compost, and green manure. Farmers also raised the height of paddy borders, so that more rainwater could be stored, thus ensuring that the rice paddies were continuously submerged. Clermont-Dauphin et al. (2010) reported that approximately 20% of rice yields decreased because of salinity, but 87% decreased due to drought. Therefore, water management is very important for rice cultivation, especially in saline paddies.

Table 4 Rice production and farm management information of sampled households

Information	Households without saline paddies (6 households)	Households with saline paddies (34 households)
1) Averaged size of total paddies (ha/household)	2.74	2.63
2) Averaged size of saline paddies (ha/household)	-	0.89
3) Household's total rice production (tons/ha)	2.0	1.9
4) Income (Baht/household)	133,000	108,000
5) Labor force (persons/household)	4.06	3.50
6) Total costs of rice production (Baht/ha)	9,791	10,770
6.1) Land preparation and rice growing (transplanting and sowing)	3,095 (31.61%)	2,618 (24.31%)
6.2) Maintenance costs	3,892 (39.75%)	4,771 (44.30%)
6.2.1) Chemical fertilizer application	3,022 (77.64%)	2,775 (38.15%)
6.2.2) Manure application	548 (14.07%)	451 (9.46%)
6.2.3) Pesticide application	-	64 (1.35%)
6.2.4) Organic fertilizer application	-	1,294 (27.11%)
6.2.5) Rice husk & mulch application	323 (8.29%)	187 (3.93%)
6.3) Harvesting costs	2,804 (28.63%)	3,381 (31.39%)

Note: USD1 ~ 30.64 Baht as of December 14, 2012.

CONCLUSION

Soil salinity is a prolonged issue for many farmers in Northeastern Thailand. Its distribution is likely to expand if deforestation in recharge areas continues to occur. Despite the low correlation between soil ECe and distance from saline plots to the closest vegetation, high salinity frequently occurs in lower elevations and areas farther away from forest cover. Approximately 34% of the rice paddies with soil salinity issues also encountered low soil nutrients. The average rice yield of farmers experiencing soil salinity is lower than the productivity from non-saline paddies. This finding illustrates that soil salinity negatively affects rice production. However, household income and labor force did not show significant correlations with farm management practices. Fertilizer

application is likely dependent on available on-farm resources and word-of-mouth. As long as soil salinity remains an issue, then farmers will be forced to adapt. Use of on-farm resources, such as cow manure, compost, and green manure are environmentally sensitive ways to reduce soil salinity. Another effective strategy is raising the height of paddy borders, so that rainwater capture can continuously submerge the rice paddies.

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Research article

Climate Change Vulnerability: Household Assessment Levels in Kampong Speu Province, Cambodia

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Abstract Cambodia's Ministry of Environment (MoE) conducted vulnerability and adaptation assessments using two different methodologies: the Global Circulation Model (MoE, 2001) and Household Surveys (MoE, 2005). They found that Cambodia is vulnerable to climate change and has a low adaptive capacity compared to other countries in Southeast Asia. Flood and drought were identified as the climatic hazards that imposed the greatest threats to rural farmers. This study, which assessed vulnerability at the household level in the drought-prone Kampong Speu (KPS) province, calculates climate change vulnerability based on the framework developed by the Inter-governmental Panel on Climate Change (IPCC). The results indicate that drought is the most severe climate hazard experienced in KPS. Farmers reported that they regularly experienced irregular rainfall distribution during cropping season that results in crop damage and/or loss. Adaptations to drought adopted by farmers include water storage, introducing drought-tolerant crop varieties, and improving knowledge about farming techniques. Other mechanisms that are also feasible are providing or enhancing secondary income capacity.

Keywords climate change, vulnerability, adaptation, assessment, rural development

INTRODUCTION

Climate change is the term most frequently used in global studies to refer to significant and lasting changes in the Earth's weather pattern that are evident in effects such as worldwide changes in in precipitation, and temperature (IPCC, 2007). However, 'climate change' is not commonly used in Cambodia, where this phenomenon is instead called 'climate variability'. The impacts of climate change can be seen spatially, temporally, socio-economically and through many other factors. An assessment of vulnerability to climate change is required before any prescriptions are given to mitigate and/or to adapt to climate change.

As defined in the IPCC report Climate Change 2001, vulnerability is a function of the sensitivity of a system to changes in climate (the degree to which a system will respond to a given change in climate, including beneficial and harmful effects), adaptive capacity (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate), and the degree of exposure of the system to climatic hazards (IPCC, 2001 , p. 89). The definitions of exposure, sensitivity, and adaptive capacity can be found in climate change literature (Adger, 2006; Fankhauser et al., 1999; Eriksen and O'Brien, 2007). Explanations of how to quantify vulnerability can be found in Fussel (2007) and Hinkel (2011).

When studying vulnerability on a fine scale, for example at a household level, the study of climate change is associated with the outcomes of changes in climate in a particular geographical area such as a commune. A study may focus on a single element, such as changes in productivity, economic loss, or local knowledge of adaptation.

This paper aims to estimate and quantify vulnerability to climate change in Cambodia using

household data and to identify the household characteristics that are most impacted by climate change effects such as flood and drought.

Background

One study on vulnerability related to climate change at the household level in Cambodia was completed by the Ministry of Environment (MoE) in 2005. Climatic hazards including flood, drought, and windstorms were studied. That study (MoE, 2005) demonstrates that Cambodians have observed changes in weather patterns and experienced losses in farming production due to climatic hazards because of their low adaptive capacity. A number of possible coping and adaptation mechanisms were identified by the study, which noted there were a number of constraints to effectively adapting to climate change such as lacks in the financial, knowledge and skill aspects required to mitigate impact. Following the MoE's study, there have been a number of studies related to climate change assessment that use different frameworks, such as Try Toun (2009) and Yusuf and Francisco's (2010) EEPSEA's study. From these studies, it can be concluded that Cambodia is exposed to climate variability and that even with low degree of exposure; rural communities are highly vulnerable to changes in climate due to low adaptive capacity.

Fig. 1 shows the production lost due to flood and drought between 1984 and 2011. During the 1990s, droughts were more common than floods and occurred with very high severity, except for in 1996 when both disasters hit Cambodia at the same time during growing seasons. During the 2000s, the both floods and drought occurred every year, with the highest concentration of disasters occurring in the middle of the decade.

There was flooding in Cambodia every year between 1998 and 2011, with the most severe floods occurring in the 2000-01 growing season, based on the average level of flooding in Cambodia as recorded over the last 70 years (the 2011 flood is not included for the comparison due to lack of literature). The 2000-01 floods caused extensive damage to many social infrastructure systems, properties and agricultural plantations and during the wet season affected both people and animals in 22 provinces.

The Kampong Speu (KPS) province is the second priority project implementation in the National Adaptation Program of Action to Climate Change (NAPA) of Cambodia. The NAPA priority for adaptation is consistent with the finding of EEPSEA vulnerability mapping study, which identified that Kampong Speu is the third most vulnerable province of the 17 provinces in Cambodia. As mentioned earlier, KPS has a high incidence of poverty, and experienced drought more often and intensively than other provinces in Cambodia.

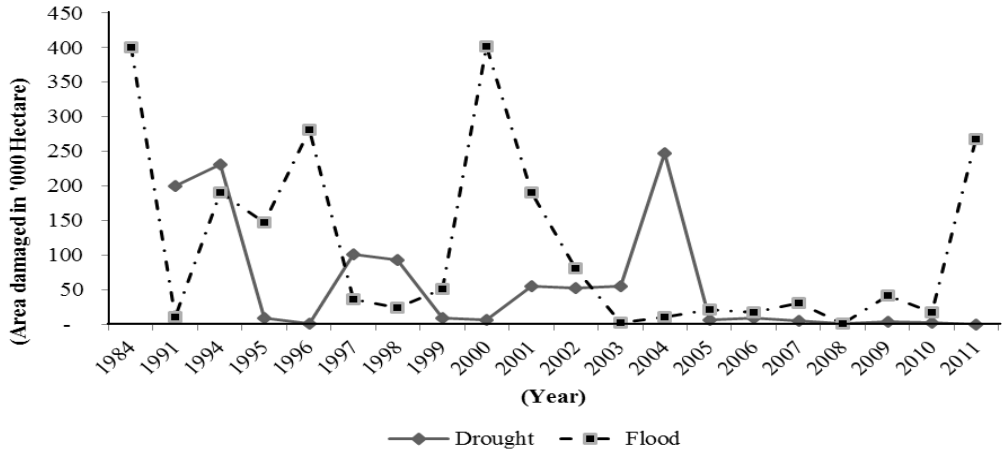

Fig. 1 Distribution of paddy rice destroyed by flood and drought in Cambodia, 1984-2011

Kampong Speu is about 40 km to the west of Phnom Penh. The province is comprised of 8 districts. The total population of the province is 716,944, of which 368,432 are female. Similar to other provinces in Cambodia, the economy of this province is agriculture-dominant and primarily

involved in rice production. The total paddy rice area of this province in 2007 was 78,000 ha, which accounted for 3.81% of the total paddy rice in Cambodia. KPS produces 245,000 tons of rice annually, approximately 4% of the county's total rice production.

Data gathering

The household survey samples were selected from 6 communes in 6 districts within two geographical areas: highland areas (2 districts/communes: Phnom Sruch/Morhasang, Oral/Tasal) and lowland areas (4 districts/communes: Chbar Mon/Chbarmon, Oudong/Peng Lavea, Bor Sedth/Kork, Somrong Tong/Rolang Chork). A total of 600 questionnaires were collected of which 200 from highland and 400 from lowland. The occurrence of natural hazards, including flash flooding, drought and windstorm, were recorded based on yes/no questions. Other variables that contributed to the index calculation were collected based on Table 1, 2 and 4.

METHODOLOGIES

Composite indicators involve two steps. First, it involves in normalizing of each indicator based on Eq. (1) and then, aggregating the indicators into one index as in Eq. (2).

The normalizing procedure is based on Eq. (1).

$$Ii = (xi - x\min)/(x\max - x\min) \quad (1)$$

Where I_i is the normalized value of indicator i, x is the original value for indicator for individual household, and x_{max} and x_{min} are the highest and lowest values of the indicator.

In order to aggregate the indicators (as in Eq. 2), weighting among the indicators is employed. The weights are obtained from focus group discussion, expert judgment and key informant interview from the study site. This is to reduce subjectivity[*]. It is very important to quantify vulnerability according to the different weights for each indicator and dimensions. The consensus method was used to gather the weight of different determinants and indicators. Eight Focus Group Discussions (FGDs) were conducted with participants from a range of backgrounds at the provincial, district and commune levels in order to come up with different weights. Weights were then averaged among all FGDs and levels.

$$Dj = \sum_{i=1}^{n} IiWi \quad (2)$$

Where D_j is the aggregate value from the product of normalized value of indicator, j is the name of index, n is the number of indicators within a particular index and I_i and W_i are the normalized value of indicator and weight of each indicator respectively.

Exposure Index (EI)

Table 1 Example of Exposure Index calculation

HH No.	Number of hazard events			Normalized Value (index)			Hazard Index
	Drought	Flood	Windstorm	Drought	Flood	Windstorm	
1	10	3	0	1.00	0.75	0.00	0.77
2	5	0	1	0.50	0.00	0.33	0.31
3	2	2	0	0.20	0.50	0.00	0.27
4	3	1	2	0.30	0.25	0.67	0.34
5	0	4	0	0.00	1.00	0.00	0.33
6	1	0	3	0.10	0.00	1.00	0.22

Exposure index in this study is composed of three hazards indicators: flash flooding, drought and windstorms. Based on social perception of hazard, we recorded number of events that household

[*] In our study site, the weights are 0.53, 0.32, and 0.15 for drought, flash flood, and windstorm respectively.

experienced. For example, within 1990-2010 one household may experience 10 drought events, 3 flash floods and 1 windstorm. Different localities of household experienced differently (Table 1). Each hazard event, such drought, is normalized to get the value between 0 and 1.

Sensitivity index (SI)

Sensitivity of a household composed of four dimensions (with different weight) namely: human capital (0.23), livelihood (0.26), infrastructure (0.21), and financial capital (0.30). Meaning that sensitivity index is the aggregated value of the four dimensions after applying weight. Each dimension is measured by different indicator as in Table 2.

After normalizing the indicator based on (Eq.1), we aggregate the normalized value of indicators with weighting of each indicator by their own dimension (Table 3). We assume that the higher the weight, the more sensitive to natural hazard. For example, in human dimension, a household may experience more hardship if there are more children compared to other households.

Table 2 Sensitivity indicators and weight

Dimension	Indicator	Indicator Weight
Haman	Dependent ratio (S1)	0.55
	Number of family laborers working in agriculture (S2)	0.45
Livelihood	Percentage of annual income generated from agriculture (S3)	1.00
Infrastructure	Distance from household to a body of water (S6)	1.00
Financial	Percentage of debt in (S9)	1.00

Table 3 Example of Sensitivity Index calculation

HH No.	Indicator		Normalized Value (index)		Weight Value
	S1	S2	S1	S2	
1	25	2	0.31	0.25	0.28
2	20	2	0.17	0.25	0.20
3	14	5	0.00	1.00	0.45
4	33	2	0.53	0.25	0.40
5	16	1	0.06	0.00	0.03
6	50	2	1.00	0.25	0.66

Adaptive capacity index (ACI)

This index composed of five dimensions (with different weight) namely: infrastructure (0.19), economics (0.21), technology (0.20), social capital (0.18) and human capital (0.22). The adaptive capacity index is also based on the same principle as in sensitivity index. Each dimension has different indicator with different weight as in Table 4.

Vulnerability index

Vulnerability assessment is based on Eq. 3. For a comprehensive discussion of the Indexes Approach, see 'Handbook on Constructing Composite Indicators: Methodology and User Guide' jointly developed by OECD and JRC European Commission (OECD, 2008). The example related to this approach can be found in Yusuf and Francisco (2010) and International Crop Research Institute for the Semi-Arid Tropics (2009).

The Vulnerability Index (*VI*) is based on three-dimensional indexes (see the definition above) including exposure index, sensitivity index, and adaptive capacity index. The *VI*'s formula is shown in Eq. (3).

$$VI = \left(EI + SI + (1 - ACI)/3\right) \quad (3)$$

Before aggregating vulnerability index (VI), there is a manipulation of adaptive capacity index (ACI) by *'1 – ACI'* so that the direction of ACI is the same as exposure and sensitivity index, meaning that for EI and SI the higher the value, the higher vulnerability while the higher the ACI,

the low vulnerability. So, the manipulation of ACI will keep ACI value the same direction as EI and SI.

Table 4 Adaptive capacity and their weight

Dimension	Indicator	Indicator Weight
Infrastructure	Percentage of irrigated agricultural land of household	1.00
Economic	Income per head	0.31
	Amount of remittance per year	0.31
	Percentage of income generated from non-agriculture	0.38
Technology	Number of TVs and radios	0.30
	Number of line phones and cell phones	0.30
	Number of motorcycles	0.40
Social capital	Amount of money that can be borrowed from relatives and/or friends in case of disaster	0.10
Human	Number of laborers	0.53
	Level of education	0.47

RESULTS AND DISCUSSION

Hazard exposure

Almost every household in the sample (574 out of 600 cases) reported that they were impacted by drought at least once between 1999 and 2010. During this 12-year period, 20% of households experienced drought once every two years. Flash floods and windstorms were very rare and, out of 600 cases, 540 were not impacted by flash floods and 558 by windstorms at all during the study period. Compared to flash flooding and windstorms, drought is the major thread to rural households.

Table 5 shows the number of occurrence of natural hazards (windstorms, flash floods and drought) reported by households from 1999 to 2011. It can be inferred from the data that windstorms occurred with a low frequency and had a greater effect on lowland communities more than highland communities. Based on the FGD data, highland residents reported that windstorms are not a major concern and only 6% of both highland and lowland respondents reported experiencing windstorms over the last 12 years.

Table 5 Hazard events experienced by respondents in KPS, 1999-2010

Class	Highland			Lowland		
	Drought	Flash flood	Windstorm	Drought	Flash flood	Windstorm
0-1	58	192	198	107	378	393
2-3	79	8	2	160	20	7
4-5	23	0	0	54	1	0
6-7	10	0	0	7	1	0
8-9	0	0	0	6	0	0
10-12	30	0	0	66	0	0

Sensitivity

Figure 2 shows the comparison of the means of the four determinants of the sensitivity index and meaning that the higher the value, the more sensitive to natural hazards. Horizontal axis is the sensitivity dimensions that will be composited into sensitivity index and vertical axis is the mean value of weighted of each dimension from highland and lowland. The livelihood determinant had the highest mean value at 0.684, followed by human at 0.396. The other determinants were negligible. This implies that the livelihood of households is highly sensitive to the changes caused by climatic events and that the ratio of dependency is also high.

The mean value of human sensitivity in the lowland area (N=400) was 0.26 compared to the highland area (N=200) at 0.29 with the standard deviations of each commune at 0.10 and 0.01 respectively. The independent samples test found that the group means of sensitivity index of

highland community are significantly different as the value in the p-value at 0.001 (less than 0.05). Therefore it can be concluded that the highland area is more sensitive to climate change impacts than the lowland area. This is due to either highland households are highly depending on agriculture.

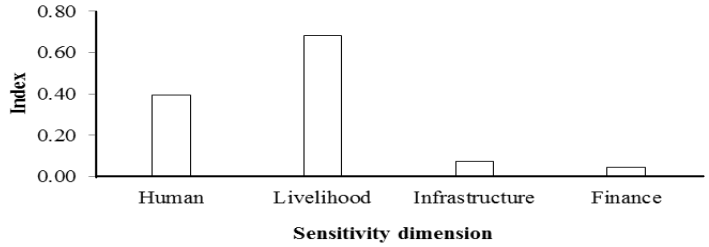

Fig. 2 Comparison of sensitive indicators to climate change in the KPS province

Adaptive Capacity

Fig. 3 compares adaptive capacity dimensions which finally be composed into adaptive capacity index. The values on top of the bar are the mean of the dimension, meaning that the higher the value, the higher adaptive capacity. The graph illustrates that the human component of adaptive capacity is twice as significant as the other components (infrastructure, economics and technology). It can be interpreted that labor is the best way to handle shock. Other factors, such as the level of social capital, play an insignificant role compared to other determinants.

By disaggregating adaptive capacity index (ACI) into highland (N=200) and lowland (N=400), the means of ACI of lowland and highland commune are at 0.77 and 0.83 with the standard deviations of 0.11 and 0.09 respectively. The independent samples test shows that the group means of the lowland and highland are significantly different as the p-value is 0.00 (less than 0.05). Based on this statistics, we can conclude that highland community is statically lower than lowland communes.

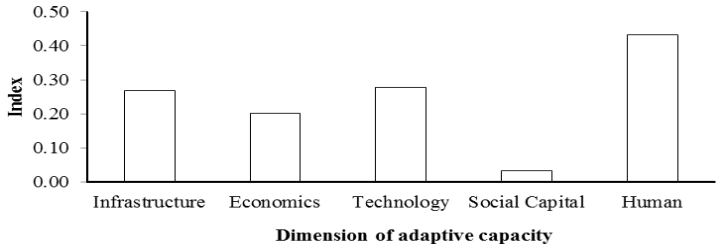

Fig. 3 Comparison of adaptive capacity of household in the KPS province

Vulnerability assessment

Figure 4 also presents the index of hazard, sensitivity, adaptive capacity by disaggregating the index value into topographical areas (highland and lowland) based on household data. Both areas experienced hazards to a similar degree. Given the index value of hazards is low, the main hazard is drought, which is considered the most serious hazard among the three hazards studied in this paper (drought, windstorms and flash floods).

There is a slightly variation between highland and lowland areas in term of adaptive capacity index value. However, it is concluded that the highland area is more vulnerable than the lowland area because of a lower adaptive capacity and higher sensitivity to climate stimuli. It is worth noticing here that livelihood of households who are heavily depending on paddy rice is more vulnerable than those with raising livestock and having engaging in non-agricultural activities.

Fig. 5 shows a comparison of households with the vulnerability index categorized into low and high vulnerability. The graph shows that 43% of households are in the medium vulnerability category with 19% and 7% in the high and very high vulnerable categories respectively. By lump-

summing these three categories it was found that there are 67% of household in the KPS province that are potentially impacted by hazards, while the rest are in the low vulnerability category.

From a qualitative point of view, natural disasters, particularly drought, have resulted in insecurity amongst communities. Due to losses in rice production, some people turn to theft in order to support their families. The FGDs disclosed this had happened in the Prekdey village (Rolang Chork commune, Somrong Tong district). FGDs in the Chrok Trach village (Morha Sang commune, Phnom Srouch district) confirmed that some families were in hardship because of the drought and did not have enough money for their children go to school. Some families, often the ones who had suffered the most difficulties and who experienced serious damage to rice production from drought, had decided to sell their properties and migrate other places, especially to Phnom Penh. Moreover, the FGD in the Krang Troak village (Kok commune, Borsedth district) reported that some families experienced increased domestic violence between husbands and wives which was attributed to stresses caused by drought that damaged their rice production.

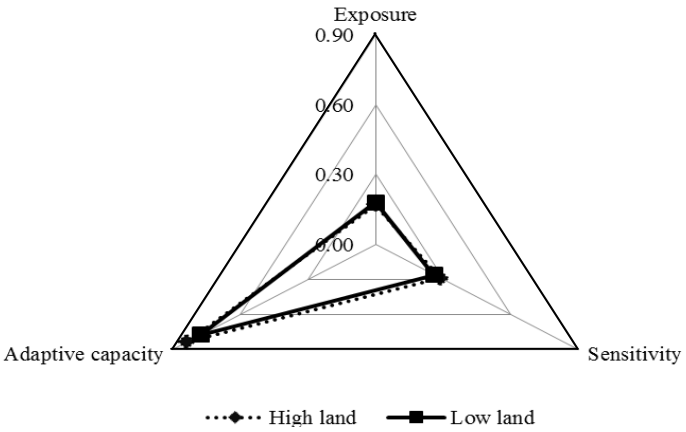

Fig. 4 Vulnerability comparison of high and lowland households of the KPS province (1999-2010)

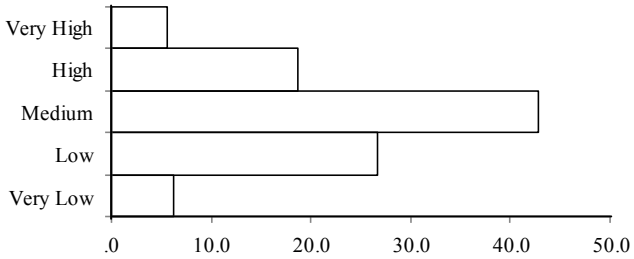

Fig. 5 Vulnerability Index by Households

Adaptation identification

In this study, the practices of adapting to drought were determined through a household survey, FGDs and expert recommendations. Some farmers stated they did not employ any adaptive practices, while others protected their paddy rice from drought impacts by pumping water from nearby water bodies such as ponds or wells and/or changing to drought-resistant practices (for example by planting a short-duration rice variety). Some farmers also increased the amount of fertilizer they used in order to maximize their yield, especially during years when drought occurred.

The key informant interviews also found that participants believed that modern crop varieties should be and in some cases have been introduced to areas which experience frequent and/or severe drought. This is one of the primary interventions of the Department of Agriculture at the provincial level through their line authorities. While establishing a supplemental irrigation scheme is a long-term drought mitigation strategy, providing ad hoc water pumping to local community is a must

during drought spells. The practice of water pumping has been used throughout Cambodia, especially in Kampong Speu province, with the assistance of the Department of Water Resources and Meteorology. Although it would involve many different government agencies, the next urgent drought mitigation intervention should be increasing farmers' knowledge about farming techniques including Systematic of Rice Intensification (SRI) and improving general education.

CONCLUSION

Cambodia is highly dependent on agriculture, therefore it is vulnerable to climate stimuli such as flood and drought. Every province in Cambodia is vulnerable to climate change to some degree, however some are more affected by flood and others by drought. This research found the Kampong Speu province is prone to drought, with many residents reporting they experienced drought impacts almost once every two years.

This empirical study reconfirmed that the present vulnerability of households in Kampong Speu is high due to high sensitivity, low adaptive capacity and low exposure factors, and the study identified that 67% of this province is in the medium to very high vulnerable range. People have adapted to drought, but their practices are not productive. Therefore, enhancing adaptive capacity is very critical, including promoting more drought-resistant crops, (perhaps, as suggested in the literature, on a small scale) implementing an irrigation scheme, and improved knowledge about how to use farming techniques to mitigate drought.

ACKNOWLEDGEMENTS

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Research article

A Feasibility Study on Payment for Forest Environmental Services in Cambodia

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Abstract The study conducted a feasibility study on payment for forest environmental services in Cambodia, combining quantitative and qualitative data sources. Literature reviews and interviews were conducted to determine conditions required for payment for ecosystem service success, and focus groups discussion and household surveys were employed to capture villagers' behaviors in forest management and payment for forest environmental services. Results showed that conditions required for PES success include clear defined ecosystem services; flexible contracts and payments; transaction costs that do not exceed potential benefits: a reliance on multiple sources of revenue delivering sufficient and sustainable money; a close monitoring of compliance, land use change and provision of ecosystem services; and the flexibility to improve effectiveness and efficiency and adapt to changing condition. PES-like failures in Cambodia resulted from inequity of benefit-sharing, a lack of management committee capacity to monitor participants and carry out punitive measures, and the poor quality of services and communication skills. Factors contributing to PES-like successes were simple and local program organization, low administrative costs, transparency of benefit-sharing to services providers, and active participation from villagers in complying with the regulations of programs. PFES could be integrated into the REDD finance mechanism. As a result, the case study in Chambok exemplified a community-based forest suitable for PFES implementation and possibly a joint program. This would lead to improved livelihood conditions of local communities through forest cover protection, and increase the awareness of downstream and upstream villagers in ensuring the sustainable provision of services.

Keywords Cambodia, feasibility, forest management, livelihood improvement, PES

INTRODUCTION

Commercial logging, shift cultivation, wood harvesting for woodfuel and charcoal production, and habitat destruction by local villagers and in-migrants are the major driver to deforestation and forest degradation, and great threat to biodiversity. Government policies or incentives for forest management are urgently needed to secure sustainable use of forest resources and improve local livelihoods. In light of the failure of the command and control approach, payment for forest environmental services (PFES) may be considered a potential solution. There are number of successful studies on payment for environmental services (PES) from both other countries and Cambodia. In Costa Rica, environmental services (ES) is being bought through biodiversity conservation, carbon sequestration, watershed protection, landscape beauty and bundled services (Alcamo et al., 2008). The payment was made to water services at about (USD 40-43/ha/yr), biodiversity (grant from CBD, UNFCCC, Global Environmental Facility, CI and other bodies), Carbon sequestration (based on Certifiable Tradable Offset, CDM) and landscape (paid by hotel, tourists and other users) (Pagiola, 2008). In Cambodia, there are three types of PES-Like ranging from community based ecotourism, agri-environmental, and bird-nest protection programs.

OBJECTIVES

The overall objective of this research is to conduct feasibility study on payment for forest environmental services in Cambodia. The specific objectives of the study are to: (i) determine condition required for PES successes, (ii) identify factors contributed to PES-Like successes and failure in Cambodia, and (iii) conduct a feasibility study of PFES in Chambok area in Kampong Speu Province, Cambodia.

METHODOLOGY

The research combined quantitative and qualitative data sources from two different levels, national and local. For national level, existing literatures was reviewed for accessing of what condition to securely require PES success with the experiences from other countries. Key Informant Interview (KII) were also conducted for capturing their perception associated with the failures or successes of PES-Like schemes in Cambodia in relation to the factors driving forces to deforestation and degradation of forests. Six KIIs, who had experiences and worked closely related to PES in Cambodia, were planned for interview (two from government and four from NGOs); but only five KIIs were available for interview (one NGO was unavailable.) A fixed set of questionnaires were used and responses were recorded and later transcribed. Chambok area located in Phnom Srouch District, Kampong Speu Provinces was selected as the case study for identifying the perceptions and behaviours of villagers associated with forest management. In this regards, for local level, two small samples of twenties households were surveyed – one sample from an upstream community and one from downstream community. All households sampled make daily use of forest. The household selection was systematically selected (one household surveyed, four households missed, next household surveyed) and interviewed face to face with the complete set of questionnaires. With the purpose to capture more in-depth information, FGDs were conducted to recover the root causes of deforestation and understand the livelihood option and forest management behaviours of villagers. Two FGDs (one at the upstream and one at the downstream community) were interviewed in order to evaluate the understanding of these two stakeholder groups. Questionnaires, recorders, and flip chart were used during discussion.

RESULTS AND DISCUSSION

Motivation of PES in Cambodia

From the forest resource point of view, PES appears necessary to ensure the forest coverage. The constitution and forest law pave ways to sustainable use of forest while protected area policy warranty the minimum forest coverage area. Forests in Cambodia fall under the general jurisdiction of the MAFF, with the FA charged as the responsible Government Authority (Forestry Law 2002, Article 3), the MoE is responsible for Protected Areas (PA), and the FiA is responsible for flooded forest and mangrove areas (Fisheries Law 2006, Article 3). Cambodian Law is hierarchical, therefore all subsidiary regulations should respect to differentiation of responsibilities laid out in the Forestry Law and other Laws. Even the law on PES is not legally regulated, the Royal Government of Cambodia (RGC) has set numbers of policies to ensure forest coverage and supported PES through REDD mechanism. For instance, the REDD project in Oddar Meanchey, under the collaboration between the FA and PACT Cambodia through thirteen CF, used PES as a mechanism for the distribution of benefits from the sale of carbon credits on the voluntary market (Chervier et al., 2010). About 7.1 million metric tons of carbon dioxides could be sequestered for over thirty years, while around 1,000 participated household were benefited (Poffenberger et al., 2008). The RGC has set policies to reform land administration and natural forest resource management. The reform has focused on strengthening environmental protection and natural forest resources through enhancing sustainable forest management, the use of forests to improve the livelihoods of people, demarcated PA system to protect biodiversity and endangered species, and

decentralized forest management through community forestry program. The use and extraction of forest products are carefully regulated through the delivery of permits, regulation of guideline for management, prohibited activities, and endorsement. The RGC also encouraged manmade plantation substitute for national forest demands, and created public awareness to replant and used community plantations for firewood and charcoal needs.

Condition Require PES Success

PES schemes tend to perform successful under the conditions clear and mutual agreement linking land uses to the provision of ES (Mayrand and Paquin, 2004); clearly defined ecosystem services (Wunder et al., 2008); flexible contracts (Sommerville et al., 2009) and payments and transaction costs do not exceed potential benefits; a reliance on multiple sources of revenues delivering sufficient and sustainable money; a close monitoring of compliance, land use change and provision of ecosystem services (Arriagada and Perrings, 2009; Landell-Mills and Porras, 2002); and the flexibility to improve effectiveness and efficiency and adapt to changing conditions (Sommerville et al., 2009). The conditions require PES successes are also depended on the successful completion of a series of steps (Fig 1). First, potential service providers must enroll in the program, and secondly service providers must comply with the terms of their contract. Third, compliance must result in a change in land use compared to what would have happened without the program (Wunder et al., 2008). The development framework for successfully ES market consist of six steps (Landell-Mills and Porras, 2002): (1) Identify benefits provided by a specific service and by determination of forestry activities that deliver this services, (2) Undertake a feasibility study, (3) Establish willingness to pay, (4) Formalize property rights, (5) Establish payment mechanism and supporting institutions, and (6) Undertake pilot activities and feedback to market design. In this regards, the needs to provide training or capacity building to PES providers are required in order to increase the attraction from buyers and their willingness to pay for ecosystem services.

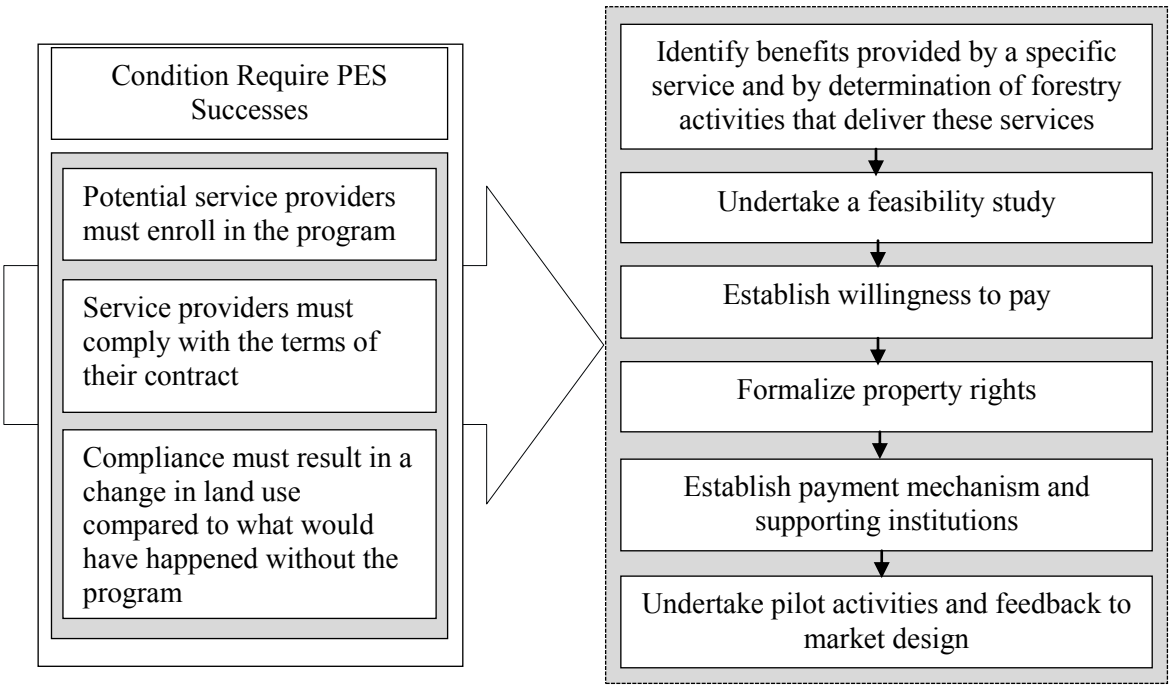

Fig. 1 Conditions require PES successes and framework for successful ES market development

The failures and successes of PES-Like in Cambodia

The opportunities costs for livelihood improvement between replanting and conserving forest to gain benefits and choosing alternative option by converting land-use to grow other crops is the first and foremost factors contribute to PES-Like failure in Cambodia. The benefits generated from replanting and conserving forests take long time while the villagers would prefer direct benefits in short time to support their daily consumption. Consequently, they would either not willing to participate in the program or participate but not respect to the rules and regulation. The second failure is induced by inequity of benefits sharing and lacking of capacity of the management committees to implement, monitor, and punish to those break the rules and regulations. Third is derived from poor quality of provided services and communication skills in particular with English language communication. When the service buyers need guides or rangers, the local villagers cannot afford to do so and even few can but not well. These would discourage service buyers to come, and then automatically fail the program through income generation shortage. Factors contributing to PES-like successes are simple and local program organization, low administrative costs, transparency of benefit-sharing to services providers, and active participation from villagers in complying with the regulations of programs. The simple locally arrangement with less administrative costs can disburse higher payments to individual villagers who provide the services. The transparency in benefits sharing to all beneficiaries can avoid jealousness and conflicts through operational management. The levels of participation and involvement from villagers and their commitments to comply with the rules and regulations are significant to retain program successes. Herein, the needs to build local support and understanding of rules and regulation for protected forests and land-use plans are also required to ensure the sustainable operation. The rules and regulation should notably be developed locally and approved by the entire village and the monitoring and evaluation should also be done continuously to check with the current statuses and the changes of existing resources.

Case study of PFES in Chambok area

The Chambok area is located on the outskirts of the Kirirom National Park about 110 kilometers west of Phnom Penh Capital via national road No. 4 in Chambok Commune, Phnom Srouch District, Kampong Speu Province. Chambok Commune administers nine villages with a total population of 546 families. The Chambok CBE is initially developed in 2001 by a local environment organization Mlup Baitong, in cooperation with the MoE. Villagers in Chambok commune are farmers and around 94% of the populations are involved in forest resource extraction activities, including firewood and charcoal trading and collection of bamboo shoots, mushrooms, traditional medicine, and rattan. This unsustainable harvesting of forest products is leading to the rapid degradation of the forest resources both inside and outside the national park. The main challenges are generating additional incomes to support their livelihood. Based on the below quote from farmer, the forest resources in Chambok area are being threatened and urgently need management tool to address this problem.

I am a farmer, but my incomes cannot support my family a whole year. I have to log trees to get money.
I log the trees not because I don't know the values and advantages of forests,
but because I have no other income generating opportunities.

Villager in Chambok Village, Chambok Commune,
Phnom Srouch District, KampongSpeu Province (Interview on 19th May 2012)

PFES may be considered as the potential solution to overcome this problem and provide additional incomes to villagers. Chambok area is appeared to be potential area for piloting program of PFES in Cambodia. First, the protected area of 1,260 hectare of forestland inside Chambok area can secure forest resources from illegal logging or invades from powerful outsiders. Moreover, inside the Chambok boundary, there are three CF and they have played important roles in forest

management. The CF enables villagers to understand clearly and recognize the benefit and importance of forest resources through closely involve them in forest resources management and protection. Second, the land uses of CF in Chambok area can potentially provide a variety of ES ranging from the regulation of hydrological flows, bird watching, waterfall beauty, and carbon sequestration potential from bamboo. The hydrological flows of waterfall in the upstream of Chambok generate clean drinking water to the downstream and are being bought by nine villages in Chambok Commune with an average expend USD 0.25 per month per household. Bird watching and waterfall beauty have considered as the most attractive ES to attract visitors to Chambok area. Third, the villagers are paid for providing forest conservation services if and only if they comply with the commonly-agreed conditions stipulated in contracts of the regulation on land-use plans, non-hunting and non-forest logging.

There is no single approach to require PES successes from theoretical and practical reviewing existing literatures. PES schemes are adapted to the very specific conditions under which they are established and to the specific characteristics of markets for different ES. The three program of PES-Like in Cambodia identified by (Clements et al., 2010) was successfully implemented based on its own specific characteristics of market for different ES and locations. However, mostly of them were heavily depended on funding project from donors. Can the program be sustained when the project was stopped funded? For sure, it could not be sustained without funds. So, the linkage of investors to invest in the program might be the best to sustain the program because their business operation are for making profits, and do so the program can get continuously support. Even the case study in Chambok shows the characteristics and ES trading inside Chambok area has complied with the criteria for implementing PFES, the knowledge and understanding on forest management of villagers are remained poor. The upstream villagers tend to easily change their behaviour through converting land-use for agriculture or encroaching forest lands for commercial and making woodfuel and charcoal. They are not critically enough to think in a longer time the negative consequences of doing so. The downstream villagers are still not aware that the services they used are being provided by upstream villagers, and its qualities could be changed in accordance to the land-use management behaviours of the upstream villagers. This means that the implementation program of PFES in context of Cambodia is not successful if the program depends on only downstream villagers to compensate to the upstream villagers.

CONCLUSION

The major driven of deforestation and forest degradation in Cambodia are caused by institutional fragmentation, limited institutional and individual capacities, unclear of tenure, limited livelihood options, and lack of law enforcement. These five factors have contributed to ineffective of sustainable forest management even policy related to land and natural resource management was reformed by the RGC. The successful experiences from previous PES-Like in Cambodia draw lessons for the future development of program on PFES. This is particularly based on the livelihood impacts of land use change activities and the challenges involving in transferring conditional payment across actors and scales. The diversification of revenues for villagers involved in PES schemes through the creation of new markets for environmental goods and services is the key for success of PFES implementation. In doing so, the villagers will actively involve in the program with respected to non-hunting rules and non-logging regulation and not to turn their land-use easily for other purposes. So, the future implementation of PFES should be jointly carried out with REDD program in order to extend financing from PFES. In this regards, Chambok area is one of the typical community forestry among the others that suitable for applying PFES and possibly joint program between PFES and REDD. The implementation of PFES program in Cambodia should be driven under the theme of improving livelihood of local communities through forest protection and enhancing forest covers in the protected area. The raising awareness for downstream villagers (the future buyers) and upstream villagers should be provided for ensuring the sustainable provision of services. The needs to support from NGOs as mediator in buying ES or/and linking the program to business and private enterprise is very importance to secure PFES successes.

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Research article

Women's Roles in Fisheries Governance in Ban Laem, Phetchaburi Province, Thailand

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Abstract In the past, men have been played key role in the way of life of small-scale fishers. Because of their physical condition is more proper than women. Therefore, the women are mainly participating in fish processing and marketing. At present, participation of women in fisheries industry has increased day by day, particularly as a labor force in fisheries production sector. In this study, women in Ban Panern, a fishing village in Laem Pak Bia sub-district, Ban Laem district, Phetchaburi province was selected to examine the women roles that contributing to fisheries governance. Using key informant interviews and participant observation was carried out from August to September 2011. The results showed that, the roles of women in this fishing village were more or less the same of women's role in the third world. These roles are classified into 3 categories, i.e., motherhood role, labor in production role and community management role. Most of them have been involved in all three categories particularly, contribution to the fishery management in their community. They have participated in many activities that relating to public utility development, they have established and conducted a fish central market in the village in order to solve the unfair price of aquatic animal problem of the fishers. These demonstrated that, women have a high potential in strengthen the capability of fishing community in fisheries governance. The success of fisheries governance will lead to better livelihood of fishing households and a sustainable of their fisheries.

Keywords woman's role, fisheries governance, fisheries management, community fish market

INTRODUCTION

For small-scale fisheries, man is major labor in this industry because of suitability in their physical condition (Arunpark, 1999). So that women have contributed to the processes after fishing work at the sea such as selling their products or fish processing. They had played important role in onshore activities. They undertook the administrative work of the fishing enterprise. In the past, most of people have had valued and expected in men should be more significant role such as leader, governor in society because men are physically stronger. Due to sex gender are defined through two factors including biological factor and social environmental as a psychological perspective. Biological factor concerns about the physical differences between male and female while social environmental is the factor to influent the appearances of sex (Jittayasothon, 2008).

As same as fisheries sector, men have been played important role in fishing at the sea for a long time while women have involved in activities after fishing including processing and selling. At the present day, women have played role in their community increasingly, especially the economical aspect. As the record of National Statistical Office, we found that 45% of Thai women

have been involved to contribute to the income of their households, communities and country (Piamsomboon, 2008). Studies on women in fisheries so far have been more or less focused on fish processing and preservation techniques and activities and socio-economic status of women. This study aimed to examine the woman roles involving fisheries governance aspect besides their contributions in fisheries economics section.

METHODOLOGY

Study area

In this study, Laem Pak Bia sub-district, Ban Laem District, Phetchaburi Province was chosen to investigate. Phetchaburi province is located in Western, Thailand at the northern end of the Malay Peninsula, with the East of Gulf of Thailand. There are four of the eight districts located along the coast that is why fisheries are economically important to the province. In 2010, fisheries provided over 25,000 tons of products or approximately THB 1.5 billion (USD 50 million) in value (Office of Phetchaburi Province). There are four villages in this sub-district including Ban Panern, Ban Donnai, Ban Donklang and Ban Donkadee (Fig. 1). Marine fishing is a major occupation in all of these villages. Ban Panern is the center for fishers due to be the place where landing, fish market and the crab bank project located.

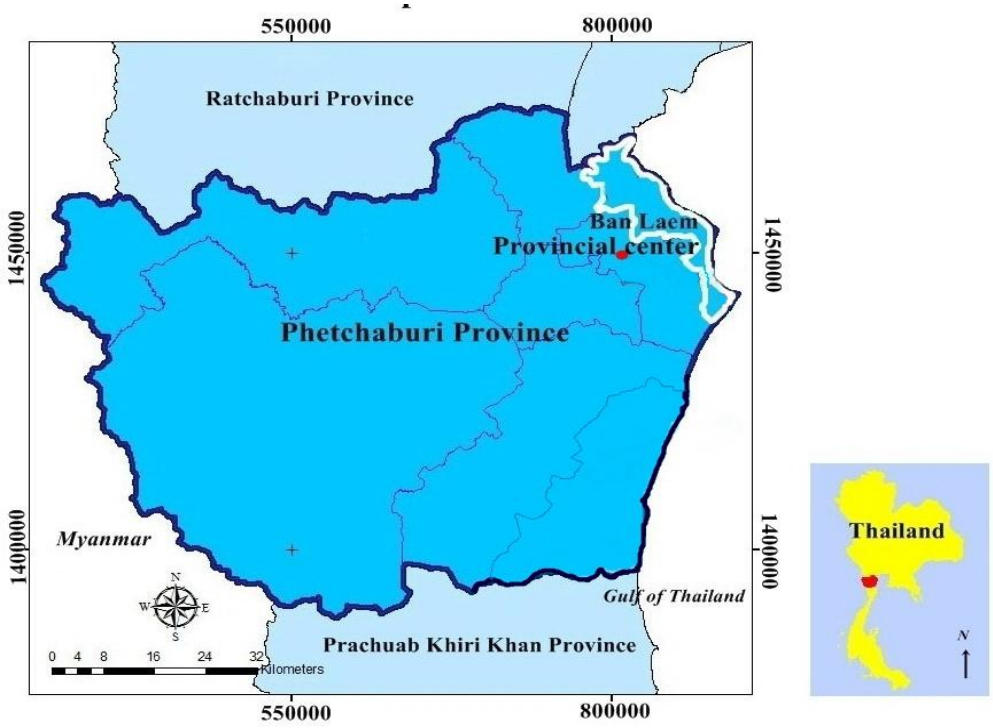

Fig. 1 Study area: Laem Pak Bia sub-district, Ban Laem district, Phetchaburi

Data collection

This study was conducted using a mixed method of literature review, key informant interviews (Table 1) and participant observation. A series of open-ended question was used in the key informant interviews. They consisted of questions related to the role of women to fisheries governance in the study area.

Table 1 List of key informants interviewed in this study

Category	Number of key informants	
	Male	Female
Fishers	2	2
Villagers who are not fishers	1	1
Housewives of fishers	-	2
Fish traders	-	1
Fisheries group leaders	2	2
Other group leaders	-	1
Governing officers	3	-
Total	**8**	**9**

RESULTS AND DISCUSSION

The natural system characteristic

Laem Pak Bia is one of the ten sub-district located in the southeast of Ban Laem district. This area consists largely of mud flats and sandy beaches, with some mangrove forests (Pollution Control Department, 2004) that serve as important habitats for juvenile fish and crabs and especially dwelling animals like clams (Aksornkoae, 2007). Numerous aquatic species were found, such as threadfin, longtail sard, sand whiting, mackerel, large-scale tongue sole, hard shell, blood cockle, razor clam, banana shrimp, blue swimming crab, mud crab and squid according to the Office of the Royal Development Project Board (1997). Dolphins and Bryde's whale could be found in the area as well. In addition, artificial reefs had been installed in this area to help increase fisheries productivity. There is also the waste water treatment system, which enhances the abundance of coastal fisheries resources, especially those in the benthic zone such as blood cockle and hard shell. These natural characteristics have contributed to fishing for a long time even though some situation happened such as mangrove forests were decreased during the aquaculture boom.

The socio-economic system characteristic

From the interviews and field observation, the study found that small-scale fishing was major occupation. The other occupations consist of salt-farmer, labor and merchant. Small-scale fishers in this area used multiple types of gear, targeting multispecies. The main type of gear were crab gill nets, fish gill nets, shrimp gill nets, octopus traps and collapsible crab traps. Large-scale fisheries also existed, to a lesser extent, using mackerel purse seine and squid nets. Most of this kind of fisheries hired foreign labor. Some women gather hard clam and blood cockle using small hand dredges and some go fishing with their husbands, in the case of small-scale fishers businesses. The majority of small-scale fishers are members of three fisheries groups; the crab bank project, the community fish marketing group and the community boat repair service. There was also a women's enterprise, which produced ceremonial flowers for funerals.

Women roles in fisheries governance

The study found that women in Laem Pak Bia sub-district, Ban Laem district, Phetchaburi province had collaborated to establish the group named "Woman development volunteer group" following the government's policy that desired to increase woman participation in their community. However, this group had not been in any action which relate to community development. Until the women in this sub-district, especially who were live in Ban Panern, had re-organized the group in order to encourage the alternative occupation for women through producing the local products or others for sell that mentioned earlier. Involving to fisheries, the some women in this community also had joined to community fish marketing community group under the leading from the mainstay fishermen.

As to consider following the woman role in the third world which were classified into 3 categories, i.e., motherhood role, labor in production role and community management role (Wangpittaya, 2008 *cited* Kittasanka, 2002), we found that the roles of women in this fishing area were more or less the same. Most of them had been involved in all three categories particularly, contribution to the fisheries governance in their community, namely:

1) Motherhood role: this role was considered as the biological aspect that women had pregnant, taking care for well-being of their children and family members.

2) Labor in production role: this role was concerned working in the way to earn their remuneration either as a monetary compensation or non-monetary compensation. For example, gathering blood cockle and hard shell using small hand dredges at the coastal area near their houses after housework finished which had been doing for a long time until the present day. Some women were hired from the large-scale fishers to sew the crab net, fish net and shrimp net. They would buy the nets, then sewn those together to the larger pieces and bounded the piece of lead at the lower net. Many women were pleased to do this work since they could do it at home that also could take care of their children as well. Moreover, these women had collaborated as a group to produce the flowers for funeral ceremony under the Laem Pak Bia Sub-district Administration Organization supporting through allocated the experts for demonstrating and training. On the other hand, some women had work without returns in cash due to they had been as a labor in fishing with their husbands.

Most of the women in Laem Pak Bia sub-district had been played both motherhood role and labor in production role because these roles were main role of general women in fishery families as Nasae *et al*. (2002) examined the role of women in fishing community and found that women had play important in motherhood role and labor in production role such as going out to fish at the sea and selling their catches. In the past, fishing has long been considered a male occupation and women were thought to be involved only in post-harvest activities. However, there is growing recognition of women's contribution in capture fisheries in all activities (Kusakabe, 2003).

3) Community management role: it involved to women's participation in planning and decision making to improve the public utilities such as canal dredging, health and education development activities *etc*. Some of women in this sub-district also had played this role in term of collaborating in those activities i.e., cleaning public areas, participation in planning and decision-making on monthly meeting through proposed their opinions in order to find the approach to solve the problem in the villages. The obviously community management role of these women were organizing community fish marketing group. Actually, this group was originated by a group of fishermen who wanted to solve the unfair price of fish. Cost in fishing, especially fuel, was high. Their income was not covering their cost which induced them to take a loan from the middleman or fish market owner with the condition to sell the catches to creditor only. These fishermen realized that creating of the community fish marketing group could solve unfair price problem.

The community fish marketing group had administrated as cooperative with all of women proceeding. The group was initiated through informal meeting of some fishermen to discussion about unfair price problem with staff from the Thai Sea Watch Associate, a non-governmental organization (NGO) based in southern Thailand. The Thai Sea Watch Associate organized a visit for a small group of women to observe an ongoing fish marketing group in Pattalung province. Upon their return, the chair-person and the committee for this group were appointed. The community fish marketing group started to proceed with private funding of the group members in 2009. Fishers who want to sell their catches must be a member to the group. Besides the fair price of fish, they would receive dividend as well. Until now, this community fish marketing group has been carried out continuously and smoothly. It demonstrated that women have potential to governing the fisheries. As Limanon (1999) examined the women have an incentive to manage that showed their high enough potential to develop of the community.

For resource conservation concerns, from the study of The Environmental Fund of United Nation in 2008 (Wangpittaya, 2008) found that women had more awareness in the problem and tend to do actions to protect the degradation of the environment and natural resource than men. Also women often had better vision to how environment decaying. As though women in this study area always had participated with community in resource conservation through attended a monthly

meeting in the their villages and encouraged her husband to donate gravid female crab to crab bank project, including to join with the government campaign involving mangrove planting.

CONCLUSION

The results in this study showed that women in Laem Pak Bia sub-district had played important roles in terms of taking care well-being of their households and economics aspect as were recognized that women's economic contribution in fisheries is divided into two categories namely; the recognized work in fishing or processing through formal employment and the unrecognized work by fishers' wives, mothers who are in charge of different tasks within the family business (Frangoudes, 2011). Moreover, women in this community had played important role to community management in term of participation and collaboration in community development activities and also organized the group "Community Fish Marketing" that contributed to solve the unfair price of fish problem. Growing in woman's role on management aspect is important part to drive to fisheries governing achieved.

Fig. 2 The community fish marketing group operation area (The Thai Sea Watch Associate, 2011)

Fig. 3 The community fish marketing group members were classifying the fish

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Research article

Acute Toxicity of Textile Metal Complex Dark Green Azo Acid Dye (53) and Anionic Surfactant Oil on Nile Tilapia, *Oreochromis niloticus* and Bioconcentration of Total Chromium and Copper in Gill Tissues

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Abstract The experiment was conducted on Nile tilapia *Oreochromis niloticus* to determine the lethal concentration of textile metal complex dark green azo acid dye in the presence and absence of anionic surfactant oil during an exposure period of 96 hr. The design consisted of four treatments: control, metal complex dark green azo dye, a mixture of metal complex dark green azo acid dye with anionic surfactant oil and anionic surfactant oil; and each was applied at four concentrations (1%, 5%, 10% and 15% of stock solution). Data were analyzed by using Probit analysis. The 96 hr LC_{50} was 7.25% (95% CL = 6.55-7.96) of stock solution for metal complex dark green azo acid dye, 2.85% (95% CL 2.14-3.90) for the mixture of metal complex dark green azo acid dye with anionic surfactant oil and 7.27% (95% CL = 6.45-8.43) stock anionic surfactant oil. Total chromium concentration in the gill filaments of tilapia increased linearly with dye concentration and was independent of anionic surfactant oil. Contrary, total copper concentration in the gill tissue increased linearly in with the present of anionic surfactant oil. The lethal effect observed during the trial was dose depended, the mortality rate increased with the increase in treatments concentration.

Keywords mortality rate, LC_{50}, dyebath, surfactant oil, aquatic animal

INTRODUCTION

Synthetic dyes and anionic surfactant oil contain substances potentially harmful to the environment and are important in the production of textiles (Christie, 2007). In Northeast of Thailand, there is evidence that the silk textile community discharge dye effluent without treatment, raising environmental concern (Thailand Institute of Science and Technological Research, 2004). One of the synthetic dye that cause environmental concern is a metal complex azo acid dye, commonly called azo dye and classified as acid dye that contain the potentially toxic metals copper, cobalt, aluminum, iron, nickel and chromium (Clark, 2011; Jo et al., 2010; Christie 2001; Hunger, 2003). These metals bind with dye ligands such as sodium sulfate and provide colour stability and firm attachment to the yarn (Clark, 2011; Adachi, 2004; Christie, 2001).

Metal complex azo acid dyes are commonly used to dye silk and cotton yarn and are applied in neutral to weakly acidic baths (Christie, 2007). Surfactant oil is used for removing the sericin or silk gum, improves the sheen, colour and texture of the silk yarn. In addition, it is also used for

colour uniform and accelerates dye firm attachment to the yarn (Chen et al., 2010). Azo dyes have been associated with skin and eye irritations in humans and carcinogenic, mutagenic and lethal effects in other organisms (Christie, 2007; Bae et al., 2006; Popma and Masser, 1999). Potentially harmful effect of metals, particularly the heavy metals, copper, and chromium, to aquatic organisms include impaired growth, reproduction (Segner, 2011; Hayat, 2007) and in extreme cause death (Eisler, 1998). This is explicit in water quality criteria (Eneji, 2007).

Acute lethal concentrations vary among metals, their chemical forms and other ambient factors. In Thailand, maximum allowable concentrations of total copper (0.1 mg/L) and chromium (0.05 mg/L) for surface water (Pollution Control Department Ministry of Natural Resources and Environment, 2007). Some metals rarely, if ever, occur in water at lethal concentrations but even at lower concentrations may, impose chronic deleterious effects particularly in the presence of other substances (Eisler, 1998).

Nile tilapia, *Oreochromis niloticus*, is a freshwater and tolerant to harsh condition such as water relatively low in dissolved oxygen and high pH (Delong et al., 2009 and Popma and Masser, 1999).

The objective of this study was to determine the lethal concentration (96 hr LC_{50}) of textile metal complex dark green azo acid dye (53), surfactant oil and a mixture of dye with surfactant oil to *Oreochromis niloticus* and bioconcentration of total chromium and copper from the dye and anionic surfactant oil in gill tissues.

MATERIALS AND METHODS

Nile tilapia (n= 630) of 6.4 to 7.9 g live weight and 7.5 to 8.3 cm total length, were obtained from Khon Kaen University, fisheries farm. Fish were held in static dechlorinated water (50 L) that was continuously aerated for 7 days. Ambient conditions included Dissolved oxygen (≥4 mg/l), water temperature (26.5 - 28.1 °C), pH (6.5 - 7.2), Total dissolved solids (89.4 mg/l) and salinity (0.09 ppt), Alkalinity (47 mg/l), NH_3 (0.01 mg/l) and NH_4^+ (0.74) (APHA, 2005). Fish were fed ad libitum daily with commercial feed (Gorbest Cooperation Co. Company). No mortality was recorded during this period. After 7 days, fish were exposed to experimental concentrations of surfactant oil, dark green azo acid dye and a mixture of dark green azo acid dye with surfactant oil.

Metal complex dark green azo acid dye (53) and surfactant oil used in this study were obtained from Chonnabot dye shop, (Khon Kaen Province, Thailand) and analyzed (EPA, 1996) for total copper (1.09 mg/l) and chromium (5314 mg/l). Water solubility of the azo dye was 64.3 g/l were analyzed using methods EN 14362-1 described in (British Standard, 2003). Surfactant oil analyzed for total copper was present at 0.002 mg/l and total chromium was present at 0.049 mg/l, sulfate (as SO_4^{2-}) was present at 553.82 mg/l, alkyl benzene sulfonate was present at 3.57 mg/l (APHA, 2005) and solubility of surfactant oil in water was > 1 kg/l.

A completely randomized design was applied and consisted of 3 replicates of each of 13 treatments. Fish were held in 39 plastic tanks, each containing 50 L of dechlorinated and continuously aerated water. Stocking density was 15 fish / tank (5 kg/m^3).

The stock solution was prepared according to dyebath procedure used by community members in Chonabot. Dye stock solution contained 65 g of metal complex dark green azo acid dye, dissolved in 1 L of hot water and boiled for 5 minutes, allowed to cool at a room temperature and the solution was made up to 30 L with tap water. Stock solution with mixture contained 65 g of metal complex dark green azo acid dye with 20 ml of anionic surfactant oil, while a stock solution for anionic surfactant oil only contained 20 ml of oil. Experimental concentrations for each of the three stock solutions (100%) were 15, 10, 5 and 1%. Control treatment was normal tape water.

Fish were not fed for 4 days during the trial. Number of dead fish were recorded and removed at 24, 48, 72 and 96 hr. The 96 hr LC_{50} values were determined by Probit analysis (SPSS software 11.5 program).

Total chromium and copper were measured in gill tissue of fish from each of the three treatments and four concentrations (1%, 5%, 10% and 15% of stock solution) and of control treatment. After 96 hrs two fish that did not survived and two live fish that survived were collected

from each tank of three replicates, from which gill tissue were collected, from six of the 45 dead or live fish. Ground gill tissues of 1 g was digested in a solution of 7 ml nitric acid (65%) and 1 ml hydrogen peroxide (30%), heated at 105 °C in a microwave, cooled, filtered (Whatman no. 1) and analyzed for total copper and chromium using Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES) (EPA, 1996; AOAC, 2005). Total chromium and copper bioaconcentration factor was calculated according to the standard method of fish recommended by OECD (1996) and USEPA, (1996): Bioconcentration factor (BCF) is a ratio of concentration of metal in fish gills (μg/kg) / Concentration of metal in water (μg/l).

The LC_{50} value was determined by probit analysis method by SPSS software 14 program (Finnery, 1971). The percentages for corrected fish mortality rate were determined by Abbot's formula (Abbott, 1925). Corrected mortality (%) = (X – Y / X) 100; Where, X = percentages of live fish in control sample and Y = percentages of live fish in treatment sample.

RESULTS AND DISCUSSION

Lethal toxicity

No mortalities occurred in any of the control tanks over the 96 hr experimental period. Exposure to metal complex dark green azo acid dye in the absence of anionic surfactant oil produced no mortality rate at a concentration of 1 % and 36% fish mortality rate at 5 % concentration, while the mortality rate was 91% at 10% concentration and 96% at 15% concentration within 96 hr. The fish mortality rate of fish exposed to a mixture of metal complex dark green dye with anionic surfactant oil was 2% at 1% concentration and 100% mortality rate occurred at 5, 10 and 15 % concentrations in 24 hr. No fish mortality rate occurred at the lowest concentration of 1% anionic surfactant oil only, 2% mortality rate occurred at 5% concentration and 100% fish mortality occurred at 10 and 15 % concentrations within 24 hr. Clearly, the lethal effects of all treatments of metal complex dark green azo acid dye, the mixture of metal complex dark green azo acid dye with anionic surfactant oil and anionic surfactant oil reflected a concentration rather than exposure time effect.

The 96 hr LC_{50} for dye without anionic surfactant oil was 4.71 g metal complex dark green azo acid dye per liter, equivalent to 7.25% (95% CL = 6.56 - 7.96) of that in the stock solution. The lethal toxicity of the mixture of dye and surfactant oil was calculated to contain 1.85 g metal complex dark green azo acid dye per liter, equivalent to 2.85 % (95% CL = 2.14 - 3.90) of that in the stock solution, much less than that in the absence of oil. The mixture of oil and dye was calculated to contain 0.57 ml/l of oil at the lethal toxicity, equivalent to 2.85% of that in the stock solution. The LC_{50} of anionic surfactant oil alone was 1.45 ml/l, equivalent to 7.27 % (95% CL = 6.45-8.43) of that in the stock solution and well above that calculated at the lethal toxicity of the oil and dye mixture.

Acute toxicity of metal complex dark green azo acid dye increased in the presence of surfactant oil. It is interesting that for each of metal complex dark green azo acid dye and anionic surfactant oil the lethal toxicities represented almost equal proportions of their respective stock solutions. This indicates the mixture to be proportionately more toxic than the additive toxicities of metal complex dark green azo acid dye and surfactant oil.

Water quality parameters in experimental tanks were in the range recommended for tilapia survival rate and production (DeLong et al. 2009), where, dissolved oxygen 4.6±0.4 mg/l - 6.7±0.3 mg/l, pH 6.7 ± 0.1 – 7.1 ± 0.2, temperature 27.8±0.3 ºC – 28. 3 ± 0.0 ºC. Total dissolved solids were the higher when dye was present and increased directly with concentration from 95 ± 0.3 to 165 ± 0.2 mg/l and similar pattern occurred with the concentrations of mixture of metal complex dark green azo acid dye with anionic surfactant oil were 96 ± 0.2 to 161 ± 0.2 mg/l. The anionic surfactant oil was expected to increases overall solubility of dye in solution. However, total dissolved solids increased with dye concentration with values being almost identical to those for mixtures of metal complex dark green azo acid dye and anionic surfactant oil at comparable concentrations. Total dissolved solids associated with surfactant oil alone increased slightly from 91 ±0.1 to 96 ± 2.4 mg/l with ambient concentration. This implies the toxic qualities of metal

complex dark green azo acid dye may not relate to its solubility but instead to total concentration.

Bioaccumulation of total chromium and copper in *O. niloticus* gills in 96 hr exposure periods

Table 1 Mean total chromium and copper concentration in pooled gill samples
from O. niloticus after 96 hr exposure to concentrations of metal complex dark green azo acid dye (D), a mixture of metal complex dark green azo acid dye with anionic surfactant oil (SOD) and anionic surfactant oil (SO)

	Total Cr concentration (μg/kg)					
Concentration	**D**		**SOD**		**SO**	
	Cr	**Cu**	**Cr**	**Cu**	**Cr**	**Cu**
0	72	900	72	900	72	900
1%	354	809	300	862	191	704
5%	508	760	530	953	116	771
10%	534	713	600	999	92	1109
15%	757	994	750	1222	125	1042

Total chromium concentration in gill tissue increased with dye concentration between 0 and 15 % of stock solution in each of the two treatments containing metal complex dark green azo acid dye (Table 1). Some chromium was present in the gills of fish from untreated water (controls). Total chromium concentration in gill tissue correlated significantly ($P < 0.05$) with dye concentration when exposed only to metal complex dark green azo acid dye ($n = 5$, $r = 0.91$) and equally on exposure to a mixture of metal complex dye and oil ($n = 5$, $r = 0.93$). These relationships are described by the regressions: Metal complex dark green azo acid dye only: Cr (μg/kg) = 36.49 stock solution (% Total) + 218.79 ($R = 0.82$). The mixture of metal complex dark green azo acid dye with anionic surfactant oil: Cr (μg/kg) = 39.28 stock solution (% Total) + 206.87 ($R = 0.86$). Thus, from the equations the rate of total chromium concentration is similar for the two treatments, on the contrary, in gill tissue exposed to anionic surfactant oil only ($n = 5$, $r = 0.11$) did not correlated significantly ($P > 0.05$) as expressed by regressions as Cr (μg/kg) = -0.81 stock solution (% Total) + 124.24 ($R = 0.01$).

Total copper was detected in the gills of fish exposed to normal condition. Total copper accumulation in gill tissue correlated significantly ($P < 0.05$) in fish gills exposed to a mixture of metal complex dye with anionic surfactant oil ($n = 5$, $r = 0.94$) and those exposed to anionic surfactant oil ($n = 5$, $r = 0.74$). These relationships are described by the regressions, where, a mixture of metal complex dark green azo acid dye with anionic surfactant oil: Cu (μg/kg) = 21.06 stock solution (% Total) + 856.65 ($R = 0.88$) and the anionic surfactant oil: Cu (μg/kg) = 20.26 stock solution (% Total) + 779.57 ($R = 0.55$). Therefore, from the equations the rate of total copper accumulation is similar to the treatment with a present of anionic surfactant oil. However, in gill tissue exposed only to metal complex dark green azo acid dye ($n = 5$, $r = 0.26$) did not correlated significantly ($P > 0.05$) as described by regressions, where, Cu (μg/kg) = 4.77 stock solution (% Total) + 805.61 ($R = 0.07$).

Total copper and chromium concentrated in *O.niloticus* gills exposed to normal condition (Table 1) might come from the water as copper was detected at 0.4 μg/l which is below recommended 50 μg/l for water consumption and 20 μg/l for aquatic animal production while chromium was below detection level 50 μg/l recommended for water consumption in Thailand (Pollution Control Department, 2007). Generally metal occurs in naturally water from the weathering of rocks, industrial discharges and leakage (Eneji, 2011; Yilmaz et al. 2011). Fish uptake the metal across body surfaces and thin epithelium of gill filaments become concentrated in gills as their outer layer is negatively charged and attracts positively charged metallic ions (Heath, 1995). Prior to the experiment fish were fed with commercial feed. Normally fish are supplemented with copper and chromium in feed because essential elements for animal health at the low concentration (Abdel-Baki et al., 2011; Watanabe, 1997) but can inflict deleterious effects at higher

concentrations (Eisler, 1998).

Chromium concentration in the gill filaments of tilapia increased linearly with dye concentration and was independent of anionic surfactant oil. Total chromium bioconcentration factor (BCF) in a present of metal complex dark green dye concentrations was 6.71 (1%), 2.03 (5%), 1.22 (10%), 1.54 (15%) and in control was zero. Similar pattern occurred in fish exposed to mixture of metal complex dark green dye with anionic surfactant oil concentrations were 5.18 (1%), 2.43 (5%), 1.55 (10%), 1.41 (15%), and in the present of anionic surfactant was zero. Hence, the concentration of total chromium was higher in fish gills than in water. Despite similar chromium accumulations in the gills at comparable dye concentrations the presence of anionic surfactant oil increased lethality in a synergistic manner. It is interesting that Hickey (1990) found some heavy metal toxic in the presence of SO_4^{2-}. As noted earlier the surfactant oil used in this study contained a considerable amount of SO_4^{2-} which could relate to synergistic response of the mixture of metal complex dark green azo acid dye and surfactant oil.

Contrary, total copper concentration in the gill tissue increased linearly in the present of anionic surfactant oil and also increased lethality in a synergistic manner. In addition, the BCF for total copper in the present of mixture of metal complex dark green dye with anionic surfactant oil concentration at were 57 (15%), 38 (10%), 20 (5%) in a control and at 1% concentration was zero, in the present of anionic surfactant oil was 329 (15%), 38 (10%) but in control, 5%, and 1% concentration was zero, while in a present of metal complex dark green dye at 15% was 147 and at 10%, 5%, 1% and 0% stock solution was zero. Similarly, the concentration of copper was higher in fish gills than in water.

Generally, it is found that surfactant action activates Cu permeability through Na^+ uptake pathway in gills (Grosell et al., 2007). In a present study lethal toxicity was supported by Sharma et al. (2009) finding that methyl red composed of Cd, Cu, Ni less toxic to fish. Sharma et al. (2006) also found that the LC_{50} of methyl red dye to be 27.2 mg/l to *Poecilia reticulate*. Fish mortality rate occurred during the exposure of period was not based only on copper and chromium but from the interaction of chemical used during the study.

In Thailand the estimated contaminant from dyeing 1 kg silk yarn in Chonnabot community was COD was 6315 mg, SS 121 470 mg and DSS 248 180 mg (Thailand Institute of Science and Technological Research, 2004). The study indicated that waste from silk dyeing are harmful and can accumulate in tissues to *O. niloticus*, the accumulated chemical can be transferred to human through fish consumption that potentially caused negative effect on human health in a long run.

CONCLUSION

The metal complex azo acid dye and surfactant oil used by the community for silk dyeing are harmful to *O. niloticus*. Therefore, results of the present study strongly suggest that unmanaged discharge of effluent from silk dyeing, especially those that employ azo dyes is likely to impose harmful effects to aquatic ecosystems and recommend the wastewater to be handle with care. Therefore, this warrants further research.

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Research article

Understanding Socio-Ecological Production Landscapes in the Context of Cambodia

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Abstract In Cambodia, a large portion of the population engages in primary sector production such as agriculture, forestry and fishery, and the people's livelihoods are directly dependent upon the availability of natural resources. The natural environment, however, has been undergoing severe deterioration for several decades. Similar challenges are being faced in many different countries and it is therefore of global importance to explore ways to conserve the environment while allowing people's livelihoods to develop. In this context, the term socio-ecological production landscapes and seascapes (SEPLS) was coined to refer to areas shaped by production activities characterised by harmonious human-nature interactions. The aim of this study is to deepen the understanding of Cambodian production landscapes using three different perspectives drawing on the SEPLS concept: structure, benefits and changes. Based on a literature review, key characteristics of SEPLS were identified including their mosaic structure and the diverse benefits they provide. Further study is needed to understand the significance of SEPLS in Cambodia in terms of the biodiversity and environmental benefits they provide.

Keywords socio-ecological production landscapes and seascapes, mosaic structure, ecosystem services, land use

INTRODUCTION

In Cambodia, people's livelihoods are highly dependent upon access to natural resources from agricultural lands, forests, rivers and lakes. One of the most important industries is agriculture, in which 66% of the total population was engaged in 2010 (FAO, 2010a). The natural environment, however, was severely damaged during the country's civil war and the following years of political instability, while today the environment is strained by the impacts of modernization and globalization. In many parts of the world, recognition of the extent of damage humans have caused to the environment, and the fact that this degradation is now threatening people's lives, has created an understanding that it is essential to explore ways to conserve the environment while allowing people's livelihoods to develop. The underlying conceptualization of this is to consider humans as a part of nature, and that they have adapted to local ecosystems by carefully modifying their features, and derive their livelihoods from these close interactions with their surroundings. Such interactions have often maintained biodiversity while providing humans with a continuous supply of goods and services. Such conceptualizations have begun to be applied in the research, policies and practices dealing with environmental conservation and livelihood development, while leading to the launching of new efforts such as the Satoyama Initiative, a global initiative aiming to conserve and revitalize landscapes and seascapes created through long-term human-nature interactions around production activities such as agriculture, forestry and fishery (UNU-IAS, n.d.).

This paper aims to understand Cambodian production landscapes by using the concept of socio-ecological production landscapes and seascapes (SEPLS), a term coined to refer to the target areas of the Satoyama Initiative. After introducing the Japanese *satoyama* landscape, from which the Initiative and the term SEPLS originated, the characteristics of the Cambodian landscapes are identified based on several points included in the description of SEPLS.

SEPLS IN JAPAN: SATOYAMA LANDSCAPES

Historically, a large portion of Japanese landscapes has been under the influence of human activities, such as agriculture, forestry, and fishery. Adaptation to the surrounding environment through such activities has created unique areas called *satoyama* landscapes, which are characterized by mosaics of paddy fields, upland fields, woodlands, grasslands, ponds and canals, and settlements. Careful management of land uses based on knowledge accumulated across generations, has made it possible for *satoyama* landscapes to continuously provide humans with food, fuel and building materials, while nurturing unique cultures. Management of woodland areas includes collecting fallen leaves and grasses, which are used to maintain soil fertility in combination with manure. A continuous supply of firewood was secured by coppicing of trees where farmers left stumps to sprout again after cutting. After several years of management, including removal of unnecessary branches and weeds, farmers could cut trees again for use as firewood (Takeuchi et al., 2003).

Regular management practices in *satoyama* landscapes, including cutting of trees and mowing, maintain favourable habitats for some plant and animal species, which have adapted to the natural conditions created by such practices. Furthermore, the mosaic landscape has contributed to high levels of biodiversity by including different land uses, each with its own associated vegetation, constituting habitats for a wide variety of animals. This structure is also important for species such as dragonflies and frogs, which need different habitat types during their life stages and for obtaining different resources (Katoh et al., 2009).

Recognition of the importance of *satoyama* landscapes and recent negative trends such as degradation due to urbanization, agricultural modernization and an aging population led to the Japan Satoyama Satoumi Assessment (JSSA), which is a thorough study of ecosystem services and their contribution to human well-being in Japan that included the involvement of more than 200 stakeholders. The assessment recognized the benefits of the landscapes' multifaceted nature, which produces a bundle of ecosystem services for human well-being (JSSA, 2010). It also recognized the global importance of the concept underlying *satoyama* landscapes, which assumes a mutually beneficial relationship between humans and nature, if properly maintained. Based on the JSSA results, the term "socio-ecological production landscapes and seascapes (SEPLS)" has been applied by the Satoyama Initiative to refer to its target areas around the world. Drawing on the similar JSSA definition of *satoyama* landscapes, the Initiative describes SEPLS as "dynamic mosaics of habitats and land uses that have been shaped by the interactions between people and nature in ways that maintain biodiversity and provide humans with goods and services needed for their well-being in a sustainable way". Attempts have been made to understand various production landscapes and seascapes using the SEPLS concept (Gu and Subramanian, 2012; Ichikawa, 2012). Further study, however, is needed to understand the characteristics and significance of SEPLS across various parts of the world. Drawing on the above description of SEPLS, the following sections describe Cambodian production landscapes along three points: structure, benefits and changes.

SEPLS IN THE CONTEXT OF CAMBODIA

Structure: "dynamic mosaics of habitats and land uses"

Situated in the tropics, Cambodia experiences a monsoonal climate with distinct wet and dry seasons. A dry period starts in late November and lasts until April. Cambodia's topography is characterized by extensive areas of extremely flat floodplains containing the Tonle Sap Lake and river complex at the country's centre, and hills in the south-western and north-eastern regions. The Mekong River flows from Laos in the north and at Phnom Penh it converges with the Tonle Sap River, which flows from the Tonle Sap Lake. The Mekong River's water level fluctuates by approximately 9 metres each year. During the wet season, some water flows back up the Tonle Sap River into the Tonle Sap Lake, which can experience a tenfold increase in area to approximately 25,000 km^2 between May and November (Nesbitt, 1997).

A large portion of Cambodians live in lowland areas where their livelihoods have depended on paddy rice cultivation for at least the last 2,000 years (McKenney and Tola, 2002). Other elements of Cambodia's lowland landscape include forests, settlements, rivers, ponds and lakes. One distinct land use is called *chamkar*, a term which encompasses all agricultural land uses except paddy rice cultivation, basically areas where farmers grow cereals, vegetables, etc. (Chann et al., 2011). The distribution of different land uses is directly affected by topography and associated water regimes. For example, in one village in Kampong Cham Province, large areas are dominated by rice fields, which are located in the lower part of the land, while vegetable fields are located in elevated land surrounded by the paddy field (Siriwattananon et al., 2010).

There are several different types of paddy rice field, which vary according to different growing conditions determined by micro-topography and water regime. Accordingly, each type of field utilizes the appropriate variety of rice, which differs in terms of physiological properties such as photo-sensitivity and elongation ability (Javier, 1997). Deep water (floating) rice is primarily grown in areas that are submerged at a depth of 50-300cm for at least one month during the rice growing period. In areas where the water is less than 50cm deep, field levels are further subdivided into three different water levels, in which farmers grow rice varieties that mature at different times. This allows farmers to reduce the risk of a total crop failure due to droughts and floods, optimize labour resources, and increase food security (McKenney and Tola, 2002).

Forest vegetation also occurs in a mosaic pattern consisting of plants of different height and species, affected by seasonal water-level changes and different recovery stages from human disturbance. For example, in the area near the Tonle Sap Lake in Siem Reap Province, forests which are along the shoreline during the dry season and flooded during the wet season, experience fewer disturbances by humans and have a relatively closed canopy of tall trees. Vegetation in inland areas, however, is constantly disturbed due to the collection of firewood, and is characterized by low, sparse cover (Araki, 2007).

Studies on land use and livelihoods in hilly areas in Cambodia shows that landscapes consist of evergreen forests, semi-evergreen forests, deciduous forests, shrubs and grasslands, *chamkar* areas, homegarden, cash crop fields, and settlements (e.g., Fox and Vogler, 2005). Wetland rice is less common in hilly areas (Evans et al., 2003), where *chamkar* has been practiced for centuries in a form of shifting cultivation by ethnic minorities such as the Phnong in Ratanakiri and Mondulkiri Provinces. Shifting cultivation refers to the intermixing of upland rice and other crops (e.g., soybean, sesame, banana, maize, sugarcane, and potato), and plots are usually cultivated for about three years, after which they are left fallow. Old fallow is cleared by burning the trees and grasses (McKenney et al., 2004). Soil can rest and regenerate during the fallow period, and the ashes from the burning provide nutrients to the soil (Andersen et al., 2007). Through this sort of mechanism, shifting cultivation creates unique landscapes composed of a dynamic patchwork of crop fields, fallows of various ages, secondary forest and remnants of the original vegetation.

Benefits: "maintain biodiversity and provide humans with goods and services for well-being"

A set of different land uses provides a diverse range of goods, which are important for subsistence and generating cash income. Historically, rice has been a staple food for Cambodians, and the country depends on rice as a strategic commodity for income growth, poverty reduction, and national and household food security (Yu and Diao, 2011). Paddy fields can also provide a variety of aquatic animals such as fish, crabs, shrimps, edible insects, and frogs, which are sources of animal protein for people, although their importance has not fully recognized in policies and research in Cambodia (Gregory and Guttman, 1997). More than one million Cambodians depend on inland fisheries to support their livelihoods. The Great Lake and Tonle Sap River area produces roughly 50-60% of Cambodia's inland commercial fish catch (McKenney and Tola, 2002).

Forests provide villagers with a variety of goods known as non-timber forest products (NTFPs), such as firewood, food, and medicinal plants. An assessment conducted in four provinces found that medium-income households obtain 30% (345 USD/year) of their total livelihood value from NTFPs, while low-income households obtain 42% (280 USD/Year) (Hansen and Top, 2006). Resin is recognized as one of the most important NTFPs in Cambodia, and is used domestically for

sealing/waterproofing boats and is exported for these uses as well as for manufacturing paint and varnish. It is tapped mainly from evergreen tree species such as *Dipterocarpus alatus* without substantially damaging the trees, which allows for continuous yields across decades (Tola and McKenney, 2003). Income generated from resin collection is estimated at 338 USD/year per family in Ratanakiri Province, helping to cover the cost of buying rice, which runs short several months after harvest (Evans et al., 2003). Firewood continues to be an important cooking fuel and is used by 94% of the population in rural areas (NIS, 2009). Medicinal plants are also important, especially in remote and poor areas, because they help to significantly reduce healthcare costs (Laval et al., 2011). Kimhy et al. (1998) insist on the significance of different "forests", including trees around the households and paddy fields. The woodlands that are left around the dwellings can provide villagers with a variety of food and materials, and contain various species such as neem, coconut, palm, mango and bamboo (Siriwattananon et al., 2010). Trees that are scattered along dikes of rice fields and uncultivated land are not only used for grazing, but also for improving soil fertility and providing shade to people and animals (Kimhy et al., 1998).

Although the environmental benefits of the ecosystems in production landscapes have been discussed in general, aside from the case of carbon sequestration, these issues have not been extensively studied within the Cambodian context. For example, the function of forests in maintaining water quality and flood mitigation is generally known, but the clear and quantifiable link has not been made between deforestation and the change in water quality or flow (Hansen and Top, 2006). Regarding carbon sequestration, the Cambodian Government has made a strong commitment to managing the forests under the anticipated new international climate change agreement on the REDD+ mechanism. Estimation of potential carbon credits generated from improved forest management is underway for existing forest (e.g., Ty et al., 2011).

Changes: "shaped by the interactions between people and nature"

It is believed that population densities were generally low in pre-colonial Cambodia and there was abundant food coming from rice fields, forests and lakes. The farmers, however, also demonstrated innovation by adopting rice production technologies to the poor soils, erratic rainfall, and complex hydrology of Cambodia (Helmers, 2007). This included, for example, subdividing the fields into levels for growing different crops and varieties as mentioned above. The history of water management in Cambodia goes back to before the Angkor period. Modern irrigation systems that were first developed from 1950-1953 by the French include the Colmatage canal system, which uses dykes and sluices to provide controlled annual inundation, allowing a fertile layer of silt to settle on the fields (FAO, 2010b).

The land and people of Cambodia were seriously impacted by the agricultural policy of the Khmer Rouge regime (1975-1979), which aimed to increase rice production by expanding the area under rice cultivation into cleared forest lands and developing irrigation systems, many of which have been assessed today as useless or unusable. The rural labour force was reorganized to conduct collective agriculture, supplemented by people from urban areas, who were forcibly relocated (Helmers, 2007). During the 1980s, in accordance with socialist development policy, agricultural land was collectivized and became state property. Solidarity groups known as *krom samakki*, consisting of 20-25 families, were organized and constituted the basic unit of production, although in practice collectivization was not vigorously pursued. In 1989, the State of Cambodia instituted a new policy favouring a transition to a market economy. Private land tenure was established and most communal lands were broken up and allocated to families (Helmers, 2007).

Fox and Vogler (2005) report that shifting cultivation has maintained a relatively stable percentage of forest cover in Southeast Asia's montane mainland during the latter half of the 20th century. However, there have recently been major shifts in land use in hilly areas. In the 1990s, governmental forest management in Cambodia only focused on timber production from high value forests managed by private companies under large-scale forest concessions (Hansen and Top, 2006). Concession forestry has, however, experienced implementation challenges, resulting in high levels of illegal logging and corresponding degradation of forest resources. It has also caused conflicts over rights with local communities who traditionally used to collect natural resources

from the concession forests (McKenney et al., 2004). In 1969, forests represented more than 74% of the land area, which had changed marginally to 73% by 1990, but decreased drastically to 65% in 2000 and is currently at 57% (Broadhead and Izquierdo, 2010). The advent of cash crop farming by indigenous communities, which has largely emerged since 1993 when the government opened up for international investment, has increased the rate of conversion from shifting agriculture to cash crops. Other factors impacting land use change include the development of road networks, population increase, inadequate enforcement of land laws, together with the dissolution of the communal system, which has led farmers to sell land to outsiders. In Ratanakiri Province, planting of cashew by indigenous communities has increased in part to claim the land, and in part to increase cash income (Ironside, 2010).

In lowland areas, forests in floodplains are decreasing due to exploitation for firewood and conversion to agricultural land (McKenney and Tola, 2002). In areas under rice cultivation, farmers have begun to plant faster-maturing varieties in many areas previously cultivated for late-maturing varieties, because the shorter the time that crops spend in the field, the lower the risk of crop failure (McKenney and Tola, 2002).

CONCLUSION

It was found that the SEPLS concept was applicable in the Cambodian context. Mosaic landscapes were clearly identified in both the lowland and hilly regions. Although lowland areas are characterized by extensive flat areas dominated by paddy field, micro-topography and different water regimes have created heterogeneity, which determines land use distribution, and has created diverse rice growing conditions where appropriate rice varieties are grown. In hilly areas, temporality has also created mosaic patterns of land uses due to shifting cultivation. Recent land use changes seem to be creating more uniform landscapes, a common trend across many other countries. A range of different land uses provides a variety of goods that are crucially important to local people as they directly contribute to their subsistence and cash income. Forests, in particular, produce a variety of resources that supplement diets, provide traditional medicines and can be used to construct shelter. Rice paddies not only produce rice, but also fish and other protein-rich aquatic animals. Regarding the environmental benefits, the author could not find enough evidence that these issues have been studied in-depth within the Cambodian context. While local farmers have historically adapted and developed practices that are applicable to their unique local conditions, the past several decades have seen frequent and dramatic changes in political and economic regimes, which have affected production activities and land uses.

Although Cambodia has recently been experiencing a decline in natural resources, a relatively large area of forests remains compared with the other Southeast Asian countries, and many people depend directly on natural resources for their livelihood. Many studies exist on the various material benefits that SEPLS provide, but in order to explore the paths towards sustainability, it is also important to understand the landscapes holistically, including environmental functions as well as the social and cultural benefits they provide.

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Research article

Assessment of Local Livelihood of Forest-Dependent Communities in Cambodia

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Abstract Forests are important sources of ecosystem goods and services to billion people around the world. As tropical forests are gradually disappearing while population is increasing, the livelihood of forest-dependent communities is being threatened. Cambodia's forest subsector contributed 8.4% to agricultural GDP over the period from 1999 to 2008. Although this figure provides an indication of the importance of forest resources in national development, assessment of the detailed contribution of forest goods and services at the local level is urgently needed so that appropriate intervention and development policies could be introduced. The objectives of this study are to better understand the contribution of forest resources to household livelihood by classifying such contribution to four main forest and non-forest products and to propose a policy recommendation. Questionnaires were developed to interview 600 households in three communes, namely the Takaen, Sangke Satob, and Tumring in Kampot, Kampong Spoeu, and Kampong Thom provinces, respectively. The interviews were performed quarterly throughout the year so as to increase the accuracy of the responses from the households. Our analysis found that forest income contributed 76,892±8,160 riel or 13% of the total household incomes in the first quarter. However, forest income increased to 24% (142,645±17,540 riel), 33% (146,422±16,967 riel), and 31% (122,512±9,693 Riel) in the second, third and fourth quarters, respectively. Other sources of household incomes were agriculture, outside forest, and other income, all together, contributing 87%, 76%, 67% and 69% of the total incomes in the first, second, third, and fourth quarters, respectively. These findings suggest that forest resources are important sources for the survival of forest-dependent communities. It is recommended that incorporating forest resources into the development planning with the active participation of local people could contribute to sustainable development while protecting the forests.

Keywords forest income, dependence, livelihood, ecosystem

INTRODUCTION

Forests are important sources of ecosystem goods and services to billion people around the world. As tropical forests are gradually disappearing while population is increasing, the livelihood of forest-dependent communities is being threatened. Foreseeing the urgent needs for forest protection, roles of tropical forests for climate change mitigation and sustainable development have been increasingly recognized by world leaders through their efforts to reducing deforestation and forest degradation. The Copenhagen Accord of the United Nations Framework Convention on Climate Change (UNFCCC) recognized a new scheme, the REDD+ or reducing emissions from deforestation and forest degradation, conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks as cost-effective measures for climate change mitigation and sustainable development (Sasaki and Yoshimoto, 2010). At the 16th and 17th Conference of the Parties to the UNFCCC, biodiversity and socio-economic safeguards was one of

the major components of the REDD+ negotiations because it is an important component for achieving the REDD+ objectives.

Extreme weather such as storm, floods, and droughts resulted from the impact of climate change has resulted in decline of agricultural productivities compared to that in the normal year (Heng and Pech, 2009). The decline in agricultural productivities causes more poverty to local people. In order to cope with these natural disasters as well as to improve their livelihood, local people adopted many strategies including increasing their activities for collecting various products from forests and nearby. Activities of local people for collecting various products occur differently throughout the year. For instance, in Kupe, the South of Cameroon, local people increased their activities for collecting forest and non-forest products during the rainy season after crop cultivation because there was little work in the farms except waiting for food crops to mature (Ngane et al., 2012). The situation is not different from local people in Cambodia where about 85% of the total population are farmers. Forests are also important for local livelihood in Cambodia. In addition to providing services, forests are important sources of food, medicine, construction material, and firewood for household consumptions and income generation in Cambodia. Cambodia's forest subsector contributed 8.4% to agricultural GDP over the period from 1999 to 2008 (Theng and Koy, 2011). Unfortunately, rapid deforestation and forest degradation driven by rapid economic development and growing population have put pressure on the resource availability and therefore assessment of the dependency of local people and how their activities for collecting forest and non-forest products is required so that appropriate policy interventions could be adopted.

OBJECTIVES

The objectives of this study are to assess the contribution of forest resources to household livelihood and seasonal variation of this contribution throughout the year.

METHODOLOGIES

Study site: In order to reduce biases in our assessment, study sites were carefully selected taking into account such factors as deforestation rate, threats from industrial cultivation, and distance of local people to the forests. The three selected communes are Takaen, Tumring, and Sangke Satonin Kampot, Kampong Thom, and Kampong Spoeu provinces, respectively (Fig. 1). It was observed that a large rubber plantation has emerged in the site selected in Kampong Thom province while no rubber plantations were found during field survey in other two sites. Based on forest cover changes published by Forestry Administration (FA, 2011), annual deforestation rates in the three provinces from 2006 to 2010 were 0.8%, 0.7%, and 0.3%, respectively. In Tumring commune, some of forest area was converted into rubber plantation.

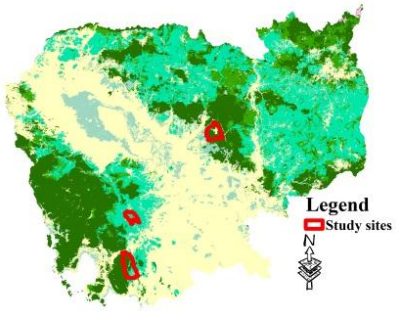

Fig. 1 Map showing study sites

Household selection: National Institute of Statistic (NIS) defined household as a group of persons who commonly live together and take their meals from a commons kitchen unless the exigencies of work prevented any of them from doing so (NIS, 2007). This definition was taken into account for

identifying household for this study. Two hundred households were selected in each study site; and so a total of 600 households were interviewed for this study.

To facilitate the selection of household for survey in each study site, complete lists of household were obtained from village chief prior to carrying out the field work. The first household was randomly drawn from the list while the subsequent households were selected based on the interval of each site.

Interview justification and data collection: Local people in Takaen, Tumring, and Sangke Satob communes have practiced many livelihood activities throughout the year. These activities change seasonally as shown in Fig. 2.

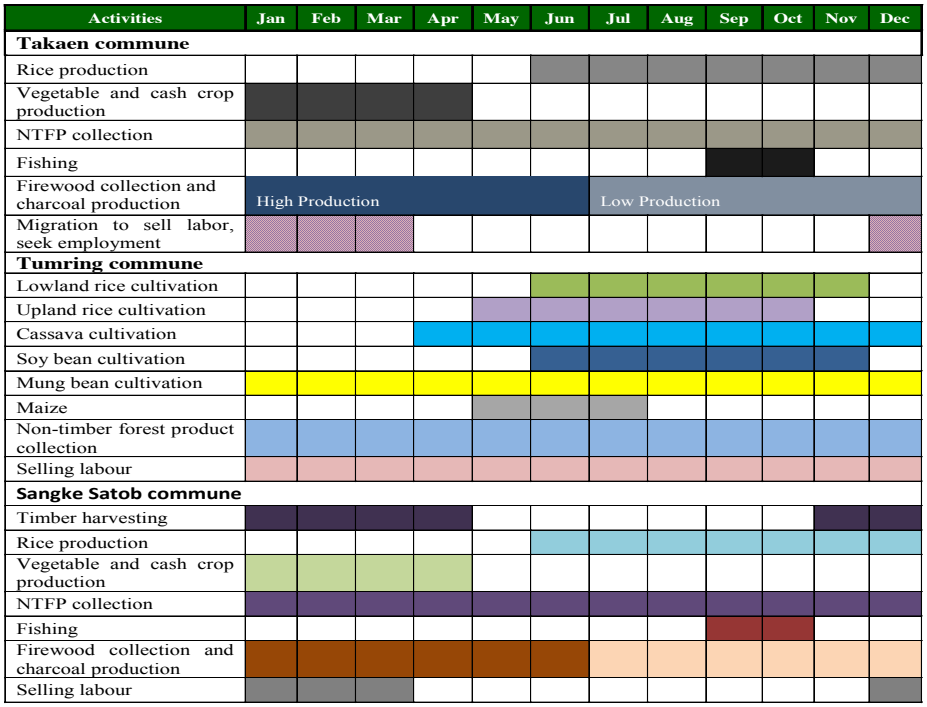

Fig. 2 Livelihood activities in Takaen, Tumring, and SangkeSatob Communes

As livelihood activities change seasonally, data on household income should be collected seasonally. For this study, questionnaire was carefully designed to collect seasonal data of the same household every 3 months (quarterly based interview). Therefore, better data and information were collected. Questionnaire was designed to focus on income generation from four main income sources: i) forest (direct, derived, service payment from forest income); ii) agriculture (crop and livestock); iii) outside forest (fish, aquaculture, and other from non-forest area); and iv) other (wage, own business, and other income). The first data collection was done in January for income generation between October and December, the second, third and fourth interviews were done in late April for income generation from January to March, July for income generation from April to June), and October for income generation from July to September, respectively.

Data analysis: Although 600 households were interviewed in the first round, not all households were interviewed at the subsequent rounds because some of them were not available during the field surveys. For this analysis, only data of households that were interviewed at all four rounds were analyzed. So far, 518 households or 86.3% were interviewed in all quarters.

RESULTS AND DISCUSSION

Income generation in each study site: The study found that the annual average household income

ranges from 1,797,000±44,000 Riel[†] (± refers to standard error) in Takaen commune of Kampot province to 2,564,000±102,000 Riel in Tumring commune of Kampong Thom province (Fig. 3). The contribution from forest to annual average household income ranges from 303,000±22,000 Riel or about 12% of the total income sources in Tumring commune of Kampong Thom Province to 618,000±18,000 Riel or about 34% in Sangke Satob of Kampong Spoeu province. These results confirm that forest resources play a very important role for the rural livelihood in Cambodia.

Specifically, forest was the main income source (618,000±18,000 Riel or about34% of the annual average income) followed by Agriculture (455,000±15,000 Riel or 25%), outside forest (138,000±4,000 Riel accounted to 8%), and other (613,000±23,000 Riel or about 34%), in Sangke Satob commune of Kampong Spoeu province (Fig. 3). In Takaen commune of Kampot province, agriculture was the main income source which contributed to 605,000±20,000 Riel (accounting for 34%) and followed by forest which contributed 512,000± Riel (29% of the annual average income), other (467,000±21,000 Riel or 26%), and income from outside forest (212,000±8,000 Riel or 12%). Figure 3 also shows that the contribution from other to income source in Tumring commune was very high (1,370,000±54,000Riel or about 53% of the annual average income) and followed by agriculture (845,000±73,000 Riel or 33% of the annual average income), forest (303,000±22,000 Riel or 12%), and income from outside forest (45,000±2,000 Riel or 2%). This reflected that the rural activities have a very strong link with natural resources, especially forest. The results of this study showed that the contribution from forest to annual household income was lower than previous study which reported that the annual contribution from forest to household income ranged from 668,000 Riel to 1,696,000 Riel (Kasper and Neth, 2006). This difference could be due to the different methods used in our respective studies or forest condition. Development activities would also have contributed to the variation of forest contribution to household livelihood. However, the results of this study shows higher income contribution from forest than that in Malvi where contribution from forest to poor household was only 15% of the total income (Camanga et al., 2008) and quite similar with Ethiopia where income from forest contributed to 34% of household per capita income (Yemiru et al., 2010). Thus, incorporating forest resources into development planning with the active participation of local people could contribute to sustainable development while protecting the forest.

Seasonal variation in income share: In order to understand the seasonal activities of the local people, we further analyzed the data by four quarters as shown in Fig. 4. It is noted that income was peak in the first quarter in which the average total income was 608,000 Riel and started to decrease in the subsequent quarter while the lowest income was in 4th quarter (392,000 Riel).The analysis found that forest income contributed 76,892±8,160 riel or 13% of the total household incomes in the first quarter. However, forest income increased to 24% (142,645±17,540 riel), 33% (146,422±16,967 riel), and 31% (122,512±9,693 Riel) in the second, third and fourth quarters, respectively. Other sources of household incomes were agriculture, outside forest, and other incomes, all together, contributing to 87%, 76%, 67% and 69% of the total incomes in the first, second, third, and fourth quarters, respectively.

High income in the first and second quarters was contributed mainly by agriculture while contribution from forest plays as a second main income source in quarter 3 and 4 which contributed to 33% and 31%, respectively, to the average total household income. This is because first and second quarter covered the period from October to March which was in harvesting period of agriculture crops while the third and fourth quarter people started investing on planting their crop, especially rice in order to enable them to harvest it within the first and second quarters.

As mentioned previously, the annual average total income in Takaen commune was 1,796,000 Riel in which income share from agriculture was the first main income. The share of agriculture changed seasonally being the first main income source in the first quarter but started to decline the subsequent quarters this is because the first quarter is the rice harvesting period between October to December (Fig. 5). Households sold their agricultural products immediately after harvesting.

[†] USD1 = 4,000 Riel

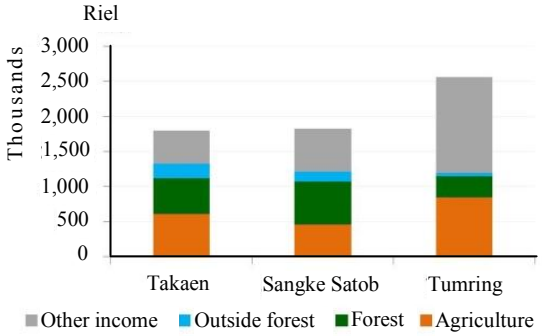

Fig. 3 Annual household income by source in each study site

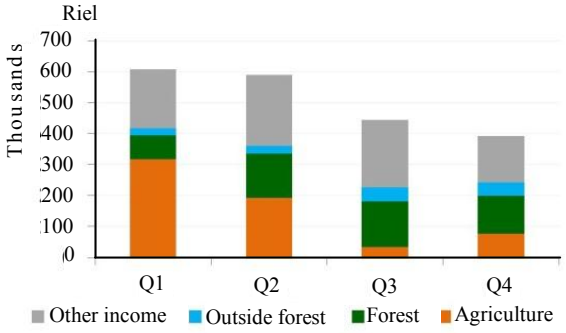

Fig. 4 Average total income by quarter

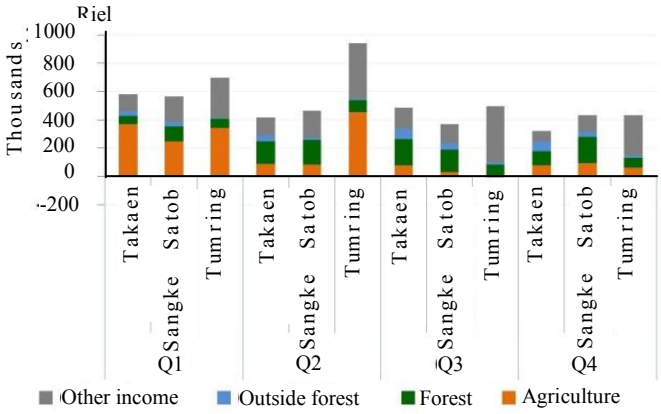

Fig. 5 Seasonal variation in income share in each study site

The average share of forest resources to household income in Takaen commune in the first quarter was only 59,831±9,634 Riel (10%) 39% (160,000±35,283 Riel), 39% (187,000±40,023 Riel), and 33% (105,000±11,857 Riel) in the second, third, and fourth quarter, respectively.

Similar to that in Takaen's site, the income share from agriculture in Sangke Satob's site was highest in the first quarter, about 247,000±17,938 Riel (44% of average quarter income) and continued to decline, while the income share from forest increased from 104,000±14,657 Riel (19%) in the first quarter to 171,000±21,800 Riel (37%), 158,000±19,389 Riel (43%) and 181,000±19,470 Riel (43%) in the second, third, and fourth quarters, respectively, (Fig. 5).

Unlike the two sites mentioned above, livelihood in Tumring's site showed more livelihood activities. In addition to producing rice, other cash crops such as maize, cassava, and mung bean were also produced at this site. The annual average total income in this site is much higher than that in the previous sites which was estimated at 2,564,000±102,000 Riel. The share of agricultural income was high in the first and second quarters amounting to 342,124±93,174 Riel (49% of average quarter income) and 451,211±166,026 Riel (48%), respectively. However, this income share show negative (loss) during the third quarter; this is because of natural calamity occurred at this site. Natural calamity disturbed the agricultural production on this site. It is noted that the share from other income source in this study site was very high in almost all quarter if compared with incomes in other two sites. More specifically, the share from other income sources was the first main income source in the third and fourth quarters, respectively accounting for 82% (402,330±74,275 Riel) and 66% (285,825±39,810 Riel) of the total quarters' income.

Our results suggest that collection of forest products varied seasonally across all study sites. These variations were driven by time availability of household and natural resource condition. These findings are similar to that reported by Neang (2009) who found that the quantity of resin flow of individual tree depended on tree location and seasonality. Seasonal variation from forest

contribution to household income found in this study is also the same with Ethiopia and Africa (Yemiru et al., 2010; Timko et al., 2010)

CONCLUSION

Forests have played important roles in local livelihood. Income from forest resource ranges from 12% to 34% of the total incomes depending on forest locations and seasonality. Income from agricultural sources is higher compared to any other sources. However, such income would decline if forests around the agricultural lands are cleared or degraded because forests regulate hydrological cycle and climate for agricultural cultivation. Our findings suggest that forest resources are important sources for the survival of forest-dependent communities. It is recommended that incorporating forest resources into the development planning with the active participation of local people could contribute to sustainable development while protecting the forests. Furthermore as household activities are influenced by the resources availability and people tend to focus on rice cultivation, creating more income generation opportunities for local people after rice cultivation could discourage them from entering forests to collect various products, and therefore deforestation and forest degradation could be reduced.

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Research article

Using Chicken Manure in Vermicompost to Manage Different Agro-Industrial Wastes

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Abstract The agro-industrial waste has been increasing every year. Without proper management, it would cause problems to soil as well as water and air pollution to the environment. Thus, the objective of this study was to investigate the use of chicken manure in vermicompost of agro-industrial waste. The vermicompost experiment was conducted by using different agro-industrial wastes (cassava pulp, cassava peel, eucalyptus peel and oil palm) and different rates of chicken manure (2.5%, 5%, 10%, 15%, 20%, and 25%). The qualities of each mixture and vermicompost in different treatments before and after 30 days were analyzed. Earthworms (*Eudrilus eugeniae*) could survive 100% in the vermicompost of chicken manure at the rate of 2.5 - 25% in cassava pulp, cassava peel and eucalyptus peel treatments, but could not survive in the oil palm treatment. After 30 days, the growth of earthworms in the vermicompost treatments with cassava pulp, eucalyptus peel, cassava peel with chicken manure were increased at 134%, 188% and 167%, respectively. Therefore, chicken manure can be used to increase the growth of earthworms in vermicompost using industrial wastes (cassava peel, cassava pulp, and eucalyptus peel) to produce biofertiliser and reduce environmental pollution problem.

Keywords chicken manure, earthworm, vermicompost

INTRODUCTION

The economy of Thailand is greatly expanding nowadays at the expense of natural resources. An Agro industry, in particular, has consumed raw materials from those resources for production. With industrial processes, there are byproducts of colossal wastes that pollute soil, water, and air. Moreover, the large amounts of agro-industrial wastes produced bring about impact on our environment and nature. Without proper management or the wastes are too great a quantity to handle, the environment problems will be increasing. Furthermore, chicken manure is a cause of environmental impact that highly pollutes the soil, water and air (Tacon, 1991). The problem doubles during the rainy season when floodwater leaches the wastes to soil down into canals or rivers. This affects every life that lives in soil and water. One way to manage organic wastes is using earthworms to handle industrial wastes (Iwai et al., 2011; TonsCho, 2010).

Using earthworms does not cost a lot of money for waste treatment and does not disturb nearby communities because manure from sludge waste can produce good vermicompost and earthworms transform the sludge to a good fertilizer (Suthar, 2007). Vermitechnology is a type of compost production from earthworm activities and the product is vermicompost, a solid that

includes vermicast and worm casting, decomposed organic fossil, and vermin-juice which is liquid from the earthworm and the fermentation process. Liquid is used in the production and liquid from the fermentation process is used to make manure (Iwai et al., 2011).

Chicken manure is an agro-waste that is filled with essential minerals which are important for plant growth (Garner, 1966; Edwards, 1988). When chicken manure is mixed with organic materials from many agro-industrial factories, vermicompost is the outcome. Vermicompost speeds up the growth rate of earthworms. Hence, we were interested to study the use of chicken manure in vermicompost production to manage agro-industrial wastes.

OBJECTIVE

This study was aimed at investigating the use of chicken manure in vermicompost to manage different agro-industrial wastes.

MATERIAL AND METHODS

Chicken manure makes good nutrient for earthworms that in turn increase the rate of compost production. Our study comprised 4 trials of chicken manure blending: 1) with cassava pulp, 2) with cassava peel, 3) with eucalyptus peel, and 4) with oil palm.

Each agro-industrial waste was mixed with sandy soil (Yasotorn soil) by using 70:30 ratio and the mixture blended with chicken manure at the rates of 0, 2.5, 5, 10, 15, 20 and 25% by weight. The earthworm used in this trail was *Eudrillus eugeniae s*pecies; its common name is African Night Crawler.

The experimental materials, namely, chicken manure, cassava peel, cassava pulp, eucalyptus peel and sandy soil were dried indoor for specific ratios of weight. Earthworms were selected based on similar size and explicit maturity based on Clitellum (System of propagation species). The moisture content of materials for feeding earthworms was maintained at 50% throughout the study.

Data was collected by recording the rates of survival of earthworms and their weights before and after the experiments.

Table 1 Chemical characteristics of agro-industrial degradation (chicken manure, cassava pulp, cassava peel, eucalyptus peel and oil palm)

Chemical characteristics	Natural Organic Adsorbents				
	cassava pulp	cassava peel	eucalyptus peel	oil palm	chicken manure
Hydrogen ions (pH)	4.95	5.45	7.47	5.32	8.80
Electric conductivity (EC)	0.67	1.25	0.34	5.92	6.20
Organic matter (OM %)	89.57	58.00	38.96	78.11	24.50
Total nitrogen (% N)	0.24	0.49	0.25	0.92	1.50
Available phosphorus (% P)	0.02	0.05	0.08	0.41	5.10
Extractable potassium (% K)	0.36	0.51	0.18	1.23	2.40
C/N ratio	220.87	69.05	89.64	45.03	9:1

RESULTS AND DISCUSSION

The survival rates of earthworms when using chicken manure blended with agro-industrial wastes

The usage of cassava pulp blended with chicken manure: Earthworms could survive 100% in various ratios of blending cassava pulp with chicken manure (0, 2.5, 5, 10, 15, 20, and 25% by weight). However, the usage of chicken manure at the highest rate of 25% blended with cassava pulp did not affect the rate of the survival of earthworms after 30 days. This suggests that application of chicken manure at an optimum rate could increase reproductivity of earthworms. Nevertheless, over-dose rate use of chicken manure could decrease earthworm growth. This

resulted from high EC or salinity which was not suitable for earthworm living. Our result was consistent to the report of the Department of Public Work, Los Angeles County (2002) which stated that in environment with high organic matter content, growth rate of juvenile *L. rubellus* was better than *E. eugeniae*.

The usage of eucalyptus peel blended with chicken manure: Earthworms could survive 100% in various ratios of blending eucalyptus peel with chicken manure (0, 2.5, 5, 10, 15, 20, and 25% by weight). Similarly, the usage of chicken manure at the highest rate of 25% blended with eucalyptus peel did not affect the rate of the survival of earthworms after 30 days (Mertus, 1993). Earthworms are very sensitive to pH or H^+ changes. Normally, earthworms can exist in environment that has pH ranging from 4.2 - 8. However, pH 7 is the most suitable for earthworms (Edwards and Bohlen, 1996).

The usage of cassava peel blended with chicken manure: Earthworms could survive 100% in various ratios of blending cassava peel with chicken manure (0, 2.5, 5, 10, 15, 20, and 25% by weight). It was shown that the usage of chicken manure at the highest rate of 25% blended with cassava peel did not affect the rate of the survival of earthworms after 30 days. This can be explained by higher electrical conductivity (EC) or salinity of the compost (Edwards and Bohlen, 1996). In addition, raw materials used in this study mainly contained organic nitrogenous compounds that can be easily decomposed, which resulted in releasing large amount of NH_4^+ contributing to rapid pH increase that influenced earthworm existence.

The usage of oil palm blended with chicken manure: Earthworms could not survive in various ratios of blending oil palm with chicken manure (0, 2.5, 5, 10, 15, 20, and 25% by weight). Although it did not have chicken manure (0%), the result showed that the oil palm blended with earthworm feed and chicken manure could not make the earthworms survive even for a short time of just 1 week. This can be explained by higher electrical conductivity (EC) or salinity of the compost (Edwards and Bohlen, 1996). In addition, raw materials used in this study contained mainly organic nitrogenous compounds that can be easily decomposed, which resulted in releasing large amount of NH_4^+ that contributes to rapid pH increase influencing earthworm existence. (Mertus, 1993).

The growth of earthworm when using chicken manure blended with agro-industrial wastes

The usage of cassava pulp blended with chicken manure: The blending of cassava pulp with chicken manure at 5% rate resulted in increased weight of earthworms (2.32 g). The highest weight of earthworms at 134% was changed from when earthworms were fed 1 month ago. They became heavier than at the blending rates of 0, 2.5, 10, 15, 20, and 25%, or an increase of 22, 85, 105, 50, 35.4 and 11.8%, respectively (Fig. 1 and Fig. 2). Edwards and Lofty (1972) found that organic matter content was a crucial factor affecting earthworm weight. In this study, cattle manure vs. other materials added with P, K, Na, and Mg were compared for vermiculturing. It was found that weight of earthworms cultured in cattle manure increased more than 75%.

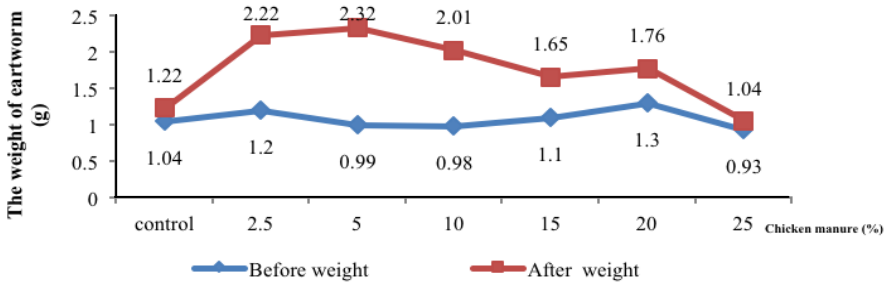

Fig. 1 The weight of earthworms (g) while using of the cassava pulp blended with chicken manure by ratios after 30 days

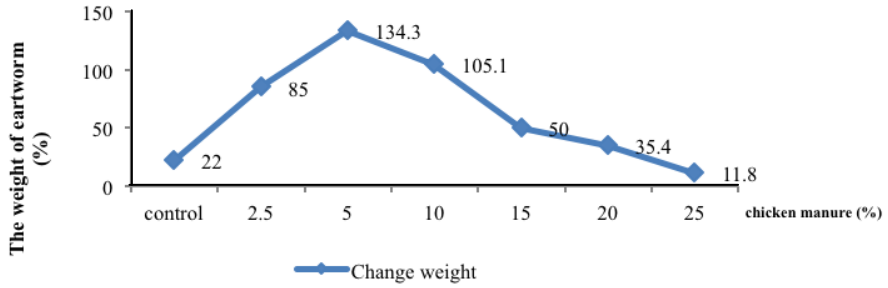

Fig. 2 Change of the weight of earthworm (%) before and after experiment by using the cassava pulp blended with chicken manure by ratios after 30 days

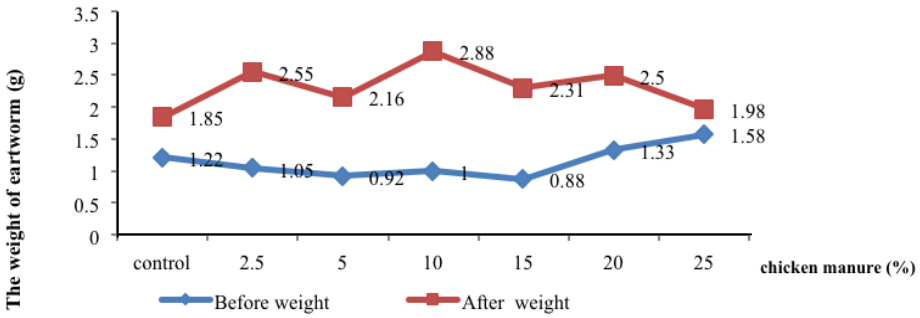

Fig. 3 The increasing of the earthworm's weight (g) while using cassava pulp blended with chicken manure by ratios after 30 days

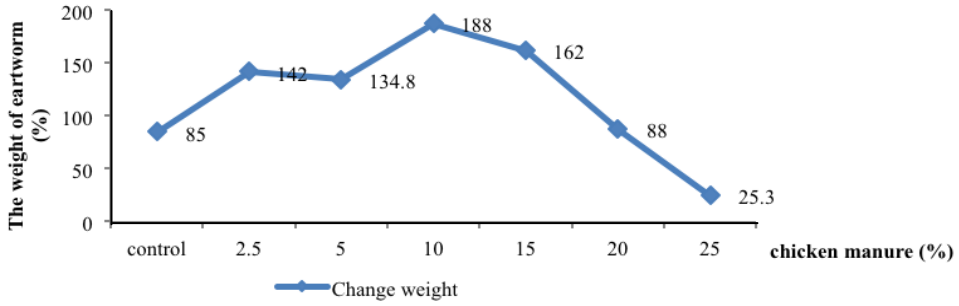

Fig. 4 Change of the weight of earthworms (%) before and after experiment while using cassava pulp blended with chicken manure by ratios after 30 days

The usage of eucalyptus peel blended with chicken manure: The blending of eucalyptus peel with chicken manure at 10% rate showed an increase in the weight of earthworms (2.88 g). The highest weight of earthworms at 188% was changed from when earthworms were fed 1 month ago. They were heavier than when the rates were 0, 2.5, 5, 15, 20, and 25%, an increase of 85, 142.9, 134.8, 162.5, 88 and 25.3 %, respectively, as shown in Fig.3 and Fig.4. This might be caused by high EC, salinity (Edwards and Bohlen, 1996), and pH values resulting from release of NH_4^+ from labile organic nitrogenous compounds were not suitable for earthworm existence (Mertus, 1993).

The usage of cassava peel blended with chicken manure: The blending of cassava peel with chicken manure at 2.5% rate increased in the weight of earthworms (2.94 g). The highest weight of earthworms at 167% was changed from 1 month ago; the weight was higher than at the blending rates of 0, 5, 10, 15, 20, and 25%, or an increase of 124, 91.5, 88.2, 35.8, 34, and 27.7 %, respectively (Fig. 5 and Fig. 6). This is consistent with Kwansod (2003) who reported that using low ration of chicken manure led to high potential transformation of nutrients in raw materials in earthworm biomass.

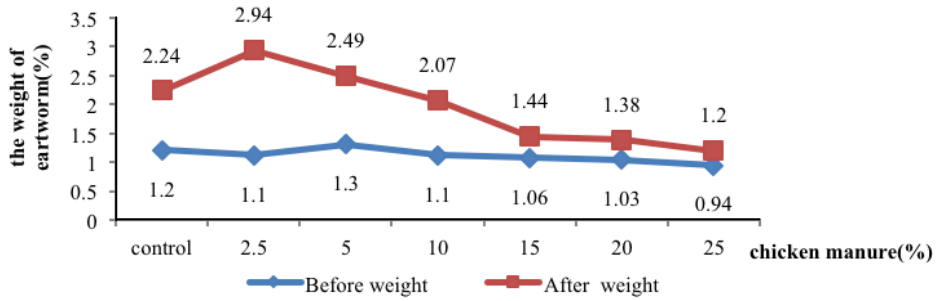

Fig. 5 The increasing of the earthworm's weight (g) while using cassava pulp blended with chicken manure by ratios after 30 days

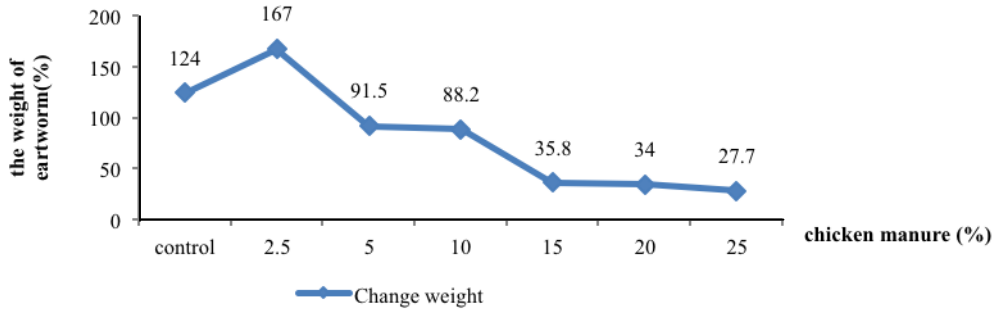

Fig. 6 Change of the weight of earthworm (%) before and after experiment while using cassava pulp blended with chicken manure by ratios after 30 days

CONCLUSION

The survival of earthworm when using chicken manure blended with agro-industrial wastes

The usage of chicken manure in all ratios (0, 2.5, 5, 10, 15, 20, and 25% rates) blended with cassava pulp, cassava peel, and eucalyptus peel can increase % survival of the earthworms at 100% after 30 days. The chicken manure of the highest rate at 25% by weight with oil palm blended did not make the earthworms survive; not even without chicken manure (0% rate). With time proceeded, EC and salinity of vermicompost influenced earthworm survival. Edwards (1988) reported that high salinity of the compost could reduce earthworm growth. Generally, the optimum EC or salinity for earthworm survival ranges from 1.58 to 3.35 dSm^{-1} (Owojorl et al., 2008).

The growth of earthworm when using chicken manure blended with agro-industrial wastes

The usage of chicken manure at 5, 10 and 2.5% with cassava pulp, eucalyptus and cassava peel, peel, respectively, better increased the weight per body than other chicken manure ratios. This shows that use of optimum rate of chicken manure could increase earthworm biomass. However, employing over-dose rate (> 10%) of this material contributes to decrease in earthworm weight. Our results suggest that poultry manures such as chicken manure are not suitable for vermiculture. This is likely because these manures contain enriched ammonia and inorganic salts in which earthworms cannot survive. However, if ammonia and inorganic salt contents can be reduced, chicken manure is very appropriate for vermiculture. This is because chicken manure has a number of nutrients, which can increase the compost value. (Edwards, 1988)

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Research article

Guidance of a Transplanting Skid Steer Vehicle with Variable Center of Gravity

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Abstract In this study it is proposed a photovoltaic powered farming robot system that consists of a delivery vehicle and a working vehicle. The proposed system is designed based on a newly proposed farming method called shaft tillage cultivation. So, we have developed two automatic vehicles, as well as a 2-D localization method for positioning of the working vehicle. In addition, we have developed an attachment for shaft tillage and transplanting which is derived from commercially available transplanting machines. This movable transplanting attachment was mounted over two rails which are disposed transversally on the frame of the working vehicle which in turn permits transplanting multiple rows. The working vehicle is based on a skid steer vehicle with independent left and right motors that allow for motion direction control by turning the left- and right-side wheels at different velocities. However, within the field, even if same turning velocities are applied to both left- and right-side wheels a yaw angle is generated due to the sinkage and rolling resistance. Additionally, controllability of the working vehicle is greatly affected by variable changes of the center of gravity caused by lateral motion of the transplanting attachment. So, this paper focused on the effect of the position of center of gravity on the yaw angle in the working vehicle. The least square method was examined as method to find out the instantaneous center of rotation (ICR) and its effectiveness was confirmed. When the position of center of gravity was on the faster wheels the turning of

the skid steer vehicle was more difficult than in other positions. The ICR changed even when the left- and right-side wheels were driven at the same velocities. Therefore, considering the position of center of gravity in the skid-steer vehicle would allow a rational guidance of the vehicle.

Keywords transplanting, skid steer vehicle, trajectory, variable center of gravity

INTRODUCTION

A current trend in agricultural area is the development of mobile robots and autonomous vehicle for precision agriculture. These are usually required to travel across unpaved terrains to operate or transport material. In this kind of terrains, the mobility and the controllability of the robot is strongly influenced by the physical properties of the terrain (Gonzalez et al., 2009).

Authors are involved in the development of a photovoltaic powered farming robot system that consists of a delivery vehicle and a working vehicle (Tajima et al., 2008). The proposed system is designed based on a newly proposed farming method called shaft tillage cultivation method which promotes weed and crop coexistence. Figure 1 shows an image of cross section of plants cultivated with the shaft tillage method. The tool has two different diameter sections as is shown in Fig. 1. The principal characteristics of this farming method are to minimize the power required when tillage and weed control is done separately by trimming periodically (Tajima et al., 1996). Shaft tillage cultivation method involves drilling a vertically shaped shaft with the rotary sinker that achieves an effect of tillage and the soil is not exposed on the surface of the field (Tajima et al., 1997). As such, we have developed two automatic vehicles. Figure 2 shows the developed photovoltaic powered farming robot system. Functions such as, transportation and positioning of the robot system, electric power generation and storage, transportation and supply of seedling trays etc. were distributed in these two vehicles. The delivery vehicle is guided outside the field through a magnetic tape and has functions such as, positioning of the working vehicle, electric power generation and storage as well as transport and seedlings supply. On the other hand, the working vehicle receives control information, power and a seedling supply from the delivery vehicle, and has function of positioning and transplanting of seedlings. Positioning of the working vehicle is being carried out by a 2-D localization system using a laser distance sensor (Tatsuno et al., 2005). In addition, we have developed an attachment for shaft tillage and transplanting which is derived from commercially available trans-planter. This movable transplanting attachment was mounted over two rails which are disposed transversally on the frame of the working vehicle which in turn permits transplanting multiple rows. The transplanting attachment is equipped with a tillage device for transplanting and a seedling tray tank which also move transversally within the frame of the working vehicle.

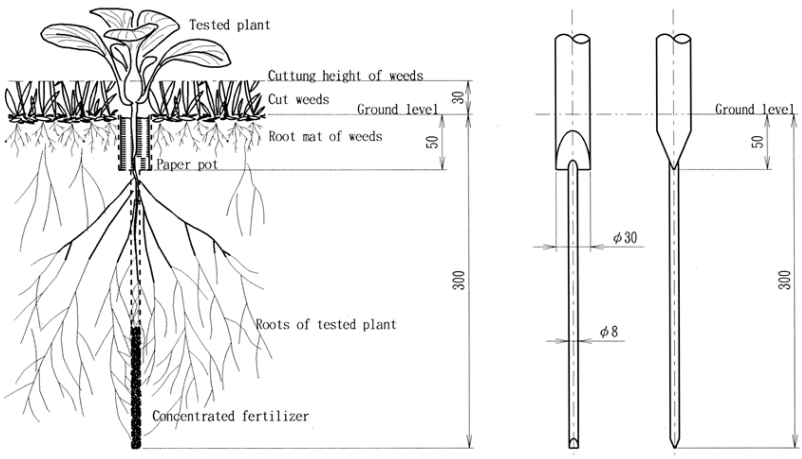
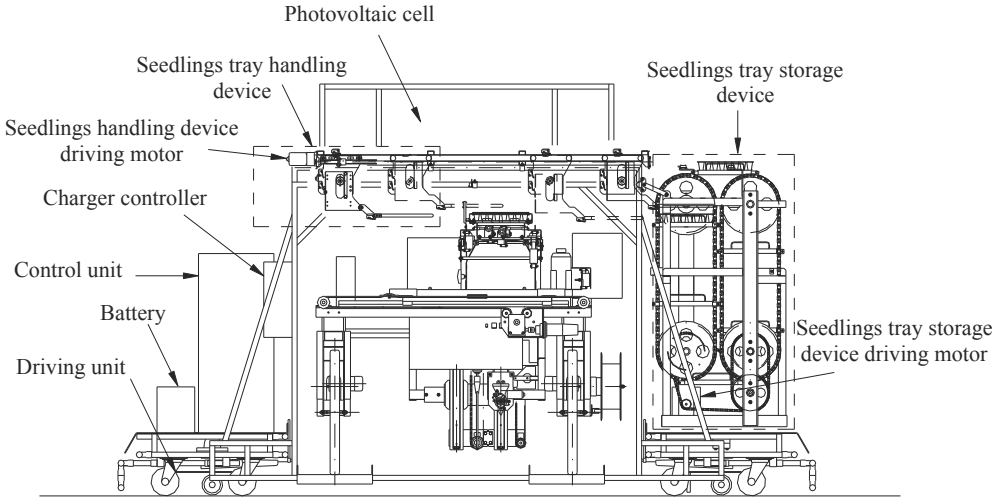
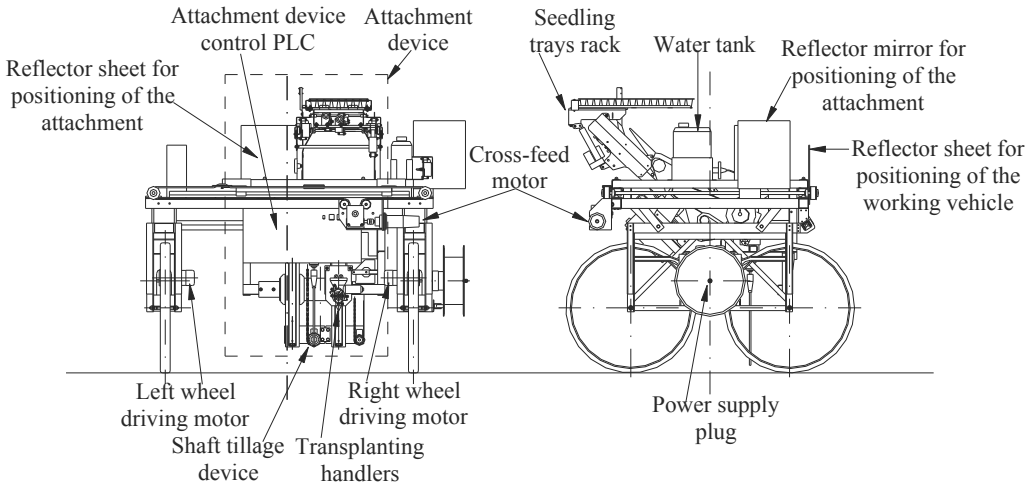


Fig. 1 Cross section of plant under cultivated by the shaft tillage method and the rotary sinker for the shaft tillage cultivation



(a) Delivery vehicle



(b) Working vehicle

Fig. 2 Photovoltaic powered robot system

The working vehicle is based on a skid steer vehicle with independent left and right motors (Tajima et. al. 2003). As the right- and the left-side wheels are driven independently, the wheel speed and direction of rotation determine the direction of the skid steer vehicle. Skid-steer vehicle is capable of zero-radius, "pirouette" turning. This is very important for positioning the skid steer vehicle when transplanting due to its facility in correcting the position in polar coordinates. In other words, the vehicle can turn based on a specific vertical axis within the frame. This system is designed to carry out multitasking. So eventually, it would be possible to perform variable cultural practices (by changing the attachment) using a manipulator, such as disease detection and control by image processing (Velazquez et al. 2011) creating the necessity to combine the general coordinates system in the field with that in the image so a more accurate positioning of the working vehicle could be achieved.

However, within the field, even if the same turning velocities are applied to both left- and right-side wheels a yaw angle is generated due to the sinkage and rolling resistance. Additionally, mobility and controllability of the working vehicle is greatly affected by changes in the position of center of gravity caused by lateral motion of the attachment. It is known that the turning characteristics of a skid steer vehicle are highly dependent on the position of center of gravity, especially for lateral changes (Sasaki et al. 2005), though enough knowledge has not been obtained for the development of an algorithm to guide the proposed system where the center of gravity moves transversally while traveling.

OBJECTIVE

The objectives of this paper are to find out the effect of the position of center of gravity on the yaw angle in the working vehicle and to consider a method to find out the instantaneous center of rotation.

METHODOLOGY

In order to measure a turning circular trajectory, it takes a lot of time due to the velocity of our skid steer vehicle is very slow, when the circular trajectory is large a wide area is needed and it is difficult to maintain the same ground conditions. Therefore, an accurately method to find out the ICR and the turning radius (R) from a small trajectory was necessary. In that respect, the least squared method was proposed.

Experiments were carried out inside a greenhouse using the skid steer vehicle showed in Fig.3. This skid steer vehicle is based on the Agri-cart manufactured by Alumis Co., Ltd. Turning experiments were carried out at very low speed. As power supply a regulated power DC supply was used. PWM driver was used for control of the left- and right-side motors. A load of 196 N was used for all experiments. Tires pressure was set to 196 kPa. 9 load conditions were set as is shown in Fig. 4. Driving speeds of the wheels were set as shown in Table 1. The turning direction was set to counterclockwise. Experiments were conducted as follows: First the load on each wheel was measured for each condition of the load. A mark was collocated each 90 degrees on the right-front and left-rear wheels. Then after traveling a distance of 2 m, 8 m trajectory was plotted on the ground. Plotted points were then measured in Cartesian coordinates with a tape.

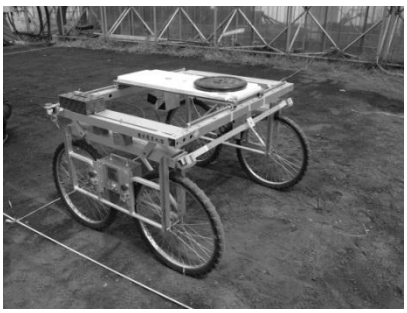


Fig. 3 Skid steer vehicle

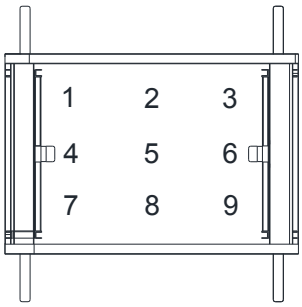


Fig. 4 Load conditions (Top view)

Table 1 Driving setting speed of the wheels

Speed setting	Left-side angular Speed ω_l (rad/s)	Right side Speed ω_r (rad/s)
1	0	1.24
2	0.64	1.24
3	1.20	1.24

Least square method

The turning radius and ICR were calculated using the least square method. Eq. (1) represents the equation for a circle. This method is based on minimizing the mean square distance from the circle to the data points

$$x^2 + y^2 + ax + by + c = 0 \quad (1)$$

Where $\left(-\frac{a}{2}, -\frac{b}{2}\right)$ represents the center of the circle and $\frac{\sqrt{a^2+b^2+c}}{2}$ represents the radius. The residual ε_i obtained from the circle trend line and data points, x_i and y_i, obtained from the trajectory of the skid steer vehicle are expressed by Eq. (2).

$$\varepsilon_i = x_i^2 + y_i^2 + Ax_i + By_i + C = 0 \quad (2)$$

Then the squares of the residuals ε_i^2 are summed and A, B and C are determined so that the sum is minimized as shown in Eq. (3). Here, A=-2a; B=-2b and $C=a^2+c^2-r^2$.

$$S = \sum_{i=1}^{n} \varepsilon_1^2 = \sum_{i=1}^{n} (x_i^2 + y_i^2 + Ax_i + By_i + C)^2 \quad (3)$$

Particularly, the estimated values of A, B and C can be obtained by partial differentiation and equating to zero.

RESULTS AND DISCUSSION

Figure 5 shows the load on wheels under the 9 load conditions (Fig. 4). The load was distributed symmetrically for load condition 5 on the left-and right-sides of the vehicle with values from 201-249N. The load moved to right-side for condition 6 and to left-side for condition 4 confirming that the center of gravity moved along with the load. Fitting the circle equation to plotted data points with the least square method allowed calculating the ICR and turning radius, from a small trajectory in a short time, confirming the effectiveness of the method.

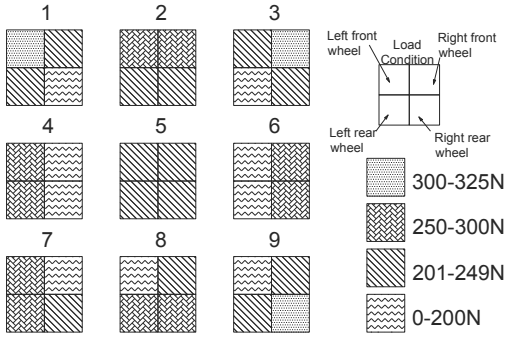


Fig. 5 Load on wheels

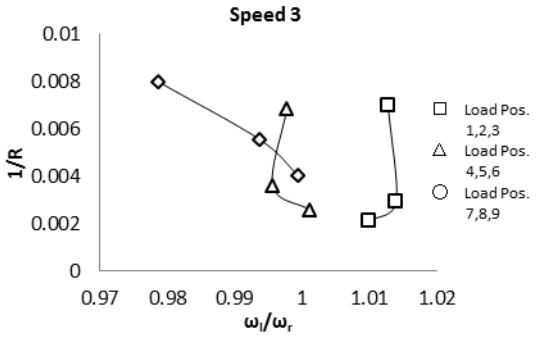


Fig. 6 Relationship between ω_l/ω_r and 1/R for Speed setting 3

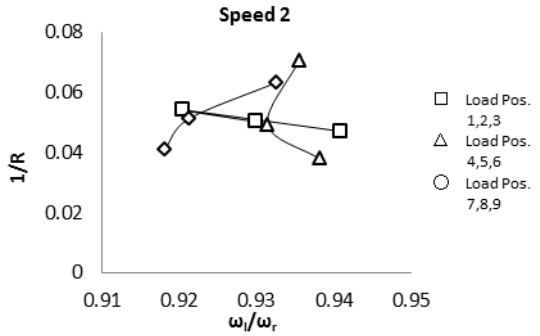


Fig. 7 Relationship between ω_l/ω_r and 1/R for Speed setting 2

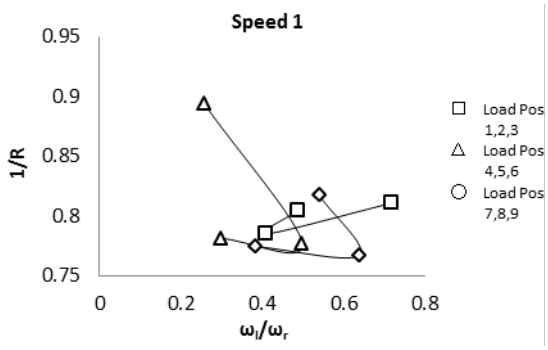


Fig. 8 Relationship between ω_l/ω_r and 1/R for Speed setting 1

Figures 6, 7 and 8 show the relationship between the ratios of ω_l/ω_r and 1/R. R represents the turning radius and ω_l and ω_r are the left- and right-side wheels angular speed, respectively. As it can be observed in each figure the turning radius varied for each load condition even when experiments were carried out under the same speed and ground setting conditions. When the load was on the faster wheel (right-side), braking effort on the slower wheel (left-side) reduced as a result of wheels sinkage and rolling resistance making the turn more difficult. On the other hand, when the load was over the slower wheel (left-side) the braking effort increased facilitating the turn. In other words, when the load is over the faster side the vehicle tends to travel straight and when the load is over the slower side the vehicle tends to tight turn.

CONCLUSION

The least square method fitting the circle equation was proposed and examined as a method to find out the turning radius and the ICR of the vehicle from plotted point data obtained from a short trajectory and its effectiveness was confirmed. The ICR changed even when the left- and right-side wheels were driven at the same speed. Considering the position of center of gravity in the skid-steer vehicle would allow for a rational guidance of the vehicle. Hence, analytical studies are necessary in order to achieve a more accurate control for positioning of the skid steer vehicle. In other words, mathematical modeling (equations of motion) and simulation of the working vehicle taking into account changes in the position of the center of gravity are required. As a result, velocities for the left- and right-side wheels as well as the appropriate position of the center of gravity could be obtained. Finally, in order to evaluate the accuracy of the mathematical model, comparison between experimentally obtained data and those obtained by simulation is required.

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Research article

The Change of Phosphorus Form in Vermicompost Using Cassava Pulp

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Abstract The aim of this study was to investigate the change of phosphorus form in vermicompost using cassava pulp. The ratio of cassava pulps: soil mix (sandy soil and cow manure) were applied at 75%:25% (W/W) in compost (CP: without earthworm) and vermicompost (VCP: with earthworm). The qualities of vermicompost and the form of phosphorus after 60 days incubation were analyzed. The results showed that the pH and EC (Electrical conductivity) were increased in CP and VCP. The water-soluble P in VCP was increased by 21.55% from initial and higher than CP 16.07%. The exchangeable P in VCP was increased by 39.57% from initial and higher than CP 24.25%. Total P in VCP was increased by 21.55% from initial and higher than CP 16.07%. The total N in VCP was increased by 87.61% from initial and higher than CP 85.14%. Moreover, the decrease of %OC (organic carbon), C/N ratio, C/P ratio were found in VCP more than CP, the percentage of decreasing from initial was 76.93%, 97.27%, 82.15%, respectively. The humic acid (%) content in VCP was higher than CP and the percentage of changing after 60 days of VCP was 56.41% and of CP was 32.83%. The growth and reproduction of earthworm showed that the growth rates of earthworm were 10.75 $worm^{-1}day^{-1}$ (mg) and the numbers of cocoons produced in vermicompost were 6.8 $earthworm^{-1}$. Therefore, the activity of earthworm and microbial was helpful to phosphorus available form and nutrient fertilizer content in vermicomposting. These data suggest that vermicompost helps to enhance phosphorus availability in compost.

Keywords phosphorus, cassava pulps industrial wastes, vermicompost, earthworm

INTRODUCTION

There are many cassava agro-industrial factories in Thailand, large and growing industries. When they finish the manufacture process with about 10 million tons of fresh cassava roots used for the production of starch, generates at least 1 million tons of pulp annually (Sriroth, 1994). Cassava pulps wastes can be used as nutrient fertilizer cycling and managing which is sustainable in agricultural systems. However, if cassava wastes were not be controlled and managed the environmental problem with disposal would happen. Therefore, the easy and fast management of wastes is using earthworm to breakdown wastes and enhance nutrients fertilizer for compost. Vermicomposting is normally more capable than composting because earthworms were feed on organic and create conditions that favor the degradation of decomposed and fragmented organic material by aerobic microorganisms (Edwards, 2004). The interactions between earthworms and microorganisms were the non-thermophilic biodegradation of organic wastes. (Arancon et al.,

2004). Vermicomposting increases P bioavailability, microorganisms, and earthworms; including organic acid production, which solubilizes inorganic P (Scervino, et al., 2010). Saha et al. (2008) showed that phosphatases was helpful on faster transformation of organic P by using of earthworm casts in soil. Organic matter modifies supplement soil phosphatase activity. Phosphorus available forms are important for plant production. Earthworm and microorganisms were helpful, changed mineralization P of organic forms that transform P from non-available, organically bound forms, into bioavailable phosphate ions (Eivazi and Tabatabai, 1977). In the study of Jader et al. (2012) showed that vermicompost was an alternative technology for increasing P availability for plant nutrition. Accordingly, the degradation of organic wastes by earthworm and microorganism were helpful on the amount and quality of the humic acid. For example, this fraction in composts and vermicomposts are respected as important indicators of their biological perfection and successful performance and insurance for a safe impact and chemical consistency in soil (Senesi et al., 2007; Benítez et al., 2000; Atiyeh et al. 2000).

OBJECTIVE

The objective of this study was to investigate the change of phosphorus form as using cassava pulp and relationship of nutrient cycle in vermicompost process.

METHODOLOGY

Cassava industrial wastes: cassava pulps located Kalasin province northeast of Thailand. Earthworm: the earthworms (*Eudrillus eugeniae*) were carefully brought to the laboratory along with the moist soil and culture in laboratory and acclimatized for 1 month under laboratory conditions in polyethylene buckets (culture pot) containing soil. Sandy soil (Nampong Soil) and the fresh manure amendment, which material was collected form a local cattle farm were used in the experiment.

Experiment design: The vermicompost (VCP) cassava pulp waste material in process was used. Experiment plan was CRD (Completely Randomized Design), 3 replication, the experiment repetitions were mixed in the rate of 75%:25% (cassava industrial wastes: soil mixture) for the experiments compost (CP: without earthworm) and vermicompost (VCP: with earthworm). The 25% in compost process is Soil mix. It was featured Nampong soil, cow manure. VCP and CP were decomposed cassava pulp waste; soil mix (soil and cow manure). The mixture was composted for 15 day before earthworm addition at incubation. The fermentation processes have a high temperature because of earthworm breakdown. The mixture of moisture content was adjusted to 70-80% of WHC (Water Holding Capacity) by water and it keeps content in plastic black block 2 L by adding 10 earthworm(*Eudrillus eugeniae*)/1 kg (mix waste), which was covered with a net to prevent direct exposure to sunlight(Maity et al, 2008). The times incubation of study were VCP and CP at 0, 30 and 60 days. The temperature was 30±2 ◌C in laboratory.

Chemical analysis: The compost (CP) and vermicompost (VCP) were measured for pH using a digital pH meter in 1/ 2.5 (w/v) by deionizered water. Total Organic carbon was determined by the partially-oxidation method (Walkley and Black, 1934). Total N (Total nitrogen) was measured by micro Kjeldahl method (Jackson, 1973; Bremner and Mulvaney, 1982). Total P (TP) was digested with acid (HNO_3: H_2SO_4:$HClO_4$ (5:2:1)). The sample used 1 g / 10 ml (mix acid) (w/v). Water soluble P (WSP) was measured in DI water extraction ratio VCP and CP 1 g/ 25 ml (W/V) and shaken for 2 hour (150 rpm). Exchangeable phosphorous (Exch. P) was determined by following Bray II extraction method (Schroth et.al, 2003). The total form P solutions were determined the ascorbic acid molybdenum blue method by UV spectrophotometer (Murphy and Riley, 1962). C:N ratio was calculated from the measured value of C and N. C:P ratio was calculated from the measured value of C and P. TOC in the VC was estimated using the dichromate oxidation method (Nelson and Sommers, 1982; Walkley and Black, 1934). Humic acid extracted soil and vermicompost caste derived humic acids (HA) were extracted with a slightly HA modified

procedure recommended and used by the IHSS to isolate standards of humic acid (Chen, et al., 1977).

RESULTS AND DISCUSSIONS

The characteristic of cassava pulp wastes: the pH was 3.823±0.586, EC (mS/cm) was 0.867± 0.029, Total P (%) was 0.063±0.001, Total N (%) was 0.206±0.016, Total K (%) was 0.322±0.004, and C: N ratio 94.63±6.73. The characteristic of soil: the pH was 4.500 ±0.557, EC (mS/cm) was 0.357± 0.051, Total P (%) was 0.008±0.000, Total N (%) was 0.021±0.003, Total K (%) was 0.121±0.000, and C: N ratio 9.432 ±0.165. The characteristic of cow manure: the pH was 9.233 ±0.029, EC (mS/cm) was 3.577± 0.025, Total P (%) was 0.664±0.178, Total N (%) was 1.350± 0.050, Total K (%) was 0.495±0.010, and C: N ratio 17.970± 1.251.

Changing of Phosphorus in CP and VCP: the result showed that changing of phosphorus form comparing with CP and VCP in cassava pulps agro-industrial wastes in vermicomposting at time incubation 0 day, 30 days and 60 days (Table 1). The total P in content initial wastes mixtures at 0 day CP and VCP were 0.54%, after that the end 60 day TP value was increased 16.07-21.55% in both, but when the compare with CP and VCP that VCP was minimum increased than CP. Similarly, there was about water soluble P (WSP) increase in VCP better than CP. Initial at 0 day CP and VCP was value 0.037%, after that at 30 days and 60 days had increased water soluble P (WSP) in both. In VCP and CP, percentage of changing was increased 74.72% and 61.73%, respectively. The study showed that vermicomposting helped to increase water soluble P (WSP) higher than general tradition compost. Exchangeable P is important for growing plant, because it is available P form as plant was direct absorbed. The table 1 showed that exchangeable P content in VCP was better than CP. Initial at 0 day CP and VCP was value 0.227%, after that at 60 day, it had increased water soluble P (WSP) in both. In VCP and CP, percentage of changing was increased 39.57% and 24.25%. The C:P ratio (Table 1) showed that value content in VCP was decreased which better than CP. Initial at 0 day CP and VCP was value 26, after that at 60 days, it had decreased C:P ratio in both. In VCP and CP, percentage of changing was increased 82 % and 73%. After earthworm and microorganism activity, Vermicomposting can be proficient technology for transformation of unavailable forms of phosphorus to easily available forms for plants. Lee (1985) the organic wastes passing thought the gut of worm was produced phosphatase and it was released of P may be microorganisms in casts. Ghosh et al. (1999) have reported that vermicomposting can be an efficient technology for the transformation of unavailable forms of phosphorus to easily available forms for plants and it can help to enhance the transformation of organic P into mineral forms, it also to release P into in soluble inorganic forms and to increase the availability of P (Exchangeable P and WSP).

The result showed that the pH and EC in incubation at 60 day were increased in CP and VCP (Fig. 1). The pH of CP 0day value was 7.4. The pH of CP and VCP at 60 day value was 8.6 and 8.2, respectively. Percentage of increased was 13.59% and 9.98% .The increase of pH may be attributed to the decomposition of nitrogenous substrates resulting in the production of ammonia. Ammonia which forms a large proportion of the nitrogenous matter was excreted by earthworms (Cohen and Lewis, 1949). The total organic carbon (TOC) in VCP all time declined drastically compared to their initial at o day; the maximum organic C loss was observed in VCP. The comparison with CP and VCP were also calculated by using vermicomposting coefficient (VCP) that organic C loss better than CP by percentage of loss CP:25% and VCP: 76.93%. Causing of the organic C loss was vermicomposting process in organic C budget of the waste decomposition system and accelerates the waste degradation process (Garg et al, 2005). The vermicomposting cause increased total N. The comparison between CP and VCP, VCP was increased total N than CP. By percentage of increasing in VCP was 87.61%. Earthworms and microbial have an abundant impact on nitrogen transformation, by increasing nitrogen mineralization, therefore, mineral nitrogen was maintained in the nitrate form (Atiyeh et al., 2000). However, the report of Viel et al., (1987) in the substrates might be responsible for nitrogen addition stated, results to decrease in organic carbon. The nitrogen through excretory products, enzymes, mucous and even by decaying worm tissue (Tripathi

and Bhardwaj, 2004). So that the value C:N ratio was decreased in VCP and CP (Fig. 1). C:N ratio was important used indices for maturity of organic wastes, decreased with time for all the VCP and CP. Initial C:N ratio was 128. Vermicompost can be attributed to initially lower content of nitrogen in these feeds. Final C:N ratios were 3.51 by percentage of decreasing was 97.27, whereas the final C:N ratio of VCP was higher than CP feed.

Table 1 The result showed that changing of Phosphorus form compares with between CP and VCP in Cassava pulps agro-industrial wastes vermicompost at time incubation 0 day, 30day, 60 day

Total P (%)	TP(%)0d	TP(%)30d	TP(%)60d	% changing
Compost	0.540±0.009	0.513±0.002	0.643±0.043	16.07
Vermicompost	0.540±0.009	0.545±0.016	0.688±0.067	21.55
Water Soluble P (%)	**WSP(%)0d**	**WSP(%)30d**	**WSP(%)60d**	**% changing**
Compost	0.037±0.001	0.076±0.006	0.097±0.002	61.73
Vermicompost	0.037±0.001	0.091±0.006	0.146±0.028	74.72
Exchangeble P (%)	**Exch.P(%)0d**	**Exch.P (%)30d**	**Exch.P(%)60d**	**% changing**
Compost	0.227±0.010	0.239±0.008	0.300±0.004	24.25
Vermicompost	0.227±0.010	0.377±0.016	0.376±0.024	39.57
C/P ratio	**C/P(%)0d**	**C/P(%)30d**	**C/P(%)60d**	**% changing**
Compost	26.07±0.319	19.75±2.997	7.01±0.349	73.09
Vermicompost	26.07±0.319	20.22±4.978	4.65±0.432	82.15

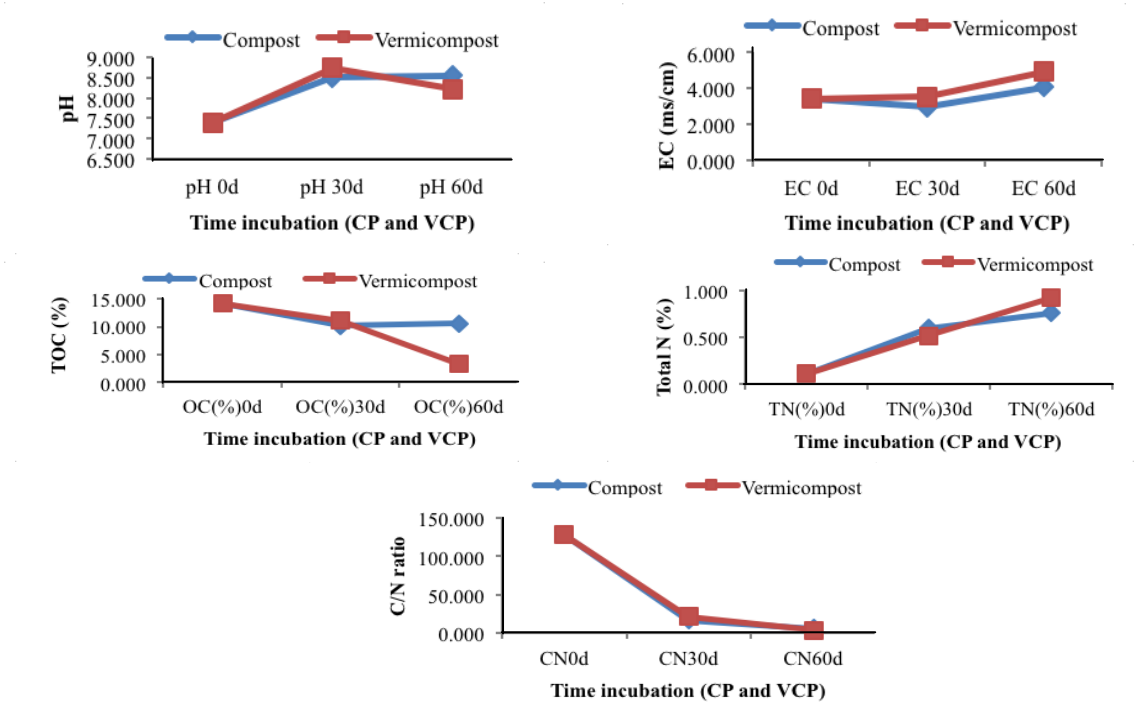

Fig. 1 The picture showed that the comparing was pH, EC, TOC(%),Total N(%), C/N ratio between CP and VCP with as cassava waste (cassava pulps) in compost at 0 day, 30 day, 60 day

The humic acid (HA) (%) contents showed in Fig. 2 the comparison between VCP and CP that at 60 day after incubation, VCP was higher HA(%) than CP and ratio of humic acid (E4/E6) in VCP was higher than CP. Percentage of changing after 60 day VCP was 56.41% and at CP was 32.83%. The HAs were one of most active fractions of OM, they improved the absorption of nutrients by plants and soil microorganisms, there was a positive effect on the dynamic of N and P in soil, stimulate plant respiration and the photosynthesis process, and favor the formation of soil aggregates, etc (Hernandez et al., 2001). Chen et al., (1977) suggested and believes that the magnitude of E4/E6 was related to the degree of condensation of the aromatic C network, with a

low ratio indicative of a relatively high degree of condensation of aromatic humic constituents. Conversely, a high E4/E6 ratio reflects a low degree of aromatic condensation and suggests the presence of relatively large portions of aliphatic structures. The values of E4/E6 ratio would depend on the average molecular weight or particle size (negative correlation) and low degree of aromatic C network content and low average molecular weight, probably due to a short period of humicfication that takes place in the composting process. This E4/E6 value suggested that during the composting process the HAs produced were similar to fulvic fraction and in this way they cloud undergoes more microbial degradation. It had been demonstrated that the fluorescent intensity of HAs and fulvic acid (FA) increase with decreasing molecular size (Edward et al., 1988; Aoyama, 2001).

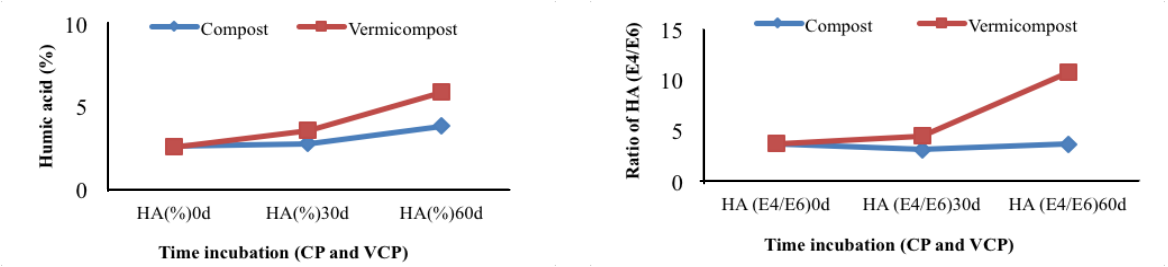

Fig. 2 The picture showed that humic acid (%) and ratio of humic acid (E4/E6) between CP and VCP with as cassava waste (cassava pulps) in compost at 0 day, 30 day, 60 day

Table 2 Growth of *Eudrillus eugeniae* cassava pulp waste industrial

Treatment	Mean initial weight earthworm^{-1} (mg)	Maximum weight achieved earthworm^{-1} (mg)	day	Net weight gain earthworm^{-1} (mg)	Growth rate worm^{-1}day^{-1} (mg)
Cassava pulp waste	323.43	645.96	60d	322.53	10.75

Table 3 Cocoon production by *Eudrillus eugeniae* in cassava pulp waste industrial

Treatment	Total no. of cocoons produced after 60 day	No. of cocoons produced earthworm^{-1}
Cassava pulp waste	68.0	6.8

CONCLUSIONS

In conclusion, the study observed the change of phosphorus form in vermicompost using cassava pulp. The transformations that resulted in phosphorus available form in vermicompost was generally more than efficient composting CP because of the activity of earthworm and microorganism that helped to change organic wastes and digestion wastes to phosphorus nutrient fertilizer. Increasing inorganic P was exchanged to P, water soluble P and total phosphorus. The vermicomposting process after 60 days was decomposing and changing, transforming by mineralization P into inorganic P nutrients form and was higher than general composting. Finally, The study observed the change of phosphorus availability form as with cassava waste (cassava pulps) in vermicompost on helping to change nutrient fertilizer: total N, C:N, total K, phosphorus available form, Humic acid for plant, growth and reproduction of earthworm. Vermicompost was encouraged as a disposal and management agro-industrial wastes which it decreases bio-wastes to change valuable nutrient to plants, and to reduce environment pollutions.

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Research article

Using Choice Experiment to Estimate the Value of Sustainable Rattan Resource Management in Cambodia

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Abstract Rattan, which accounts of approximately USD 1.5 million of total revenue in Cambodia, plays a crucial role in national and international trade for poverty reduction and conservation. Prek Thnot community, Kampot province was selected for implementing sustainable rattan management approach 5 years ago including nursery management, enrichment planting and the development of a harvesting plan. Interviews with 324 families who have a forest dependence revealed that rattan is one of the top three options for their livelihood improvement. The objective of this research is to establish the marginal utility of each attribute for sustainable rattan management. It was also used to estimate the payment of each activity for sustainable management and productions. The results revealed that 93% of local communities were willing to pay a tax fee through a revolving fund for managing natural resources at their communities and only 7% rejected the payment because they felt they did not gain profit from their contribution. All attributes were found to be statistically significant at 1 and 5 percent except the benefit sharing from Reduced Emissions from Deforestation and Degradation (REDD+), meaning that local community are still not expected to get benefit from REDD+ or they did not well educated on REDD+ in Cambodia. The marginal of willingness to pay of sustainable rattan management shows that they are willingness to pay more for increasing endangered species and recovering rattan resources in their communities through conservation and enrichment planting at degraded forest and over rattan harvesting areas. Hence, it can be stated the local community are well prepared for participating rattan management activities and these results should be contribute to the making decisions by stakeholders at the community of defining a new policy to be implemented by considering important on biodiversity before implementing any activities.

Keywords choice experiment, choice modeling, endangered species, rattan coverage, harvesting plan

INTRODUCTION

Forest products account for approximately 5% of Cambodia's Gross National Product (GDP) and 72% of the workforce is engaged in agriculture and forestry activities (FA, 2008; FA, 2010). Non-Timber Forest Products (NTFPs) is the secondary in importance and contributes to livelihood development and poverty reduction in the country with the total of approximately 70-90% of households involved in collection and trade in forest products and NTFPs and the total income of NTFPs is about USD 300 to USD 400 annually (McKenney et al, 2004). Rattan is one of the top three of NTFPs in Cambodia with value of approximately USD 1.5million (Davies and Mould, 2010; WWF, 2010) and according to Forestry Statistics (2007), the main trading of NTFPs in Cambodia, including resin, rattan and bamboo. During the last decade, the rattan trade has decreased dramatically because of land conversion, over harvesting and unsustainable management (Vuthy and Hourt, 2006). Thus, the sustainable management of this resource is widely considered to be a good strategy to both biodiversity conservation and livelihood improvement for the benefit

of the development of Cambodian economy. WWF Cambodia has selected this area for the piloting a sustainable rattan productions program. It guides policy makers or stakeholders to learn local community preferences and needed before implementing projects or activities. Main activities contributing to sustainable rattan management are harvesting techniques and harvest planning , enrichment planting native and economical rattan species in the community land and species conservation in the sustainable harvesting areas by increasing endangered species. The three year rattan harvesting plan was approved by the government in 2010 and stock, yields and location of rattan harvested has been shown in the harvesting plan. Based on Prek Thnot community protected areas roles and regulations, 5 percent of total value from selling rattan should be paid to a community trust fund for the benefit of their community development and biodiversity conservation. Approximately 0.7 USD for 100 rattan canes has to be paid for community revolving fund when they harvested rattan in sustainable management. The amount of money of local communities who is willing to pay for biodiversity conservation and their livelihood development is from the fee for harvesting rattan in their community land.

The application of non-market valuation technique to estimate benefits of alternative environment management has been limited in Cambodia. The choice experience (CE) method, a state preference technique has been commonly applied in developing countries and recently, it has been introduced in Cambodia. CE methods could also be useful in designing policies and implementation of rural development project (Kohlm, 2001). The work of Ratanak and Yabe (2009) in Mondulkiri province is one of a handful of studies employing the CE method to assess the effect of environmental services on ecotourism development and management.

OBJECTIVE

The conditional logic model as an experimental method has been used to establish the marginal utility of each attribute for sustainable rattan management. It is also used to estimate the payment of each activity for sustainable rattan management and productions. The data used in the empirical policy evaluation literature came from a survey to collect information on household behaviors before and during the project implementation.

METHODOLOGY

Choice models applied to non-marketed goods assume a specific continuous dimension as part of the framework by using a discrete choice. They were inspired by the Lancasterian microeconomic approach (Lancaster, 1966), in which individuals derive utility from the characteristics of the goods, and the first study to apply choice models to non- market valuation was Adamowicz et al. (1994) and Adamowicz et al., (1998). Recently, choice models have frequently been applied to the valuation of non-market goods.

The stakeholder analysis, participatory tools and quantitative surveys underpinned all the discussion of impacts, ensuring that differences between stakeholders identified and distribution of costs and benefits assessed. The experimental design for both questionnaires were created using a main effect orthogonal statistical design generated using SPSS19. The alternatives for each choice set were generated using a cycled design from the original fractional factorial design. In the researcher selected questionnaire, a blocking strategy was used to reduce the number of choice tasks given to each respondent. In the respondent selected questionnaire prepared experimental designs were used as templates as shown in Table 1. Respondents were advised that they could choose to include any number or type of attributes in their choice decision. The one-on-one interview survey took place at 4 villages in Prek Thnot community was conducted between March and April of 2012 with the total of 324 local community participants from local community, local authorities include forest administration, park ranger and commune council. At first, respondents received general information about the characteristics and management of community with posters, maps, and photos of main rattan activities including rattan harvesting technique, nursery management, rattan enrichment planting and large water birds and mammals captured by camera-

traps in the national park. Following this, the second part of the survey included choice modeling questions. The five attributes with four levels use to create choice sets using a 4^5 orthogonal main effects design (Louvier et al., 2000), which produced 25 choice sets that were blocked into 5 versions of 5 choice sets (see Table 1). Finally, the questionnaire elicited information about non-attribute variables such as sex, age, education, income, attitude, perception and the main threat of biodiversity conservation.

The choice Modeling (CM) technique requires respondents to choose only one among three options from each of several sets. The resulting statistical model predicts choice behavior as a function of the attributes and level that identify the different choice set. According to Lancaster (1966), CM is consistent with Lancaster's theory in which consumption choices are defined by the utility or value that is derived from the attributes of a particular good and random utility theory, which describes discrete choices in a utility. The relationship of this variable can be introduced by assuming that the relationship between utility and characteristics follows a linear path, and by assuming that the error terms are distributed according to a double leg distribution; the choice probabilities have a convenient closed-form solution known as the multinomial logit model (MNL). The conditional logit model used in this study is presented below. Because CE involves selection of a substitute policy from several alternatives on the basis of the random utility model (Ben-Akiva and Lerman, 1989), it can be expressed in equations, as shown below: When the *i*-th respondent selects *j* from the set of alternatives, *C*, the utility u_{ij} can be defined by Eq. (1):

$$u_{ij} = v_{ij} + \varepsilon_{ij} \tag{1}$$

where v_{ij} denotes the observable portion of the utility and ε_{ij} indicates error term. When the *i*-th respondent selects *j*, the utility u_{ij} of the selected alternative *j* is higher than the utility u_{ik} of the other alternatives, and its probability can be defined by Eq. (2):

$$\begin{aligned} \pi_{ij} &= \Pr(u_{ij} > u_{ik}; \forall k \in C) \\ &= \Pr(v_{ij} + \varepsilon_{ij} > v_{ik} + \varepsilon_{ik}; \forall k \in C) \\ &= \Pr(v_{ij} - v_{ik} > \varepsilon_{ik} - \varepsilon_{ij}; \forall k \in C) \end{aligned} \tag{2}$$

If this equation is subjected to total differentiation, deeming the utility level unchanged ($dv = 0$) and fixing the attribute x_k (other than attribute x_j) also at the initial level, the amount of WTP for one unit increase of attribute x_j can be defined as follows in Eq. (3):

$$MWTP_{x_j} = \frac{dp}{dx_j} = -\left(\frac{\partial v}{\partial x_j}\right) \Big/ \left(\frac{\partial v}{\partial p}\right) = -\frac{\beta_j}{\beta_p} \tag{3}$$

In this way, MWTP following a change in the alternative policy's level can be calculated.

The Attributes with four levels such as Non Rattan Coverage (RC), Sustainable Rattan Harvesting (SRH), Forest Management for REDD+ Benefit from government or donors, Increase Endangered Species Conservation (IESC) and the price. The attributes for the C option were coded with zero values for each of the attributes and the alternative specific constants (ASC) were equal to 1 when either A or B option was selected. The Choice data of the conditional logit model and marginal effects were analyzed using LIMDEP 8.0 NLOGIT 4.0 (Greene, 2002).

Table 1 Attributes and levels used in the choice models

Attributes	Levels			
	Basic Level	Level 1	Level 2	Level 3
Rattan Coverage (RC)	0 Seedling	10,000 Seedlings	15,000 Seedlings	20,000 Seedlings
Sustainable Rattan Harvesting(SNH)	500,000 canes	19 million canes	23 million canes	28 million canes
Forest Management for REDD+ Benefit (FMRB)	0%	20%	30%	40%
Increase Endanger Species Conservation (IESC)	5 species	10 species	15 species	20 species
Price	USD30	USD50	USD70	USD90

RESULTS AND DISCUSSION

Table 2 shows the respondent profiles. Almost 55% were male and about 45% were female. The majority of local communities were between the ages of 31-40 years (28.40%) and 41-50 years (25.31%). The lowest percentage was age of under 25 and over 51 years old. A high percentage of respondents were farmers with the total almost 50%, followed by fisherman (28.70%), and government staff (10.80%). The educational level of local community was very low with majority of them being between Grades 1 to 6, which accounted for almost 42%. More than 30% of interviewees were uneducated. Nearly 90% of respondents were under Grade 9. Most of people living in remote areas were strongly dependent on using natural resource as their income was low. Almost 60% of them had incomes between 51 USD to 100 USD and almost a quarter of respondents had incomes below 50 USD. Almost 85 % were below 100 USD. The percentage of local community who were willing to pay for sustainable rattan management and species conservation in the park was nearly 93% (302 respondents) and only about 7% of them were not willingness to pay for these activities because they felt that they did not get any benefit from these activities as shown in Table 3. The amount of willingness to pay for community development was from 1 USD to 7 USD and relied on the number of time rattan was collected. Harvesters always collected rattan in the dry season from January to April and October to December. In the rainy season people rarely collected rattan because they were busy with their agricultural practice. About 30% of people were willing to pay for the community trust fund which was 3 USD per collecting time meaning that they could collect about 600 rattan canes per one time. Meanwhile approximately 21% of them were willing to pay 5 USD. Almost 30% (88 people) of respondents were willingness to pay from 1 USD to 2 USD and only 11% of them preferred to pay between 6 USD to 7 USD.

The ASC found statically significant with positive sign implying that all attributes included in the CE capture all systematic determinant of alternative choice. Most of attributes of major activities contributing to sustainable rattan management were found to be statistically significant at the 1 and 5% level. Table 4 reveals the estimate of coefficients of alternative specific constant; sustainable rattan harvesting; increase endangered species for conservation, and price were statically significant at 1% level, while rattan coverage found statistically significant at the 5% level. Only the attribute of forest management for Reduced Emissions from Deforestation and Degradation (REDD+) benefit was not statistically significance.

Table2 Demographic information of respondents

Category		Number	Percent (%)
Gender	Male	178	54.94
	Female	146	45.06
Age	Under 25	48	14.81
	26-30	52	16.05
	31-40	92	28.40
	41-50	82	25.31
	51-60	38	11.73
	Over 60	12	3.70
Occupation	Farmer	159	49.07
	Fishermen	93	28.70
	Government Staff	35	10.80
	Student	37	11.42
Education Level	Under 1	108	33.33
	Grade 1-6	135	41.67
	Grade 7-9	53	16.36
	Grade 11-12	20	6.17
	Over Grade 12	8	2.47
Income	Under USD50	80	24.69
	USD51-USD100	193	59.57
	USD101- USD 200	43	13.27
	USD201- USD 300	6	1.85
	USD301-USD400	2	0.62

Source: Survey Data

The marginal willingness to pay for sustainable rattan management is shown Table 5. Interestingly, the results revealed that the local community was willing to pay the most for rattan coverage (rattan enrichment planning) with the total of around 18 US$ per year; thus, the total amount of financial contributions from villagers for enrichment planting was estimated to be 15,000 US$ per year if all community members were willingness to pay this amount. Their second preferences were to pay for increasing endangered species for conservation, followed by sustainable rattan harvesting. The positive sign of these attributes indicated that probably the respondents were probably interested in enjoying these activities and the negative sign of price indicated that the price could affect respondents' choice.

Table 3 Willingness to Pay for Sustainable Rattan Management

Category		Number	Percent
WTP	Yes	302	93.21
	No	22	6.79
Amount of WTP	1	37	12.25
	2	51	16.89
	3	92	30.46
	4	25	8.28
	5	64	21.19
	6	16	5.29
	7	17	5.63

Source: Survey Data

Table 4 Conditional logic results

Variables	Coeff.	Std.Err.	T-statistic	P-value
Alternative Specific Constants	1.2149***	0.1345	9.0370	0.0000
Rattan Coverage	0.1097**	0.0556	1.9750	0.0483
Sustainable Rattan Harvesting	-0.0057***	0.0018	-3.2030	0.0014
Forest Management for REDD+ Benefit	0.0010	0.0025	0.4270	0.6690
Increase Endangered Species for Conservation	-0.0135***	0.0050	-2.6860	0.0072
PRICE	-1.7040***	0.1792	-9.5070	0.0000
Parameters	6			
Observations	1620			
Log-livelihood	-1716.98			

*Note: ***, **,* indicate statistical significance at 1%, 5%, 10%*
Source: Survey Data

Table 5 MWTP of sustainable rattan management from multinomial logit modeling

Variables	Attribute	MWTP (USD)
ASC	Alternative Specific Constants	71.2969 (44.9447, 97.6491)
BRC	Rattan Coverage	18.6929 (7.8031, 29.5826)
BSRH	Sustainable Rattan Harvesting	-0.3345 (-0.6873, -0.0183)
BFMRB	Forest Management for REDD+ Benefit	0.0587 (-0.4313, 0.5487)
BIESC	Increase Endangered Species for Conservation	-0.7923 (-1.7723, 0.1877)

Source: Survey Data (95% confidence interval)

CONCLUSION

This study presents results from empirical application of choice experiment to valuation of sustainable rattan management. The choice experiment aimed at identifying the preferences and behaviors of local community and all stakeholders toward all activities for sustainable rattan management both inside and outside protected areas. Each attribute that was found to be statistically significant should be helpful to policy makers to see the appreciation of forest dependent people for managing their resources. Additionally, the results showed that nearly 94% of respondents were willing to pay for harvesting their resources and sustainable rattan management in their communities with the majority of 3 USD per collection time. Thus, the government and

other stakeholders can use this approach for better management of rattan and species conservation for the benefit of poverty alleviation in rural economy.

In managerial terms, several implications for the planning and managing effectively from the results obtained in this study. First, it was observed that enrichment planting is the first preference so that they are keen on restoring and rehabilitation of their resources especially rattan. Second, it was also observed that their marginal willingness to pay value is 18.30 USD, 0.33 USD, 0.0587 USD and 0.7923 USD per month, respectively. It means that the local community and stakeholders are appreciating the benefits from sustainable rattan management. Third, among policy circle and the wide public, for long-term sustainability there is a need to look outside the public sector for additional funding for biodiversity conservation and environmental protection. Fourth, it is evident that the primary target should be the improvement of sustainable rattan management for the benefit of both conservation species and improve their living standard. Fifth, although sustainable management provides insufficient funds for the conservation and management activities suggested, the investigation of the local community shows the appreciation of the non-market value of all attributes for sustainable rattan management. Finally, local communities are strongly support in the participating of rattan management and these results should be contribute to the decision makers to define appropriated policy before implementing any projects.

Several research topics could follow up from this study in order to provide clearly insights into the application of CE especially investigating the effects of payment to revolving fund and the benefit from REDD+.

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Research article

Effect of Organic Materials from Agro-Industrial Wastes (Molasses and Distillery Slop) on Earthworms under Vermicomposting Using Cassava Waste

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Abstract The increasing of waste nowadays necessitates agro-industrial waste management, and vermicomposting technology has been offered as a viable method. However, before application of this method, a study of the effects of waste on earthworms is required. The objective of this study is to investigate the effects of organic material on earthworms as a result of the vermicomposting process. The experiment was conducted using completely randomized design with three replications. A toxicity test was administered to determine the effects of organic material (molasses and distillery slop from cassava industrial wastes) on the survival and growth of earthworms in vermicompost. The study found that after 7 days, 100% of the earthworms could survive under concentrations of molasses at rates of 1.25 - 3.75% and concentrations of distillery slop at rates of 6.25 - 25%. In addition, the application of organic materials (molasses and distillery slop) mixed with cassava industrial wastes increased the growth of earthworms. The earthworms had a survival rate of 67-100% after 4 weeks in the vermicompost treatment when molasses was mixed with cassava pulp and cassava peel, but without cassava pulp and cassava peel, the earthworms could not survive. Similar results were found with the application of distillery slop mixed with cassava pulp and cassava peel. Therefore, suitable rates of molasses and distillery slop use for earthworm survival are 1.25 - 3.75% and 6.25-25%, respectively. In conclusion, molasses and distillery slop can be used with cassava industrial waste material in the vermicomposting process.

Keywords organic material, earthworms, vermicompost

INTRODUCTION

Agro-industry has been expanding rapidly in developing countries in order to serve peoples' consumption. This expansion and its effects on the production process have led to increasing amounts of industrial wastes and environmental pollution. Vermicomposting technology was recently offered as a viable method for organic waste management. After decomposition of waste by earthworms, vermicompost is useful for agricultural sectors (Toncho, 2007; Iwai et al., 2011). The use of earthworms for organic waste management is considered a brilliant means for decomposition as their use is convenient and low cost. Vermicompost can be developed as high quality fertilizer and changes of chemical, physical and biological properties can be implemented. In addition, it has been found that vermitechnology produces more nutrients: 26-82% nitrogen, 90-94% phosphorus and 26-75% potassium (Iwai et al., 2011). Organic carbon is a food source that increases the growth and reproduction of earthworms and microorganisms in compost and is an important factor for organisms. A lot of molasses and distillery slop, currently, has been produced

from the sugar and ethanol industries.

OBJECTIVES

The objectives of this study are to investigate the effects on earthworms (*Eudrillus eugeniae*) of using organic material from agro-industrial wastes (molasses and distillery slop) for vermicomposting using cassava waste; to determine effects on the growth of earthworms; and to analyze the quality of vermitechnology fertilizer.

METHODOLOGIES

A toxicity test of organic material (molasses and distillery slop) to determine its effects on the survival of earthworms

A toxicity test of organic material (molasses and distillery slop) to determine its effects on the survival of earthworms was performed with concentrations of molasses at 1.25%, 2.5%, 3.75% and 5% and concentrations of distillery slop at 6.25%, 12.5%, 18.75% and 25% for a period of seven days. Earthworms (*E. eugeniae*) used for this study were obtained from Research Developing and Learning Centre on Earthworm for Agriculture and Environment. Adult earthworms (*E. eugeniae*) of weights ranging from 0.34 - 0.45 g and lengths ranging from 15 - 18 cm were placed in plastic containers divided into two sides with five earthworms per section. The control side was filled with 100 g dry weight of soil without contaminant and the other half of the plastic container was filled with organic material (molasses and distillery slop) in different concentrations with 100 g dry weight of soil. Survival rate of earthworms was observed and data was recorded every day.

A study of the survival and the growth of earthworms as affected by organic materials (molasses and distillery slop) mixed with cassava industrial wastes

This study included 4 sub-experiments with 4 different organic material combinations: 1) Molasses mixed with cassava pulp; 2) Molasses mixed with cassava peel; 3) Distillery slop mixed with cassava pulp; and 4) Distillery slop mixed with cassava peel. The ratio of cassava industrial wastes to soil to cow dung was 7:2:1. In each experiment, this ratio was mixed with concentrations of molasses at rates of 1.25%, 2.5%, 3.75% and 5% and concentrations of distillery slop at rates of 6.25%, 12.5%, 18.75% and 25%. This experiment used Completely Randomized Design (CRD) with three replications. Adult earthworms (*E. eugeniae*) of weights and length ranging from 0.34-0.45 g and length 15 cm-18 cm were released into plastic pot containers containing 100 g dry weight of soil with five earthworms per container. All the containers were kept at a temperature of $25 \pm 3\ ^{\circ}C$. The moisture content was maintained at 60–70% during the study period. Survival rates and weights of the earthworms were recorded before and after 30 days.

Statistical analysis: Differences among the treatments were assessed with analysis of variance using STATISTIC 8.

Table 1 Chemical characteristic of organic wastes

Parameters	Type organic wastes			
	Cassava pulp	Cassava peel	Molasses	Distillery slop
pH	4.95	5.45	4.9	4.51
EC (mS/cm)	0.67	1.25	8.18	30.85
Organic matter (%)	89.57	58	-	-
Total nitrogen (%N)	0.24	0.49	0.94	0.45
Phosphorus (%P)	0.025	0.051	0.18	0.043
Potassium (%P)	0.36	0.51	3.91	1.688

RESULTS AND DISCUSSION

A toxicity test of organic material (molasses and distillery slop) to determine its effects on the survival of earthworms

Toxicity tests of the various concentrations of molasses to determine its effects on the survival of earthworms found that 100% of earthworms could survive under molasses concentrations of 1.25 - 3.75%, but 73.3% of earthworms could survive under molasses concentrations of 5 %. In addition, the results of the different concentrations of distillery slop found that after 7 days of testing, 100% of earthworms could survive under concentrations of 6.25 - 25%. According to Toncho (2006), *E. eugeniae* can survive at pH 7.0 - 8.0, but molasses has a low pH of 4.9. It also has a high electrical conductivity (EC) of 8.18 (Sharma et al., 2007), which is considered to be very salty. Distillery slop was found to have an EC of 30.85 mS/cm, higher than molasses, but the earthworms could survive because the pH was decreased to neutral by fermentation (Pundee**,** 2006).

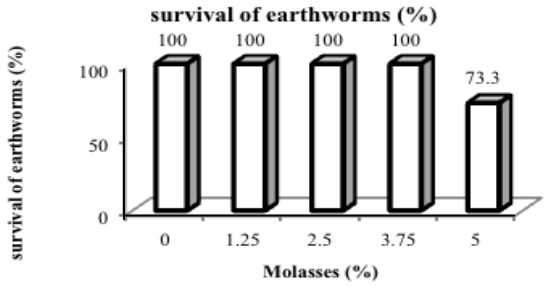

Fig.1. The % toxicity test of molasses on the survival of earthworms

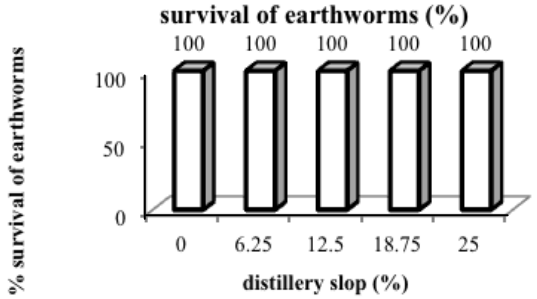

Fig.2. The % toxicity test of distillery slop on the survival of earthworms

A study of the survival and the growth of earthworms as affected by organic materials (molasses and distillery slop) mixed with cassava industrial wastes

The use of molasses mixed with cassava pulp and cassava peel: The results of both the use of molasses mixed with cassava pulp and mixed with cassava peel demonstrate that earthworm survival decreases with increasing rates of molasses concentration. After 4 weeks, 100% of earthworms could survive under molasses concentrations of 1.25% mixed with cassava pulp. Earthworms could not survive under concentrations of 5 % molasses. On the other hand, the study found that 100% of earthworms could survive molasses mixed with cassava peel under molasses concentrations between 1.25 - 2.50% but under molasses concentrations of 3.75 - 5 %, earthworm survival decreased to 55.56 - 33.33%. In other words, earthworms could survive under molasses mixed with cassava peel at higher rates than molasses mixed with cassava pulp. The cassava peel may have absorbed the molasses which would have decreased the toxicity of molasses (Cleasby, 1963). Earthworms could not survive 100% because the molasses has a high electrical conductivity (EC) of 8.18 mS/cm and a low pH of 4.9 (Pundee, 2006). According to Toncho (2006), *E. eugeniae* can survive at pH 7.0 - 8.0, so these characteristics of molasses are not conducive to the survival of earthworms.

The use of distillery slop mixed with cassava pulp and cassava peel: The results of the use of distillery slop mixed with cassava pulp and cassava peel showed that earthworm survival decreases with increasing rates of distillery slop concentration. After 4 weeks, 77.78% of earthworms could survive under concentrations of 6.25 - 12.5% of distillery slop. Under distillery slop concentrations of more than 18.75%, earthworms could not survive 100% because the distillery slop had a high electrical conductivity (EC) of 30.85 mS/cm and a low pH of 4.51 (Soongsud, 2008). The pH of cassava pulp was measured at 4.95 which is not conducive to the survival of earthworms. The use of distillery slop mixed with cassava peel found that earthworm survival declined with an increasing rate of cassava pulp concentration. However, earthworms could survive 100% under

concentrations of 6.25 -18.75% of distillery slop, but using distillery slop at concentrations more than 18.75% led to lower survival rates. Cassava peel can absorb distillery slop more than cassava pulp which decreased the toxicity of distillery slop.

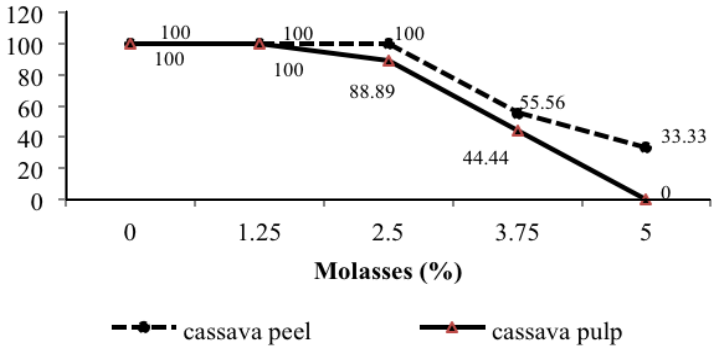

Fig. 3 The % survival of earthworms in the different concentrations of molasses mixed with cassava pulp and cassava peel

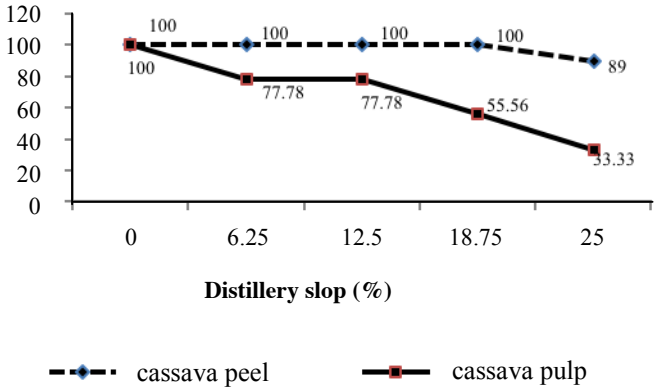

Fig. 4 The % survival of earthworms in the different concentrations of distillery slop mixed with cassava pulp and cassava peel.

CONCLUSION

The study of the survival of earthworms on organic materials (molasses and distillery slop) mixed with cassava industrial wastes found that the use of molasses mixed with cassava pulp or cassava peel at molasses concentrations lower than 2.5% resulted in an earthworm survival rate of 100%, but the use of molasses at concentrations more than 3.75% resulted in lower survival rates. On the other hand, cassava pulp mixed with distillery slop at 6.25-12.5% concentration levels of distillery slop promoted an earthworm survival rate of 77.78%. The use of distillery slop mixed with cassava peel, with distillery slop concentration levels of 6.25-18.75% promoted an earthworm survival rate of 100%. High concentrations of molasses and distillery slop have high electrical conductivity (EC), or salinity, which affects the survival of earthworms. Therefore the use of molasses and distillery slop should be kept at an optimum rate.

ACKNOWLEDGEMENTS

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Research article

Enhancing the Use of Value-Added Products from Underutilized Fruit of the Endangered Mabolo (*Diospyros blancoi*) Tree

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Abstract Mabolo fruit is from an endangered Mabolo tree in the Philippines. It is an ideal source of calcium, vitamin B, iron and protein and contains numerous phenolic compounds that provide powerful antioxidants. It is nutritious but it is underutilized as human food because of its unpleasant odor comparable to rotten cheese or cat feces and is covered with hair which is irritating to sensitive skin. Because of this, it got rotten, eaten by the birds, used as feeds to domestic animals and some were thrown as garbage. This study aimed to produce Mabolo Cake, Mabolo Boat Tart, Mabolo Fritters and Mabolo Pancake, and to determine their acceptability; to promote the nutritious products to the community; to introduce them to the entrepreneurs; and to encourage everybody to have in their snack boxes the value-added Mabolo products. This is an experimental study utilizing the five-point Hedonic scale in assessing the acceptability of the products in six sensory attributes; appearance, texture, odor, taste and overall liking. The products were assessed by twenty-five panelists. It was found out that Mabolo Cake and Boat Tart ranked first and second respectively in six sensory attributes, with a rating within the range of Like Very Much while Pancake ranked third with a descriptive rating of Like in all attributes. Fritters ranked fourth in all attributes with descriptive rating of Like in appearance and taste and Neither Like nor Dislike in Texture, Odor and Overall Liking. It can be concluded that the products are generally acceptable. Proper promotion of Mabolo products can on one hand provide useful livelihood source while in the other hand provide incentive for communities for protecting the endangered tree.

Keywords mabolo tree, mabolo cake, mabolo boat tart, mabolo fritters, mabolo pancake, hedonic scale sheet

INTRODUCTION

Mabolo (*Diospyros blancoi*) is an evergreen forest tree that belongs to the *Ebenaceae* (Ebony) family. In the Philippines, it is commonly identified by its wood locally known as *Kamagong*. Because it is iron-like and nearly unbreakable, *Kamagong* is popularly called "iron-wood" and is often used for furniture and carved into hair combs and knife handles (Bilton, 2012).

Like Narra and Molave, *Kamagong* is a premium wood. It is protected by Philippine laws by regulating its extraction from the forest through a Special Private Land Timber Permit issued only by the Secretary of the Department of Environment and Natural Resources (DENR, 1990). Its economic value however undermines such regulation so that by 2007, DENR issued Administrative Order No. 01 declaring Mabolo Tree/*Kamagong* as one of the critically endangered species.

Mabolo bears fruit that is about the size of an apple. Its skin that turns into purple or maroon when ripe is covered with hair. Its seeds are contained in its pulp.

The fruit itself lacks sweetness and is rather dry. However, it is highly nutritious. It is an ideal source of calcium, vitamin B, iron, and protein. Research shows that it "contains numerous phenolic compounds that provide powerful antioxidants (Alvarez, 2012)."

The pulp of the Mabolo fruit emits a strong cheesy odor when opened thus, while bats, birds and domestic animals feed on it, humans shy away from its foul odor leaving it to rot and be

thrown away. This makes Mabolo fruit unpopular and underutilized for human consumption despite its rich nutritive value.

It is in this context that the researcher was inspired to discover recipes using Mabolo fruit. Acceptable Mabolo food products will lead to the utilization of the fruit as ingredient of human food thereby increasing its economic value. This will in turn encourage protection and propagation of the tree that has been mainly cut down for furniture or ornamental use of its wood.

Producing value-added food products from the underutilized fruit of the endangered Mabolo tree reinforces the implementation of the Forestry Laws of the Philippines. Specifically, it supports Presidential Decree No. 705 that calls for the "protection, rehabilitation and development of forest lands" to ensure continuity of productivity. Mabolo fruit food items could encourage locals to utilize Mabolo fruits instead of its wood as an alternative source of livelihood and thereby preserve and protect Mabolo trees. Likewise, this study generally supports the 1987 Philippine Constitution. The use of Mabolo fruit as an ingredient to food products that become additional food items and the bases for manufacturing and production directly responds to Section 10 Article 14 that encourages and prioritizes research and development for the country's "productive and national life (Nolledo, 2009)."

As a development of food recipe, this study involves fortification or enrichment process which the Food and Agricultural Organization (FAO) of the United Nations define as "the addition of one or more essential nutrients to a food whether or not it is normally contained in the food (Codex Alimentarius, 1991)." The addition of shredded Mabolo fruit to the basic cake and pancake recipes; putting Mabolo filling to tart; and making fritters from Mabolo fruit increase nutrients and therefore enhances the value of the food products.

The researcher fully believed that this study can significantly benefit the following:

Mabolo Growers. The findings of this study will make them realize that food products aside from wood can be a source of income from Mabolo trees. This will refrain them from cutting and encourage them to grow more Mabolo trees.

Community**.** Mabolo fruit products which are highly nutritious are good additional items to the people's snack or meal.

Entrepreneurs. This study provides them with the recipe of the value-added products of Mabolo fruit. It could enable them to mass produce new food items for another income.

Bureau of Forestry and the Department of Environment and Natural Resources of the Philippines. As Filipinos could potentially be encouraged to protect and propagate Mabolo tree in their locality, this study will support these two Philippine government agencies in enforcing the law to protect the endangered Mabolo tree.

Food Technology Teachers and Students. The results of the study will inspire them to continue to experiment and come up with more recipes utilizing Mabolo fruit.

OBJECTIVES

The study aimed to determine the acceptability of the value-added products of Mabolo fruit developed at Bohol Island State University, Main Campus, Tagbilaran City, Bohol, Philippines for Academic Year 2011-2012. It also aimed to introduce the food items from the seemingly worthless Mabolo fruit to the community, to entrepreneurs and to consumers in general.

METHODOLOGY

This study used experimental method in formulating the recipes. After perfecting the recipes, the finished products were subjected to sensory appraisal which is the scientific method to evoke, measure, analyze and interpret reaction to those characteristics of food materials as they are perceived by the senses of sight, smell, taste, touch and hearing. In this study the finished products were evaluated by the panelists using the five point Hedonic scale sheet.

This study was conducted in the Food Technology Laboratory of Bohol Island State University Main Campus, Tagbilaran City. Twenty five individuals who were chosen through

purposive sampling were the panelists/participants of this study. They were the fifteen third year students from Bachelor of Science in Industrial Technology who come from rural communities, the five Food Technology instructors and the five Food Technology graduates who are now practicing their craft in rural communities. They were selected because of their expertise in food preparation and processing. The researcher used the 5-point Hedonic Scale comprising – 5- Like Very Much, 4- Like, 3 Neither Like nor Dislike, 2 Dislike and 1- Dislike Very Much was constructed based on the work of Gatchalian et el. (2009). It was pilot tested to the second year Food Technology students who were not the actual panelists of the study. After making the necessary improvement, it was then finalized and reproduced for the purpose of the study.

After recipes utilizing Mabolo fruit were perfected, they were prepared and food products were subjected to evaluation in three trials. The first trial was done right after cooking while the products were still hot; the second was in the afternoon when the products were already cold and the third was in the following morning. Different trial times were intended to identify possible change in the ratings of participants. The Hedonic scale was used in the evaluation. The weighted mean derived from the assigned numerical and descriptive ratings was the basis of analysis.

Table 1 Range used to evaluate Mabolo food products

Numerical Ratings	Description
4.50-5.00	Like Very Much
3.50-4.49	Like
2.50-3.49	Neither Like nor Dislike
1.50-2.49	Dislike
1.00-1.49	Dislike Very Much

Source: The range is adopted from the 5-pont Hedonic Scale of M. Gatchalian.

Table 2 Mabolo fruit Products and Recipes

Name of Product	Recipe
Mabolo Cake	Beat 2 pieces eggs; add ¼ cup oil and ¾ cup sugar. Blend the mixture for 30 seconds. Mix together 1 cup all purpose flour, ½ teaspoon baking soda and 2 teaspoons baking powder. Add the mixed dry ingredients to the egg mixture then add ¼ cup evaporated milk and the 1 cup shredded mature Mabolo fruit and blend well. Add 1 teaspoon vanilla. Pour the mixture into a well-greased 31/2x9x3 inches loaf pan. Bake at 350 degrees Celsius until done. Remove from oven and allow to cool. Slice and serve.
Mabolo Boat Tart	Tart filling: In a bowl, mix together 1 big can condensed milk, 1 cup all purpose flour, 1 teaspoon vanilla, 1 piece egg, 1 cup shredded Mabolo fruit, ¼ cup peanuts and ¼ butter. Mix well and cook in a double boiler until mixture spreads consistently. When done, remove from fire and allow to cool. Set aside. Crust: Cream 1 cup butter until floppy. Add ¼ cup butter until floppy. Add ¼ cup sugar and 1 piece egg, beat well. Add 1 cup flour and mix well. Mold in well-greased tart shell molder. Bake until done. Fill the crust with tart filling. Wrap in colored cellophane.
Mabolo Fritters	Cut mature Mabolo fruit into serving pieces about 1/3 inch thick. Slightly dust the fruit with flour. To make the batter, sift 2 cups flour, ¼ cup sugar and 1 cup water and beat to form a smooth batter. Stream before using. Dip fruit into batter and fry in hot oil until golden brown. Drain excess oil. Arrange on serving platter. Sprinkle with sugar.
Mabolo Pancake	Sift together 2 cups flour, 1 teaspoon salt and 2 teaspoons baking powder. Beat 2 pieces eggs and add to flour mixture. Mix 1 cup evaporated milk, flour mixtures and ½ cup butter. Add three cups shredded mature Mabolo fruit and blend. Pour 1/2 cup of mixture into a shallow pan brushed with oil. Pan-fry until golden brown. Serve with syrup or honey.

***Perfected recipes after several trials conducted by the researcher in the university laboratory.*

RESULTS AND DISCUSSION

Acceptability of food is usually based on sensory attributes such as appearance, texture, odor, taste, and overall liking. Appearance attribute includes color, size and shape. Texture covers the feel and touch sensation and the viscosity and consistency of the product. On the other hand, the odor refers to the smell while the taste refers to sweetness, bitterness, sourness, and saltiness of the snack item. In this study, Mabolo snack products were assessed based on the cited five sensory attributes.

First sensory evaluation result

The results of the first sensory evaluation show that Mabolo Boat Tart was rated highest in appearance and texture liking at 4.75 and 4.78 respectively. Both ratings have the qualitative description of Like Very Much. This is favorably influenced by the boat-like shape of the crust of the Tart and its crunchiness and flakiness that caught the attention of the panelists.

Mabolo Cake was rated highest in odor and taste attributes at 4.86 and 4.56 respectively. Both have the qualitative description of Like Very Much. Odor and Taste sensations are the attributes of flavor which determine the acceptance or rejection of a food product (Gatchalian, 2009). In this study therefore, Mabolo Cake is highly acceptable in flavor.

Among the food products, Mabolo Fritters is rated relatively lowest in all sensory attributes. However, all the rates have the corresponding qualitative description of Like while its Overall liking is Neither Like nor Dislike. This makes the fritters still generally acceptable.

The first sensory evaluation was carried out right after production of the food items.

Second sensory evaluation result

Results of the second sensory evaluation reveal that Mabolo Cake has the highest rates in texture, odor and taste attributes while Boat Tart is rated highest in appearance and overall liking. Consistent with the first evaluation, Mabolo Pancake and Mabolo Fritters were rated third and fourth, respectively in all sensory attributes both with the qualitative description of Like.

This evaluation was done after the food items were allowed to cool.

Third sensory evaluation result

Third evaluation results identify Mabolo Cake being rated highest in appearance. This could be favorably brought about by the enhanced appearance of the cake that attracted the panelists due to the shredded Mabolo fruit grains that became noticeable when the product was allowed to cool. Overnight, the good taste developed while the texture remained soft so that the cake was likewise rated highest in texture and taste liking. Meanwhile, Mabolo Tart was relatively rated highest only in odor attribute at 4.28.

Of the four products, Mabolo Fritter has the least rate in five sensory attributes. It has an overall qualitative rating of Neither Like nor Dislike which may be brought about by the appearance, texture and odor of the product after one day. Upon examination, the product shrank, became crumbly; the odor of the Mabolo fruit became noticeable and the taste changed as the oil started to appear in the surface.

Overall result of the three sensory evaluations

Putting together the results of the three evaluations, Mabolo Cake consistently ranked first, followed by Mabolo Boat Tart, then Mabolo Pancake and Mabolo Fritters. None of the four value-added Mabolo products were rated Dislike or Dislike Very Much.

Table 3 Overall rating of the three sensoryevaluations

Product	Evaluation			Overall Rating	Description	Rank
	1st	2nd	3rd			
Appearance Liking						
Mabolo Cake	4.57	4.8	4.88	4.75	Like Very Much	1
Mabolo Boat Tart	4.75	4.87	4.6	4.74	Like Very Much	2
Mabolo Fritters	4.0	4.0	3.16	3.72	Like	4
Mabolo Pancake	4.0	4.16	4.16	4.11	Like	3
Texture Liking						
Mabolo Cake	4.17	4.14	5.0	4.44	Like	1
Mabolo Boat Tart	4.78	4.13	4.0	4.30	Like	2
Mabolo Fritters	3.80	3.6	3.0	3.46	Like	4
Mabolo Pancake	4.00	3.8	4.0	3.93	Like	3
Odor Liking						
Mabolo Cake	4.86	4.75	4.0	4.54	Like Very Much	1
Mabolo Boat Tart	4.29	4.6	4.28	4.39	Like	2
Mabolo Fritters	3.63	3.83	3.0	3.49	Neither Like Nor Dislike	4
Mabolo Pancake	4.02	4.17	4.0	4.06	Like	3
Taste Liking						
Mabolo Cake	4.56	4.56	5.0	4.71	Like Very Much	1
Mabolo Boat Tart	4.5	4.43	4.14	4.36	Like	2
Mabolo Fritters	3.8	3.75	3.0	3.51	Like	4
Mabolo Pancake	4.0	4.0	4.0	4.0	Like	3
Overall Liking						
Mabolo Cake	4.88	4.5	4.13	4.50	Like Very Much	1
Mabolo Boat Tart	4.67	4.57	4.25	4.49	Like Very Much	2
Mabolo Fritters	3.6	3.75	3.0	3.45	Neither Like Nor Dislike	4
Mabolo Pancake	4.17	4.25	4.0	4.14	Like Very Much	3

Shelf life

Samples of the products were allowed to stand at room temperature to observe the changes that may take place. Fritters and Pancake were observed to have oil appearing on the surface on the second day but they were still edible. On the third day, they were already watery and should be discarded as molds began to appear. The cake on the other hand, had changes on the third day as the texture began to soften and molds appeared on the fourth day which makes it unfit for human consumption. Only Boat Tart survived until the seventh day.

Boat Tart thus ranked first in shelf life as it lasted for seven days. It was followed by cakes, pancakes and fritters which can only be eaten safely until the second day. However, remedy can be done in cake since it can still be toasted to last for a little longer and can be stored for future use.

Marketability

The four value-added products from Mabolo were displayed at the school cafeteria of Bohol island State University Main Campus for sale. It was observed that in one week's display of the products, cakes, pancakes fritters and boat tarts were all sold. It was noted that the product were saleable among people of all ages since the products were bought by faculty members and college and high school students. Fritters and pancakes were the favorites of high school students while it was observed that faculty members ordered cake and boat tart as their present for their children and loved ones.

CONCLUSION

Mabolo fruit can be eaten by any person without noticing its unpleasant smell. Its foul cheesy odor can be dissipated by removing the skin and by processing it adequately. It can therefore be fully utilized as food for humans and not only as animal feeds.

Snack items from Mabolo fruit were generally acceptable and they can be made more nutritious with other flavorings.

It is recommended that dissemination of this study be done to promote the use of Mabolo fruit for food items. This should specifically be introduced as an alternative source of livelihood in the rural community where Mabolo trees are still found in substantial number. The snack items are nutritious and easy to prepare. Mabolo Cake and Mabolo Boat Tart can be cooked with the use of native or clay oven while fritters and pancake can be cooked using frying pan or *carajay* which are the commonly used kitchen equipment and utensil in those areas.

This study should also be disseminated to entrepreneurs. The nutritive value and availability of fruit supply could convince them to mass produce the food items for commercial purposes.

Finally, food technologists should be informed of this study to inspire them to conduct experiment for other products that could be derived from Mabolo fruit.

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This research undertaking comes into fruition with the kind assistance from Bohol Island State University administration, Faculty and Food Technology students. In particular, the researcher is grateful to Dr. Elpidio T. Magante, CE, Ed.D., University President, for the permission and warm support in the conduct of the study. Acknowledgement is likewise due to Prof. Lucia J. Poyos, her research assistant.

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Research article

Pilot Case Studies of Climate Risk-coping Strategies of Small-scale Farmers in Cambodia

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Abstract Climate predictions for Cambodia are for increases in temperatures and rainfall with the likelihood of wetter monsoon seasons and less rainfall in the dry seasons. Developing countries such as Cambodia have few resources and capacity to adapt to climate change and are therefore considered to be the most vulnerable. Attention so far in Cambodia has focused on technical interventions and disaster relief rather than on planned adaptive responses. The aim of this study was to gain insights on how individual farm households cope with and adapt to climate variability and change. Here we present the results of pilot case studies to document climate risk-coping strategies currently employed by small-scale rice farmers in Cambodia. Community consultations and in-depth interviews with selected participants were conducted in the Communes of Trapeang Ruessei in Kampong Thom Province and Snam Krapeu in Kampong Speu Province in 2011. Data were collected by writing down notes to form the basis of the respondent's narrative. Two in-depth interviews were done in each Province. It was immediately obvious from the narratives that the households studied could not survive from on-farm income alone especially during droughts. Our pilot interviews indicated that off-farm income might be the predominant coping strategy in the rice-based farming system. There appears to be a need for researchers and policy makers to shift from an agricultural systems/commodity mind-set to a household livelihood mind-set with regard to the ability of households to cope with climate variability and climate change. A complete breakdown of household income sources is an essential baseline requirement before an assessment of climate change resilience in the rice-based system can be made. A baseline assessment of vulnerability at the household level should be considered an essential prerequisite for developing research priorities and designing interventions.

Keywords climate change, adaptation, risk, vulnerability, household, livelihood

INTRODUCTION

Climate predictions for Cambodia are for increases in temperatures and rainfall with the likelihood of wetter monsoon seasons and less rainfall in the dry seasons. Temperature is expected to rise by 0.7 to 2.7 °C by the 2060s and annual rainfall to increase with shorter-wetter rainy seasons and longer-drier dry seasons (Mac Sweeny et al., 2008). Anecdotal evidence suggests the frequency and intensity of floods, droughts and windstorms have increased in Cambodia since the year 2000 (NAPA, 2006).

Developing countries such as Cambodia have few resources and capacity to adapt to climate change and are therefore considered to be the most vulnerable (McCarthy et al., 2001). In response, The Cambodian National Adaptation Programme of Action to Climate Change (NAPA) was established in 2006 (NAPA, 2006). However, as with elsewhere in Southeast Asia, attention so far in Cambodia has focused on technical interventions and *ex post* disaster relief rather than on planned (*ex ante*) adaptive responses (Resurreccion et al., 2008).

Researchers are now beginning to give attention to climate change adaptation in Cambodia (Roth et al., 2009). However, the emphasis remains on exploring agricultural enterprise interventions without reference to the climatic risk-coping strategies that are currently being employed at the household level. This is consistent with the conventional narrow focus on exploring changes to the agricultural enterprise mix on-farm and excluding non-farm activities and income (Ellis, 2000). Sakurai (2009) posed that from the viewpoint of resilience, it is important to investigate how a farm household copes with shocks that negatively affect income. It was found that most of the households studied in Zambia used non-agricultural work as an *ex post* risk-coping strategy to respond to crop production shock in the previous cropping season.

OBJECTIVE

The aim of this study was to gain insights on how individual farm households cope with and adapt to climate variability and change and the basis for decision making at the household level.

METHODOLOGY

During 2011, a pilot project was conducted to evaluate options for improving adaptive capacity for climate variability and climate change in Cambodian rice-based systems. Community consultations were held in the Communes of Trapeang Ruessei in Kampong Thom Province and Snam Krapeu in Kampong Speu Province. The purpose of the consultations and in-depth interviews was to gain an insight into the current climate risk-coping strategies of small-scale farmers in Cambodia. Community consultations were held with 30-40 farmer participants at each Commune. The consultations were conducted according to guidance and monitoring by commune officials. On completion of the group consultations, in-depth interviews were conducted with volunteer participants. The methods were adapted from Roth (2008) and Ramamasy and Baas (2007).

The in-depth interviews were informal and included timeline analysis and narrative. The timeline analysis helped draw out a narrative from the respondent on the events leading to good times, successes, bad times and failures. Questions were structured to draw out information on the household's ability to cope with climatic events. The questions included: what was the reason for success; how did they cope/adapt; and reasons for not coping/adapting.

It was expected that this process could identify opportunities to improve coping/adaptive capacity. Some of the key driving forces could include health, climatic events, access to resources, assistance and new technology. Data were collected by writing down notes to form the basis of the respondent's narrative. Two in-depth interviews were done in each Province. A 0-100 scoring system was used for scaling time line events and for proportioning household income.

RESULTS AND DISCUSSION

Ms. Yam Pon, Kampong Thom Province: Ms. Yan Pon, 43, lives in Trapeang Krasang Commune, Kampong Thom Province. Her village, is a small distance from the Kampong Thom capital. There are six members of the household. Yam Pon's timeline is strongly affected by family tragedy with the death of her husband in 1996; her grandmother in 2001; a brother in 2004; and her youngest brother in 2010 (Fig. 1). Her life has been very difficult since her husband passed away as this made her the primary supporter for the household.

On the positive side, her 1995-2001 rice income enabled her to buy an extra 0.5 ha of land. From 2001-2008 her income increased after she got a job in Phnom Penh as a garment factory worker. She received USD 40-100 per month from the off-farm work. Her cousin is also working off-farm as a hotel cashier with a monthly income of USD 80.

By 2006, Yam Pon's income from work at the garment factory had raised the quality of life in the household. In 2009 her income from rice and livestock enabled her to buy a new motorbike. In 2010, the rice yield enabled her to buy another 0.5 hectare of land. Yam Pon has health problems

and when she gets sick she cannot work and her son and aunt need to work on her behalf.

Yam Pon's soil is sandy and poor in nutrients, she grows rice one time per year in the main wet season but growing rice can be affected by drought. The average rice yield is about 1 - 2 t/ha. She has two hectares of land and harvests around 3 tonnes of rice each year.

Yam Pon has access to finance at 1.5% per month. This is considered to be a very low interest rate for households with low income. The common interest rate within the region is about 3% per month. Her family income is derived from rice, other crop, livestock (four cattle), and on-farm and off-farm labour. She and her cousin migrate off-farm for work in times of drought. The average income for the family is around USD 40-70 per month.

In summary, when Yam Pon is faced with disasters such as drought or flood, she resorts to off-farm activities to gain income to support her family. Thus it is very hard for her to cope with the problems. To support her family, she would like to increase her rice yield and expand other sources of income.

Mr. So Chhoey, Kampong Thom Province: Mr. So Chhoey is 55 years old and a key farmer living in Serei Vong village, Trapain Russei Commune, Kampong Svay District, Kampong Thom Province. He has nine children with five already married and four remaining in his household. In 1995, after he stopped working as a soldier, his livelihood was difficult but not so serious (Fig. 1). He mainly relied on rice and a small income from livestock and vegetables. Growing rice is mainly for household consumption. If the rice yield is high, then the surplus can be sold; however, if the rice yield is low, the household needs to buy rice to make up the deficit.

In 2000, due to sickness in the whole household, their livelihood was very badly affected. They received a very low yield of rice because of insufficient labour to maintain the crop. To survive, he borrowed money from rich local people at high interest rates and sold some property. He also rented some land from a neighbour to grow vegetables for one season.

In 2005, Chhoey's livelihood improved because the health of the household improved. At that time, he had received some support that enabled him to earn some money from various agricultural activities such as vegetables, fish and fruit trees. However, his livelihood was not much better because he had two years of drought. His rice crops during that time completely failed. His family was dependent on homestead activities of vegetable, fish, fruit trees and livestock production.

In 2010, things were good and Chhoey's standard of living improved. He had learned and adopted some agricultural techniques which provided him with greater yield compared to his traditional practice. In conclusion, his life has not been easy and he has had to cope with many difficulties. When he is faced with drought, he is dependent on homestead activities and his income is reduced.

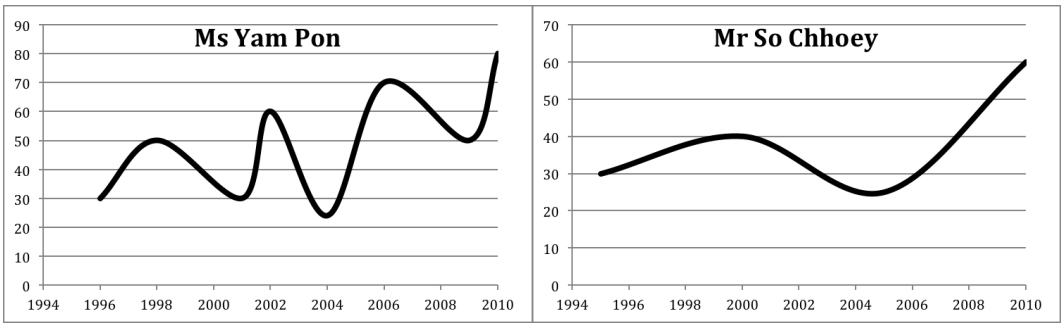

Fig. 1 Timelines for Ms. Yam Pon (left) and Mr. So Chhoey (right)

Ms. Keo Sokhom, Kampong Speu Province: Keo Sokhom is 50 years old, and a key farmer living in Snam Krapeu Commune, Kampong Speu Province. She has two daughters. In 1995 her livelihood was difficult but not so serious. It was mainly reliant on livestock (cattle), rice and vegetable.

In 1996, due her mother's sickness, her livelihood was difficult because she had to spend a lot of money on medical treatment and other expenditure for the household (Fig. 2). They received

very low yield from their rice because of insufficient labour to maintain the crop. To survive, she borrowed money at high interest rates.

In 1998, her livelihood was a bit better because the general household health had improved although her sister remained sick. At that time, she worked at needle craft which enabled her to earn some money. Her daughter also commenced migrant labour at a garment factory in Phnom Penh. Her husband is disabled but can take the cattle to grass fields off-farm. Her livelihood has been made difficult because of successive droughts and floods (1999-2004).

Droughts and floods resulted in almost complete failure of the rice crop and loss of productivity from livestock. During these times, her household was dependent on migrant labor and livestock and some on homestead activities of vegetable or fruit tree. Her land is less than 1 hectare which produces enough rice for family consumption but no surplus to sell.

In 2010, things were better and Sokhom's standard of living was improved. She had learned some new agricultural techniques that resulted in better yield compared to traditional practice.

In conclusion, Sokhom's life is not easy and she has to cope with many difficulties. When she has a problem with drought, she depends on off-farm income and homestead activities. The biggest challenges for her life are drought and flood.

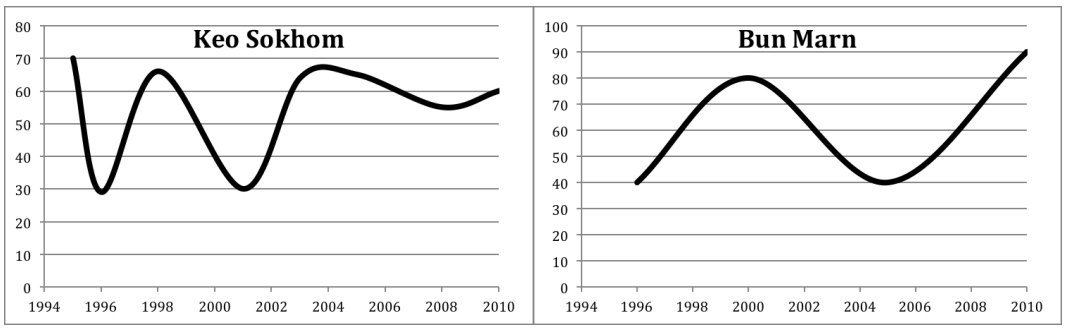

Fig. 2 Timelines for Ms. Keo Sokhom (left) and Mr. Bun Marn (right)

Mr. Bun Marn, Kampong Speu Province: Bun Marn is 42 and lives in Cham Bok Khae village, Toek La Ok Commune, Kong Pisey District, Kampong Speu Province. There are five members in the household, two daughters, one son, his wife and himself. He stopped studying after he was in grade 7 of the secondary school. His village is a long way from Kampong Speu capital and it takes around one hour to travel there.

Bun Marn's health is not good and when he falls ill, he cannot work, and this is a major problem because his whole family is dependent on him (Fig. 2). In addition, his medication costs around USD 40 per year with the total cost for family health care being about USD 75-100 per year.

The soil is a sandy loam poor in nutrients and he can grow only one rice crop per year in the main wet season. He would like to grow rice two times per year but there is not enough water. The average rice yield is about 1 - 2 tonnes per hectare. He has only 0.4 hectares of land and receives a rice yield of around 800 - 900 kg. Within the village, there is no irrigation infrastructure or water resources. But in some other villages within the commune, some channels have been dug by government projects. Marn has access to credit but with an interest rate of 3% per month which is considered excessive for people on low incomes.

Marn's family income is derived from rice, motor taxi, small store and making Khmer noodles. He doesn't do off-farm labour or migrate for work. He has one cow which has not yet produced a calf. In the past, he had several cows but sold all because he needed money for family medical expenses. The household has a small number of chickens. He does not keep pigs because it is hard to supply feed. The average income for the household is around USD 40 – 50 per month.

When Marn is faced with disasters such as drought or flood, he is forced to resort to off-farm activities to gain income to support the household. He has also had to mortgage his farm to get a loan during periods without income. To support his family, he has had to increase the time driving his moto-taxi and expand other sources of small income.

Discussion

Ellis (2000) contended that most rural families have multiple income sources including off-farm wage work in agriculture, non-agricultural wage work, trading and remittances from urban areas and from abroad. In sub-Saharan Africa, between 30 and 50 per cent of household income is derived from non-farm sources (Ellis, 2000).

A similar situation exists in Cambodia. A survey of households in Preah Nipean and Angk Popel Communes in Kampong Speu Province in 2011 showed that the average number of persons per household was 5.65 with 55 percent of households owning less than 0.5 ha of land, 35 percent having a non-farm business, 67 percent reliant on credit and 88 percent receiving remittances from migrant labour. Clearly these households do not have the capacity to survive on agricultural pursuits alone even during periods of favourable climatic conditions.

It was also immediately obvious from the narratives of respondents in our study that their households could not survive from on-farm income alone especially during droughts. We therefore introduced retrospectively, a question about the income sources that the household relied on. This yielded the dramatic results presented in Fig. 3. Three of the four farmers relied heavily on off-farm income during periods of climate stress and this ranged up to 93%.

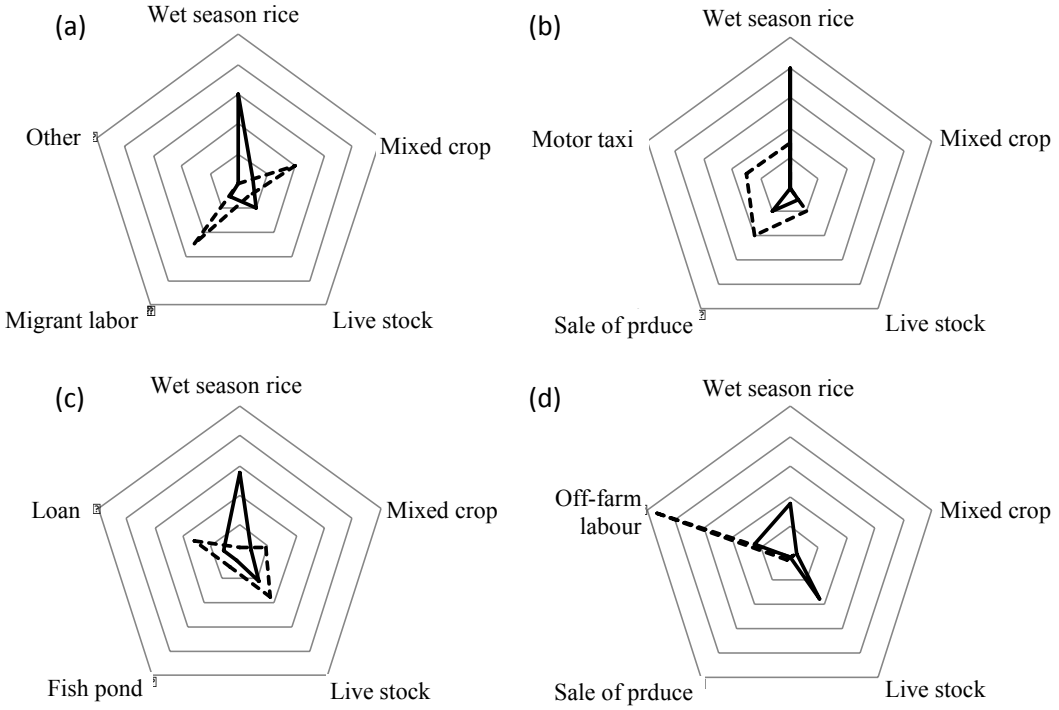

Fig. 3 Sources of household income in normal and drought years for Yam Pon (a), So Chhoey (b), Keo Sokhom (c) and Bun Marn (d). Normal year (solid line), drought year (dotted line).

CONCLUSION

In-depth farmer interviews revealed that coping strategies of households in "the rice-based farming system" did not always include rice or on-farm diversification options. Production from other crops, chickens, pigs and cattle suffer in the drought the same as the rice. There appears to be a need for researchers and policy makers to shift from an agricultural systems/commodity mind-set to a household livelihood mind-set with regard to the ability of households to cope with climate variability and climate change. In the in-depth interview pilot case studies, the rice-based system appeared to be systemically inadequate to cope with regular droughts.

It appears that natural disasters such as drought and poor health are causing significant livelihood problems for Cambodian rural households. To cope with the difficulties, some household members migrate for off-farm income, while others diversify their agricultural crops and livestock in order to secure their income. Based on this case study, access to micro-finance at reasonable interest rates would greatly assist rural households especially to reduce the impact of natural disasters and family sickness.

Access to better health care and health information is crucial. The households interviewed appeared to be having serious problems with their heath and are spending significant amounts of money on medication. Construction of irrigation infrastructure where appropriate could help farmers in coping with drought.

The concept of a "rice-based system" in the Cambodian rainfed lowlands appears to be a dogmatic construct which seems to have been unquestioningly accepted by researchers and policy makers with the potential for application of inappropriate interventions. Although the majority of farmers in the Cambodian rainfed lowland grow rice, it is not possible to determine from national statistics the proportional contribution that rice makes to the household income.

A complete breakdown of household income sources is an essential baseline requirement before an assessment of climate change resilience in the "rice-based system" can be made. A baseline assessment of vulnerability at the household level should be considered an essential prerequisite for prioritizing research projects and designing interventions.

ACKNOWLEDGEMENTS

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Research article

Improving delivery of technical information to farmers in North - Western Cambodia

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Abstract This paper presents the results of a survey of farm households carried out in North-Western Cambodia in early 2012 to gather baseline data for a new agricultural production and marketing research project. One of the objectives of the survey was to refine dissemination and communication strategies for project outputs and delivery of planned impacts. The survey gathered information about maize production issues, sources of information, training needs, as well seeking to identify ways to improve the delivery of relevant technical information and research findings to individual farmers. The survey revealed that farmers rely almost completely on each other for information about maize inputs especially seed for sowing and herbicides. The majority of training (68%) was provided by Non-Government Organisations (NGOs) with Provincial Departments of Agriculture (PDAs) providing 10% and input suppliers 7%. We put forward a conceptual communication and dissemination strategy that could be used to promote adoption of project results. It involves integrated roles based on comparative strengths for public, private and non-government organizations to achieve adoption of new technologies and better practices by farmers.

Keywords dissemination, communication, impacts, adoption, pathways

INTRODUCTION

Historically, in developing countries, governments assumed responsibility for agricultural extension but during the last 10-15 years, governments and international donors have reduced their investment in agricultural extension. Filling the void, non-government organisations and the private sector have become important alternatives to public agricultural extension (Swanson and Samy, 2002). This is also the case for agricultural extension in Cambodia.

In Cambodia, public sector agricultural extension is focused on the provision of an extension system rather than an extension service with a system being put in place by the Ministry of Agriculture, Forestry and Fisheries (MAFF) down to the District level (Anon., 2000). Transfer of information at the Commune and Village level is expected to occur through farmer to farmer links with District extension staff acting as facilitators in the process. However, there is evidence to suggest that this system is not functioning (Anon., 2010).

Such a system would require strong links between the extension department and other providers such as other government departments, private sector organizations, farmer organizations, international donors and NGOs (Anon., 2000). According to Cambodia's Strategy for Agriculture and Water (Anon., 2010), MAFF lacks the facilities and networks to disseminate technologies, and the linkages between research, development and extension remain weak. Hence, extension services

are weak overall, and farmers have limited awareness of and access to agricultural management technologies, and poor skills in agricultural production.

OBJECTIVES

This paper presents the results of a survey of farm households carried out in North-Western Cambodia in early 2012. One of the objectives of the survey was to refine dissemination and communication strategies for outputs and delivery of planned impacts in a new research project funded by the Australian Centre for International Agricultural Research (ACIAR).

METHODOLOGY

The survey gathered information about maize production issues, sources of information, training needs, as well as examining ways to improve the delivery of relevant technical information and research findings to individual farmers. The survey involved 832 farm households in Samlout District in Battambang Province (455 households) and Sala Krau District in Pailin Province (377 households). Three Communes were selected in each District on the basis of the density of households growing maize. In Samlout the Communes selected were Mean Chey, Samlout and Sung encompassing five Villages in each Commune. In Pailin the Communes selected were Sala Krau, Stueng Kach, and Ou Andoung and five villages were surveyed in each Commune (Fig. 1).

The farmers were interviewed individually based on invitations referred to by the Commune Chief in each Commune within each District and through collaboration with the previous ACIAR project partners. The farmers were assembled at a common area each day and the interviews were performed by a team of two interviewers per farmer.

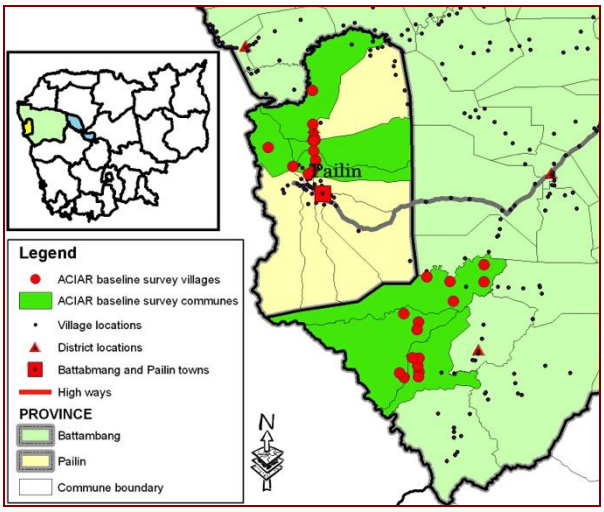

Fig. 1 Geographic location of communes and villages included in the survey

RESULTS AND DISCUSSION

Household profiles

On average in the study population, there were 5.25 people per household, of which 3.13 were working age adults. The average area of cropped land per farm was 4.21 ha (4.04 ha in Sala Krau and 4.35 ha in Samlout). In terms of wealth ranking, only 11% of the interviewed households considered themselves as 'better-off', 64% as 'average' and 25% 'as poor'. Female-headed households tended to be marginally poorer and more economically vulnerable and among them 32% were poor, 60% average and 9% were better off. 65% of households have not had any

technical training, while 33% said they have had some training in maize production.

Cropping practices

Samlout and Sala Krau had distinctly different cropping patterns. Both had a similar proportion of the farm under maize (62-63%). However the crop diversity was much greater in Samlout with 25% of the cropped area planted to legumes (mungbean, soybean, peanut). In Sala Krau, these desirable rotation crops have been largely replaced by expansion of cassava (26%) since 2009. The reasons behind the diverging cropping practices between the two Districts will be studied in the new project.

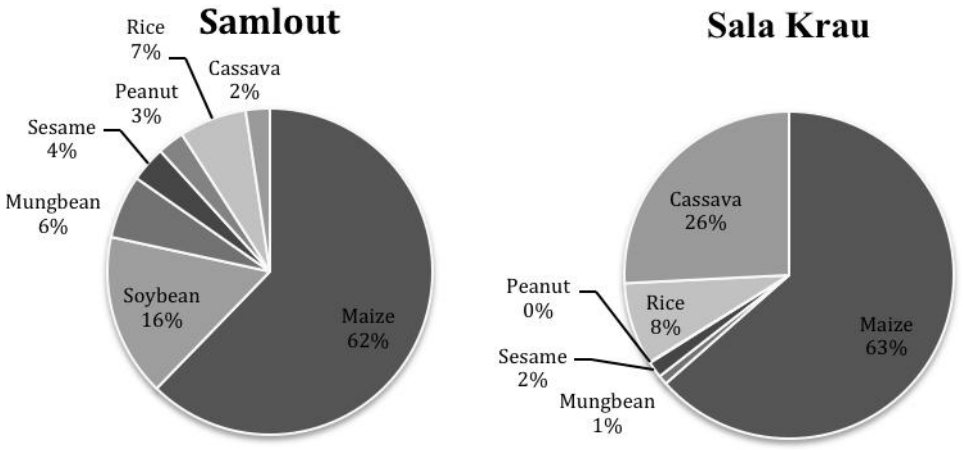

Fig. 2 Area devoted to different crop species on the farm (%)

Source of information about maize production inputs

Close to 100% of the farming households in both Samlout and Sala Krau purchased both seed and herbicide for the main wet season (MWS) crop in 2011. Very few farmers used fertilizer, fungicide or insecticide. In both Samlout and Sala Krau farmers are most likely to source their crop inputs from "Village sellers" or "Outside sellers" with seed companies registering a response from a limited number of farmers. Seed companies provided 11.8% of farmers with seed directly.

The choice of seed (crop species or variety) is an important 'strategic' decision and once this decision has been made, most of the decisions that follow in growing the chosen crop are 'tactical' with regard to the farmer's demand for advice and information. The technical advisor needs to intervene at the 'strategic' level if the objective of the intervention is a change in farming practices.

For maize production inputs (seed, fertilizer, pesticide) most farmers rely on their own knowledge (45%) or seek information from neighbouring farmers (45%). Therefore 90% of farmers relied on their own knowledge or that of a neighbouring farmer to apply input technologies. Six percent of farmers sought information from sellers of inputs. Advice on crop inputs sought from the Provincial Department of Agriculture (PDA) or NGOs was negligible.

Farmer training and information needs

The survey participants were asked whether they had participated in any training in 2011, who provided the training, what the training was about, was it beneficial and what subjects they required training in.

An average of 33% of farmers received training related to maize and this was provided by various institutions and sector actors. The majority of training was provided by NGOs (68%) with PDA providing 10% only. Input suppliers provided maize training to 7% of farmers (Fig. 3). It should be noted that the PDA provided more training in Sala Krau in Pailin Province (13%)

compared to Samlout in Battambang Province (7%). In Pailin, the PDA provided training to 23% of farmers not affiliated with the previous ACIAR project. Pailin is a much smaller Province than Battambang and the PDA office is in close proximity to the Communes and Villages targeted in this survey.

In Samlout and Sala Krau, 35% and 39% of survey respondents respectively said they were participants in the previous ACIAR project. The previous project was active in formation of farmer cooperatives and in the provision of training to farmers. This is reflected in the partner membership of cooperatives (74-79%) compared to non-partners (35-45%). Similarly, project partners (53-65%) were more likely to participate in training compared to non-partners (14-22%).

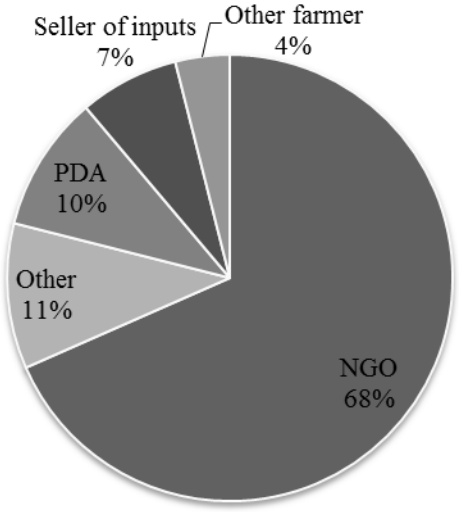

Fig. 3 Providers of training for maize farmers

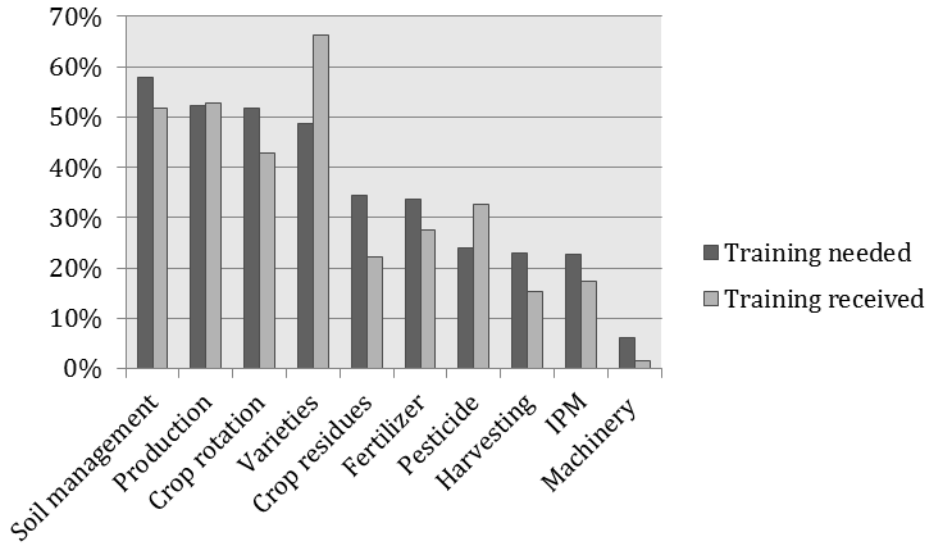

Fig. 4 Farmer training needs in relation to training received

Ninety percent of farmers indicated that they needed more training in specified subject areas. They ranked soil management, crop production and crop rotation as the top three priority training needs (Fig. 4). Other priority subjects were crop residue management, fertilizer, harvesting and Integrated Pest Management (IPM). Training needs for varieties and pesticides were ranked lower than for training received in these subjects.

Farmers were also asked if they changed practices after the training and whether they shared the information with other farmers. As a result of training 88% of farmers reported they had

changed their maize practices and 79% of those trained in new maize practices shared their acquired knowledge and skills with their neighbours. However, results show that while in Samlout 76% of maize farmers shared their 'know-how'; in Sala Krau only 62% did the same.

Importance of factors in farmer adopting new practices

Farmers were asked to rank the importance of different factors for adopting new practices. The three biggest constraints to adoption of new practices were lack of capital (89%), availability of labour (68%) and knowledge (61%). Because of the capital constraint, new technologies requiring additional input costs are not likely to be adopted unless the economics can be demonstrated. Herbicides represent an input cost but result in a labour cost saving so have been readily adopted. Farmers are aware of the economic advantage of using hybrid maize seed so hybrids have been readily adopted.

Discussion

Farmers claimed to know how to deal with biotic impacts on their maize crops such as from insect pests, diseases and weeds but few said they had solutions to deal with abiotic impacts such as flood or drought. The survey revealed that farmers rely almost completely on each other for information about crop inputs especially seed for sowing and herbicides. The sellers of the inputs accounted for only 5% of information sourced. Similarly PDA and NGOs were not sources of information for use of crop inputs.

Decisions such as changing maize variety or replacing hand-weeding with herbicides is a relatively simple process (Pannell et al. 2006). Simple substitutions are often easily adopted if they have a high 'relative advantage', are readily 'trialable' or easy to test and learn about before adoption. Changing management practice to improve water-use efficiency as a drought management strategy for example is more complex and the farmer is likely to seek more information to be certain about the consequences of adopting it (Pannell et al. 2006). A participatory action research approach is more likely to be successful in achieving crop management practice change.

Table 1 Strengths, weaknesses, opportunities and threats for potential extension partners

Strengths	Weaknesses	Opportunities	Threats
		Government Extension	
Infrastructure at District level and staff available	Lack of funds to mobilise District staff	Strengthen links with NGOs and private sector	Lack of credibility – no farmer feedback mechanism
Integral part of the wider government agenda	Lack of networks to deliver technologies	Become warehouse of public good extension information	Diversion of extension staff to regulation
		Non Government Organisations	
Projects participatory and based at community level	Narrowly focused short-term agendas	Rollout of research findings to other communities	Conflicting missions and messages
Staff well resourced often seconded from PDA	Insular, unwilling to share with other NGOs	Provision of strategic longer-term support to PDAs	Lack of long-term objectives and follow-through
		Government Education	
Infrastructure and teachers at Village level	Lack of training and resources in rural subjects	Develop and implement 'Life Skills' for agriculture	Lack of government investment in 'Life Skills'
		Input Supply Network	
Outlets at Village level with 1:1 contact with farmers	Lack of training and potential lack of credibility	Trained to become Village extension 'retailers'	Focus on sales and not on information delivery

Swanson and Samy (2002) observed that in other developing countries, alternative organizations have emerged to fill the information and training void left by withdrawal of government extension services. Similarly, in this survey, NGOs were the most important actors in the provision of training and delivered 68% of all training to farmers. However, NGO programs can be short-term in nature and can cause confusion among farmers by inadvertently delivering conflicting messages. If better resourced, the public sector extension service has an important potential role as an independent broker and warehouse of information that can provide continuity as well as a filter to reconcile conflicting messages being delivered by NGOs and the private sector.

Generally, farmers' training needs recorded in the survey were in line with the subject areas in which training was provided. However, farmer training needs in sustainable management practices such as soil management, and crop rotation took precedence over needs for training on simple inputs such as varieties, and pesticides. Input sellers were minor providers of training (7%) and might also have concluded that farmer training would not increase product sales.

In an earlier study in the research target area, Martin et al., (2010) highlighted the importance of primary schools as a fourth avenue of delivery of agricultural information into rural households. As with input suppliers, primary schools are likely to reach almost all farm households. Based on strengths, weaknesses, opportunities and threats (Table 1), we put forward a conceptual framework that suggests roles based on comparative strengths for public, private and non-government organizations to better integrate delivery of technology information to farmers.

CONCLUSION

This paper puts forward a conceptual framework that suggests roles based on comparative strengths for public, private and non-government organizations to better integrate delivery of information of new technologies and better practices to farmers. We conclude that there are four main avenues for reaching farmers in NW Cambodia —through provincial government extension offices, NGOs, the local agricultural input sellers and the local primary schools. They all have different strengths and weaknesses but collectively, the four groups have all of the elements required for integrated technology transfer. The challenge is to find a mutually beneficial or symbiotic framework for integrated delivery of new technologies and better practices to farmers via these pathways.

ACKNOWLEDGEMENTS

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Research article

Growth Performance of Planted Indigenous Trees 12 years from Establishment

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Abstract This tree domestication research is an *ex-situ* conservation effort aimed to find out the growth performance of some indigenous timber species planted outside their natural forest habitat in Bohol Island, Central Philippines. Specifically, the study sought to characterize the growing conditions of the sites and the biometrics of the trees in three sites after 12 years of growth. We also wanted to find out the best "performers" when grown outside the natural forest habitat. Only indigenous trees were used and planted in a mixed manner. Most of the planting materials were selected wildlings from the local forests. A few were brought in from the nearby island of Leyte. Standard biometrics of trees were taken of all trees. A total of 1,040 trees belonging to 49 species and 25 plant families in 3 land parcels were inventoried. The three sites totaled 2.5 hectares located within the same village and similar growing conditions. These were typical degraded karst areas: shallow soils with pebbles and rock outcrops dotting the landscape. Scrubby vegetation and few scattered trees were the precursor vegetation. The sites used to be cogonal for a long time before scrubby vegetation set in. Annual rainfall is about 2,000 mm; flat to rolling topography; elevation of 320 meters above sea level. Daytime temperature ranges from 24-28 degrees Celsius most of the year and 28-33 degrees during summer (March-May). The standout performers were *Terminalia microcarpa*, *Shorea contorta*, *Vatica mangachapui*, *Shorea palosapis*, *Parashorea malaanonan*, and *Dracontomelon dao*. The biggest *Terminalia microcarpa* area measured 48 cm in diameter at breast height (dbh). *Shorea contorta* had a dbh of 29 cm and had a total height of 29 meters. *Shorea assamica* did not do well in the sites, and was stricken by dieback of unknown cause. *Quisumbing guisok* was noted to be very sensitive to moisture stress from seedling to the sapling stage. At 12 years, many forest-based timbers including dipterocarps responded well to domestication or ex-situ conservation even in a degraded karst land in tropical Philippines.

Keywords domestication, indigenous, karst, *ex-situ* conservation, rainforestation

INTRODUCTION

The Philippines needs an ideal 54% of forest cover to maintain its natural ecological processes. (Sajise, 1996). Disastrous logging and changing land uses have reduced the original amount of 17 million ha of forested area in the Philippines to 5.5 million ha (18% of total land area) during the last 40 years. This has also earned notoriety in Southeast Asia as the country with the thinnest forest cover (Ong, 2004). Less than 6% of the originally 60% of the total forested land area have remained as prime habitats for wildlife and genetic conservation. Bohol in particular had a remaining natural forest of only 4% from its original full forested area. The island is blessed, among many other indigenous timbers, some 16 endemic dipterocarp species (Fernando et al, 2008).

Among the governing state policies of the Philippines is "to protect and advance the right of

the people to a balanced and healthful ecology" (1987 Philippine Constitution). The latest policy support at the national level was the issuance of E.O. No. 26 in February of 2011 which launched a new National Greening Program for the planting of 1.5 billion trees covering about 1.5 million hectares for a period of six (6) years from 2011 to 2016 in lands of the public domain. The National Integrated Protected Areas System (NIPAS) Law or Republic Act 7586 mandates that only indigenous species should be used in the rehabilitation of Philippine watersheds. The maintenance of sufficient forest cover in Bohol Island is not only ecologically and economically of the utmost importance but also to keep its banner, nature-based tourism industry alive and productive. For local policy support, Section 10 of the Revised 2011 Bohol Environmental Code calls for Boholanos to be self-sufficient in wood needs through *tree farming* for domestic wood needs, thus reducing the dependence on commercial fuel as well as to conserve the naturally growing trees.

In support of the national and local policies, and as the leading higher educational institution (HEI) on natural resources management (NRM) in Bohol, Bohol Island State University has long since taken significant steps to increase its role in biodiversity conservation and poverty reduction in the island -province through *in-situ* and *ex-situ* conservation. One of these is the domestication of forest-based valuable timber species in three sites with a total area of 2.5 hectares which were established in 1997- 1998 within the land of the University. These were planted with more than 40 tree species taken from the island's remnant forests. Raising these trees in farms or in homesteads would ease up the pressure of extraction from their present natural forest habitat and could also save them from eventual local extinction (Bullecer and Stark, 2002). Part of the domestication program is to come up with species-site compatibility recommendations for possible wider community adoption.

OBJECTIVE

The main aim of the study was to find out the domestication potential after more than a decade of growth of some forest-based tree species in Bohol Island, Philippines. Specifically, it sought to characterize the growing conditions of the domestication sites, the biometrics of the trees and identify the best performers after over decade of growth.

METHODOLOGY

The study sites are located the interior portion of the island- province of Bohol in the central part of the Philippine archipelago.

Site selection: The domestication sites were in 3 parcels of land, totaling 2.5 hectares, within the same village and with similar growing conditions. Climatic and elevation data were taken from existing secondary data. Edaphic and landscape characteristics were determined by field observation.

Planting stock sources and farm establishment: Wildlings of indigenous trees from nearby forests were collected and nurtured until they were big enough for field planting. Other seedlings were obtained from nearby Leyte Island. Adopting the rainforestation technology, the seedlings were planted in mixed manner, 1.5 to 2.0 meters apart.

Data collection and analysis: A 100% inventory was conducted. Total and merchantable heights were taken with the use of the Abney hand level and fiber glass tape. Diameter at breast height (dbh) was taken using diameter tape and crown diameter with the fiber glass tape.

Total height was determined by the following formula:

$$H = \tan^0 (D) + \text{eye level height} \quad (1)$$

where H is the height in meters; $\tan^0$ = the angle reading from the eye level mark the stem to the tip of the tree; D = distance from the base of the tree to the spot where the researcher stood.

The merchantable height was measured from the base of the tree up to the portion just before the heavy branching started. It was obtained using the following formula:

$$H=tan^0 = (d) + eye\ level\ height \quad (2)$$

where tan^0 = the angle reading from the eye level mark to the merchantable top; d = distance from the base of the tree to the spot where the researcher stands.

The diameter at breast height was measured at the standard point of 1.3 meters from the ground or base. Crown cover or crown area was obtained by getting the average crown diameter of each tree and calculate the radius there from. Individual crown cover was computed using the following formula:

$$A = \prod r^2 \quad (3)$$

where, A: crown area, $\prod$ is the pi (3.1416) and r = radius

Merchantable volume was obtained by making use of the dbh and merchantable height values. Qualitative description of biometric data was employed in determining the growth performance. No other statistical analysis was made. Periodical field observations were made on species reactions during summer or dry conditions.

RESULTS AND DISCUSSION

Biophysical conditions of the tree domestication sites

The domestication sites, with a total land area of 2.5 hectares, were typical degraded karst areas as evidenced by shallow soils and rock outcrops. Soil depth was less than 10 cm in most (about 90%) areas. After a decade some ground litter began to occupy the ground. The prior vegetation consisted of scrubby plants, viny thickets and a few scattered mahogany trees at the pole and young timber stage. The soil texture is silty-clayloam in all three sites. The limestone soils were generally shallow (less than 10 cm) and slightly alkaline. Annual rainfall is about 2,000 mm; flat to rolling topography; elevation of 320 meters above sea level. Daytime temperature ranges from 24-28 degrees Celsius most time of the year and 28-33 degrees during summer (March to mid-May).

Species composition and family distribution of the tree domestication farms

Table 1 lists the species at the research sites. A total of 49 species belonging to 25 plant families were planted in the three land parcels. Dipterocarpaceae was the most represented family with 7 species, followed by Fabaceae, 5 species and Moraceae, 4 species. Most (37%) families had only one species representative. Two of the species, *Vitex parviflora* and *Artocarpus heterophyllus* are already known to be thriving in open areas or outside natural forest stands.

Overall biometrics of the domesticated indigenous trees

Table 2 shows the overall list of the domesticated species with their corresponding biometrics. A total of 1,040 individuals belonging to 49 species representing 25 families were inventoried in the three domestication areas. The domesticated trees have the following biometrics: The trees had a mean dbh of 10.8 cm; mean total height of 9.0 m; mean merchantable height of 5.4 m; total merchantable volume of 47.9 cu m; mean crown diameter of 4.5 m and a total crown area of 11,608.8 sq m or 1.2 hectares. *Terminalia microcarpa* and *Shorea contorta* were among the top performers in diameter and total height growth. The biggest *Terminalia microcarpa* measured 48 cm in dbh while the biggest *Shorea contorta* had a dbh of 29 cm and had an impressive total height of 29 meters. Some 604 dipterocarps consisting of 8 species dominated (58%) the domestication farms. *Myristica philippinenses* came second with 50 individuals. The stand of trees in each domestication land parcel had provided a good ground cover through its close canopies.

Table 1 Species composition of the *Treedom* or *Rainforestation* ex-situ conservation sites in Bilar, Bohol, Philippines which were established in 1998-1999

Species	Family	Species	Family
1. Albizia procera	Fabaceae	*26.Horsfieldia megacarpa*	Myristicaceae
2. Antidesma subolivaceum	Euphorbiaceae	*27.Intsia bijuga*	Fabaceae
3. Artocarpus blancoi	Moraceae	*28.Madhuca Betis*	Sapotaceae
4. Artocarpus heterophyllus	Moraceae	*29.Mangifera altissima*	Anacardiaceae
5. Artocarpus nitidus	Moraceae	*30.Myristica philippinensis*	Myristicaceae
6. Artocarpus sericicarpus	Moraceae	*31.Ormosia calovensis*	Fabaceae
7. Barringtonia racemosa	Lecythidaceae	*32. Parashorea malaanonan*	Dipterocarpaceae
8. Bischofia javanica	Fabaceae	*33. Planchonella duclitan*	Sapotaceae
9. Callophylum blancoi	Clusiaceae	*34. Podocarpus rumphii*	Podocarpaceae
10. Callophylum inophyllum	Clusiaceae	*35.Pometia pinnata forma repanda*	Sapindaceae
11. Cananga odorata	Anonaceae	*36. Pouteria macrantha*	Sapotaceae
12. Canarium luzonicum	Burseraceae	*37. Pterocarpus indicus*	Fabaceae
13. Casuarina nodiflora	Casuarinaceae	*38. Pterocymbium tinctorium*	Malvaceae
14.Cinnamomum microphyllum	Lauraceae	*39. Pterospermum celebicum*	Sterculiaceae
15. Cynometra ramiflora	Caesalpiniaceae	*40. P. diversifolium*	Sterculiaceae
16. Diospyros copelandii	Ebenaceae	*41. Pygeum coccineum*	Pittosporaceae
17. Diospyros copelandii	Ebenaceae	*42. Shorea assamica*	Dipterocarpaceae
18.Discocalyx cymbianthoides	Myrsinaceae	*43. Shorea contorta*	Dipterocarpaceae
19, Dracontomelon dao	Anacardiaceae	*44. Shorea palosapis*	Dipterocarpaceae
20. Dracontomelon edule	Anacardiaceae	*45. Strombosia philippinensis*	Olacaceae
21. Elaeocarpus macranthus	Elaeocarpaceae	*46. Syzygium brevistylum*	Myrtaceae
22. Gomphandra luzoniensis	Icacinaceae	*47. Terminalia microcarpa*	Combretaceae
23. Guioa koelreuteria	Sapindaceae	*48. Vatica mangachapui*	Dipterocarpaceae
24. Hopea philippinensis	Dipterocarpaceae	*49. Vitex parviflora*	Lamiaceae
25. Hopea quisumbingiana	Dipterocarpaceae		

A decade of difference and initial impacts

Aside from garnering data and some learning in tree domestication and species potentials for watershed rehabilitation, the Tree Dom farms had gradually transformed what used to be a degraded landscape to a wooded land as shown in Fig. 1. In 2004, the provincial Research Consortium, where BISU is a member, put up the Bohol Biodiversity Complex (BBC) adjacent to one of the tree farms for a learning continuum in nurserying and tree farming. The Consortium and the Complex do biodiversity research, trainings and indigenous tree seedlings production. In the last 5 years, the Tree Dom farms have been part of the regular alternative ecotourism route in the island. The tree farms have become a learning area for students, farmers, policy makers, researchers and other environment advocates from the local, national and international community.

Standouts in domestication and species enrichment

Based on growth performance and general vigor, some of the tested species for domestication have stood out as having domestication potentials. These were *Terminalia microcarpa, Shorea contorta, Vatica mangachapui, Shorea palosapis, Parashorea malaanonan, Dracontomelon dao, Syzygium brevistylum, Vitex parviflora, Gomphandra luzoniensis, Cinnamomum microphyllum, Callophylum blancoi* and *Elaeocarpus macranthus*. Except for *Shorea assamica*, the rest of the plants are exhibiting acceptable survival and growth rates. The problem with *Shorea assamica* seems to be related to fungal infection causing dieback. *Hopea quisumbingiana* at the seedling and pole stage seemed very sensitive to moisture stress. In the last three years, Rainforestation Sites 2 and 3 had been enriched with the planting of more dipterocarps and other trees which are endemic to Bohol island. These are *Shorea palosapis*, *Hopea acuminata*, *Dipterocarpus kerril*, *Shorea malibato*,

Shorea falciferoides and *Vatica mangachapui*. They were not included in this inventory, yet at this early stage, the new additions have manifested promising growth performance.

Table 2 Biometric summary of the planted indigenous timber species at 12 years of age

Species	N	Mean DBH(cm)	Mean Total Height(m)	Mean Merchantable Height (m)	Total Mer. Volume(m)	Mean Crown Diameter (m)	Total Crown Area (sq. m)
Albizzia procera (topped off)							
Antidesma subolivaceum	1	9.5	4.0	4.4		3.9	12.2
Artocarpus blancoi	14	11.0	8.6	6.8	1.8	3.8	247.8
Artocarpus heterophyllus	7	9.5	8.4	5.2	0.1	3.8	75.6
Artocarpus nitidus	12	14.7	9.6	4.7	0.8	5.8	272.8
Artocarpus sericarpus	4	11.8	10.3	3.6	0.1	5.5	94.7
Barringtonia racemosa	23	10.3	9.8	5.7	1.0	4.2	71.2
Bischofia javanica	23	11.0	7.1	4.0	3.0	4.0	397.7
C. inophyllum	9	16.0	12.0	4.8	0.9	5.5	353.2
Callophylum blancoi	27	9.0	7.0	3.7		3.8	343.6
Cananga odorata	3	18.0	14.6	8.3	0.6	4.6	60.6
Canarium luzonicum	16	19.2	13.4	6.8	0.7	6.0	407.9
Casuarinas nodiflora	3	14.3	12.9	6.0	0.2	7.3	57.0
Cinnamomum microphyllum	3	14.4	6.3	2.8	0.01	2.6	15.2
Cynometra ramiflora	1	5.1	5.4	5.4		3.4	9.1
Diospyrus copelandii	5	9.7	9.9	4.6		3.8	44.3
Discocalyx cymbianthoides	2	7.8	5.0	2.8		3.6	20.4
Dracontomelon dao	33	15.3	11.0	6.6	4.4	5.3	465.2
Dracontomelon edule	1	8.5	14.3	11.4		5.8	26.2
Elaeocarpus macranthus	8	13.5	10.7	6.5	1.8	5.1	231.3
Gomphandra luzoniensis	31	10.2	5.3	5.7	0.1	5.1	633.3
Hopea philippinensis	148	7.1	7.1	4.5		3.8	284.7
Hopea quisumbingiana	152	6.2	6.6	4.1		3.0	89.7
Horsfieldia megacarpa	4	16.7	10.4	4.3	0.3	7.0	157.5
Instia bijuga	5	17.2	11.8	6.8	0.8	10.0	206.2
Kamagong-like	1	5.4	5.5	3.9		3.4	9.3
Litsea glutinosa	1	10.5	9.4	4.8		4.7	17.1
Madhuca betis	1	13.4	5.2	9.3		5.6	24.6
Mangifera altissima	5	9.0	8.2	4.6		4.0	68.3
Myristica philippinensis	50	8.5	7.2	4.2	2.7	4.3	1,836.1
Ormosia calovensis	1	10.5	9	5.9		3.4	8.6
P. celebicum	14	10.3	11.6	7.7	0.7	4.7	277.8
Parashorea malaanonan	73	7.8	8.6	4.0		4.3	22.5
Planchonella duclitan	3	8.9	9.1	6.7		2.5	624.1
Podocarpus rumphii	3	5.6	5.5	2.3		2.8	19.1
Pometia pinnata	7	13.0	13.1	8.6	0.6	5.2	184.3
Pouteria macrantha	1	5.7	9.2	4.8		2.9	6.7
Pterocarpus indicus	7	10.2	9.5	5.1	0.2	6.2	171.8
Pterocymbium tinctorium	11	10.3	9.0	5.4	0.7	4.3	241.9
Pterospermum diversifolium	13	15.5	15.1	6.7	2.9	6.0	468.1
Shorea assamica	2	6	3.2	5.3		3.1	38.7
Shorea contorta	68	14.6	12.1	8.6	4.4	3.8	216.3
Shorea palosapis	100	6.9	6.1	4.3		3.0	94.2
Shorea polysperma	16	5.4	5.3				2.6
Strombosia philippinensis	1	4.1	4.3	2.0		1.8	8.8
Syzygium brevistylum	3	9.0	11	6.9		4.6	22.0
Terminalia microcarpa	34	21.7	16.3	8.1	16.8	7.7	1,093.6
Vatica mangachapui	45	7.1	7.4	4.9		3.2	288.8
Vitex parviflora	45	13.3	9.0	4.2	2.3	5.7	1,286.1
Total / Mean	**1,040**	**10.8**	**9.0**	**5.4**	**47.9**	**4.5**	**11,608.8**

Fig. 1 A changed landscape from being a scrubland in 1998 to woodland after a decade

CONCLUSION

Many indigenous forest timbers can be successfully conserved through domestication even in degraded karstic upland environment of Bohol, Central Philippines. Except for two species, the rest of the 49 domesticated indigenous timbers studied have adapted very well after 12 years to growing conditions outside the forest habitat. Some species like *Shorea contorta* and *Terminalia microcarpa* manifest outstanding growth performance than others. Domestication of selected tree species is imperative especially in regions where communities are heavily dependent on the natural resource for daily survival.

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Research article

Agri-Supply Chain in Tourism Market: A Case Study of Koh Trong Ecotourism Community and Market in Kratie Province

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Abstract Stable supply of agricultural products into tourism business is a key for the both sectors to sustainably grow together; however, rural farmers still face challenges in effectuating such a goal. The current research addresses how agri-supply chain exists in tourism market and issues on such a chain in Cambodia through a case study in Northeastern Region. The triangulation methods were employed. Surveys were conducted on farmers, hotels/restaurants and vegetable sellers, whereas semi-structured interviews were done with middlemen, community chiefs, NGOs and local authorities. The farms of Koh Trong are operated with family labors. Most farmers do not have advanced knowledge on farming techniques. Little pesticides are applied, while chemical fertilizers are most commonly used. Most vegetables and fruits are shipped from Koh Trong by middleman across the Mekong River to town market, where they meet with the customers, hotels and restaurants. While middlemen are the price setters, farmers are the price takers. Tourism market consumes less than half of the total vegetables produced by Koh Trong farmers. Besides, agri-products are brought in from other places and imported from Vietnam. Koh Trong responds fairly little to the market demand. Small-scale farms of Koh Trong are less competitive in terms of product variety; however, they are more competitive in terms of high quality and unique products. Major issues affecting the supply chain include limited knowledge, limited transportation, supply irregularity, limited market access and imbalanced power among chain actors. Tourism is yet a small market for agri-products from Koh Trong, but implies a potential one. While conventional supply chain is adequate, there is a barrier to overcome in making the chain more equitable for all market actors.

Keywords supply chain, vegetables and fruits, farmers and tourism market

INTRODUCTION

Different researchers defined supply chain. *"Supply chains are networks of firms interacting to deliver a product or service to a predefined market segment"* (Lockamy, Beal and Smith, 2000:23). It contains network firms which are the suppliers, market which is the demand side, the products, and services. Supplying products is done in accordance with service performances because they cannot be separated in sales. Some authors such as Cooper, Lambert, and Pagh (1997) cited in Zhang, Song and Huang (2009) stated that supply chain occurred by a forward flow of products and a backward flow of information. Meanwhile, Chen and Pauraj (2004) defined supply chain as a network of materials, information, and services linked with the characteristics of supply, transformation and demand. These authors emphasized the flow of products, services and the information, which can be inferred that the producers supply based on demand. They also focused partly on the relationship between product supply and information, while Lockamy et al., (2000) paid more attention on the products and services.

Some authors highlight the difficulties for local farmers to access the market. In the article "Supply Chain Models for Small Agricultural Enterprises," Jang and Klein (2009) concerned that small farmers were not included in the coordinated supply chains. Similarly, Roekel et al., (2002) identified the problems related to the small scale farmers in supply chain that challenge of the new market adjustment, least organized group and small capital were the constrains for small scale producers, leading them to be the losers in market competition, while those accessing capital, technology and logistics enjoyed earning benefits. These issues are more severe for the businesses occurring in agriculture in terms of farmers' environment, especially the small farmers as Jang and Klein pointed out because farmers had low knowledge on business.

Some models can be used for chain analysis. Supplier models are important for supply chain. According to Philip (2006), there were several supplier models: traditional model, vertical integration, cooperatives, and marketing companies. Out of the four models, marketing companies are less applicable for the supply chain in which local farmers do the supplies. The relationship between suppliers and customers were analyzed in three levels (Croom et al., 2000). First, dyadic level referred to the relationship between only two parties, that of supplier and manufacturer or manufacturer and retailers/ distributors. Second, chain level covered all the relationships in dyadic levels. Last, network level involved the network of operations including upstream/downstream or total/immediate. Besides, Roekel, Willems & Boselie in 2002 discussed the chain knowledge (in supply chain, and the actors in chain, especially the suppliers, are required to have the chain knowledge.

There were a number of terms reflecting the linkage of tourism with agriculture. These terms are farm tourism/farm based tourism (Dernoi, 1983; Hjalarger, 1996; Ramon et al., 2000 cited in Sarpley and Vass, 2006; Busby and Rendle, 2000; Brandth and Haugen, 2011), Agro-or agri-tourism (Koc, 2008; Phillip et al., 2010), food tourism (Halloran and Deale, 2004; Ruben et al., 2006). Such terms illustrated the integrated development of tourism and agriculture. Farms were used as the main tourist attractions with the accommodation, food and beverage provided by farmers.

The interrelationship also occurred in terms of the supplies of the local products into hotels/restaurants. "*The use of local foods in restaurants is a growing trend that reflects the desire by many visitors to experience a culture through its footways*" (Hjalagar, 2002; Fields, 2002 cited in Murphy and Smith, 2009). The statement showed how important the supply of local food is in attracting tourists and the relationship between restaurants and local farmers as well. Some other studies illustrated the supplies of local agri-products to hotels/restaurants (Belisle, 1984; Torres, 2003). Farmers sold their products directly to hotels/restaurants or by means of middlemen. Farmers had relationship with hotels/restaurants in terms of fruit supply and hotels/restaurants sent their trucks to transport the fruits from famers' fields during the harvesting seasons (Verddouw et al., 2010 cited Torres, 2003). He also indicated that most of the hotels in Cancum had experience with direct supply contracts with local growers.

Three factors affected the relationship of hotels and local famers (Torres, 2003). First was the supply and production-related factors including poor local growing condition, growing insufficient year-round quantities of products to supply, competition of labour between tourism and agriculture, inconsistent and/or poor quality of local production, poor economies of scale of local enterprises, climate of uncertainty land tenure and limited local processing. Second was demand-related factors related to tourist types, tourist food preference, and the concern of tourists and chefs on health and sanitation. Last was farmers' marketing difficulty, which might be the serious problems for local farmers to access tourism market. Market-related factors included singular marketing; lack of tax payment; lack of communication and deep trust between producers, enterprisers, tourism suppliers, and hotels; and infrastructure limitation. He also mentioned various supplies done in accordance with the different sizes, grades, franchises, and the nationalities of the owners, managers and chefs of the hotels, which might consist of a variety of supply patterns.

The convenience and sanitation of products for cooking was another option for hotels /restaurants. Belise in 1985 stated that canned or frozen food was frequently used by hotels because it was more convenient and saved time for cooking. In relation to sanitation, Torres (2003) stated that the chefs of hotels chose the frozen foods on the simple consumption with higher sanitation,

and in his study on "Linkages between tourism and agriculture in Mixico", 41 % of the chefs imposed the lemmatization procurement directly from local producers owing to the concerns of health and sanitation. If hotels/restaurants use the local products, they need to spend longer time cleaning and/or preparing before cooking. However, the price of canned food may be higher, and it depends on customers' preferences.

OBJECTIVES

1. To overview family farms of Koh Trong island in the Mekong River
2. To identify the structure of agri-supply chain at the local tourism market of Kratie Town
3. To analyze the factors affecting the supply chain of Koh Trong vegetables and fruits to Kratie tourism market

METHODOLOGY

Both qualitative and quantitative methods were employed in the research. Questionnaire survey, semi-structured interview and observation were used as the methods for primary data collection. Surveys were conducted on 118 local farmers selected by simple random sampling, 23 hotel/restaurant owners chosen by convenience sampling and 61 vegetable sellers at market selected by simple random sampling. Semi-structured interviews were done with local authority, NGOs, chairmen of communities, local farmers, selected by purposive sampling, and middlemen, selected by snowball techniques. Observation was done on the situations of the site and activities of actors involved in the supply chain. Statistical Package for the Social Sciences (SPSS) was employed for analyzing quantitative data, while content analysis was used for analyzing qualitative data.

The research was conducted in Kratie province, located in the north-eastern area of Cambodia, about 240 km from Phnom Penh. Town centre is located next to Mekong River. It had 8 hotels, 18 guesthouses and 21 restaurants registered with the government (Department of Tourism, 2009). On the other side of the river is Koh Trong, one of communes (Sangkat) gown. Koh Trong is an island surrounded by the Mekong River. Boats were the only modes of transport between town and Koh Trong. The total area of the island is 223 hectares with 383 families, who mainly lived on agriculture (National Committee for Sub-National Democratic Development, 2009). This island is also one of tourism sites in Kratie.

RESULTS AND DISCUSSION

Cultivation and sales

Majority of farmers (82.6%) on Koh Trong have education lower than upper secondary school, small sizes of farming lands and traditional tools in cultivation. Pesticides are used for cropping by the higher percentage of farmers (64.1%), while chemical fertilizers are most commonly applied by the lower percentage of the farmers (35.9%). Furthermore, 29.1 % of farmers used only own kept-seeds for growth, with illiteracy of how such seeds may provide different yields from those bought from market. Besides, they lack knowledge on business related to their products.

Most of the vegetables and fruits flowed from local famers to hotels/restaurants through intermediaries. Most farmers (82.2%) sold their agri-products to middlemen. Middlemen collected the products from farmers to sell in both wholesale and retail market of the town. They were the price setters. Tourism market consumed less than 50% of the total vegetables produced by farmers on Koh Trong, while the rest were consumed by household consumers. Besides Koh Trong, the vegetables were taken from other places and from Vietnam to the market. Thus, farmers on Koh Trong have to compete with the suppliers of these vegetables and fruits, especially those from

Vietnam; however, they were more competitive in terms of high product quality and in particular, unique sweet pamelos.

Supply responds fairly less to demand. In comparison between the top five vegetables: long-string bean, salad, tender green, leak and tomato farmers at Koh Trong grew with the top five vegetables: carrot, tomato, cucumber, cauliflower and cabbage consumed by hotels/restaurants, only tomato was supplied by farmers matched the demand by hotels/restaurants, so the other fours consumed by the demand from households. Meanwhile, these hotels/restaurants bought tomato supplied from other places and Vietnam. More remarkably, carrot was the special vegetable from Vietnam that domestic farmers could not grow. Therefore, farmers of Koh Trong still supply vegetables into hotels/restaurants fewer in variety than other places and Vietnam.

Supply chain

The whole supply chains of vegetables and fruits exist in two types of structures (figure 1). The first type comprises of 5 groups of actors: farmers, hotel/restaurant owners, middlemen, NGOs and local authority. Second type consists of all actors, except middlemen. Farmers are the suppliers, whereas hotel/restaurant owners are their final customers. Middlemen play crucial roles in connecting suppliers and customers, but in second type, supply and demand connects with each other directly. NGOs and authority play roles as facilitators because they support the local farmers through the activities of community establishments, trainings, policy making, small fund, capital and technical provision and promotion through tourism. However, core actors in chain are farmers, middlemen and hotel/restaurant owners, which are similar to the statement of Lockamy et al., (2000) that in supply chain, services and products flowed from suppliers and/or producers to customers directly or indirectly through distributors and/or retailers.

The current research illustrated some relationships partly similar to the supplier models by Phillip (2006). It found that local farmers grew and sold vegetables and fruits to local middlemen after harvesting. The middlemen packed and took the products to markets to sell in both wholesale and retail-sales. This phenomenon is relevant to what Phillip described as traditional model. Moreover, some farmers, especially some middlemen, packed and took their vegetables and fruits to sell in the retail markets. Such a phenomenon occurs in somewhat Philip called vertical integration model. There are vegetable community and pamelo community on Koh Trong, of which purposes to croup local farmers to grow and sell their produces cooperatively. Though it has not worked well yet, it works to some extent with pamelo community as Cambodia Center for Study and Development in Agriculture (CEDAC) collected pamelos from Koh Trong through the community to be on sales in its shop located in the town. However, there is a trend towards cooperative model. Marketing company is not applicable.

Agriculture and tourism

The relationship between agriculture and tourism can be illustrated through the supply of agricultural products with three forms (Fig. 1). The first form is Farmer-Middleman-Hotel/restaurant (FMH). FMH refers to the supply of vegetables and fruits done from local farmers to hotels restaurants through middlemen. This is similar to the findings of some previous researches, by Belise, (1984), Field, (2002), Torress (2003) and Murphy, (2009) in relation to the supply of local agricultural products to hotels/restaurants. Differently, the research illustrated that local famers took their vegetables and fruits to hotels/restaurants through intermediaries. These show that the different supply chains may vary according to classes and sizes of hotels/restaurants.

Second form is Farmer-Hotels/restaurants (FH). FH refers to the supply of vegetables and fruits from local farmers on Koh Trong to hotels/restaurants directly. This relationship is also supportive of the previous researches in first form. It demonstrates the direct sales and/or cooperation between local farmers and hotels/restaurants, and this is more similar to what Torres (2003) found. As stated in the first form, hotels sent their trucks to carry out the fruits from farms, and he further said that most hotels in Cancum, Mexico, had direct supply contact with local

growers. The present research found that some hotels bought fruits, especially pamelos, directly from farmers on Koh Trong. They also had oral contracts with local farmers on the island for pamelo supply.

Compared with FMH, FH provides more advantages for the local farmers and hotels/restaurants. First, it provides more economic benefits i.e. the cross margins earned by middlemen can be divided for farmers and hotel/restaurant owners. Second advantage is building the relationship. Selling and buying directly could make local farmers and hotel/restaurant owners more understandable of each other. This also may lead local farmers to succeed largely in market access and be more competitive in market. However, it contains some disadvantages. Without middlemen, farmers have to take their vegetables to hotels/restaurants, or hotel/restaurant owners have to buy on farms, in which either needs to spend extra money and time. There are some problems including supply regularity, transportation, quantity, and seasonality, which is supportive of the issues raised by Torres (2003).

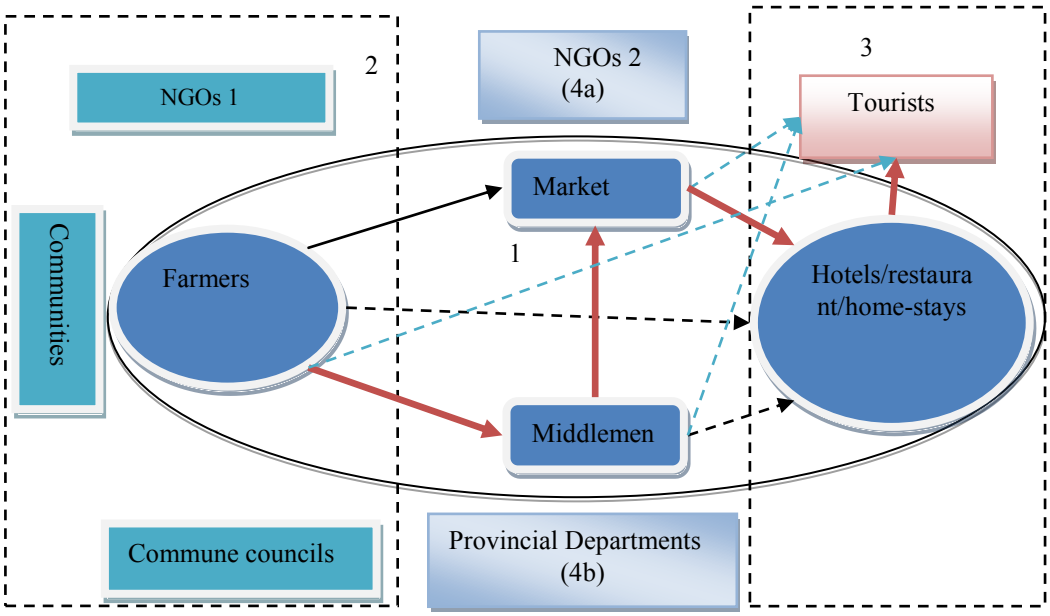

Fig. 1 Supply of vegetables and fruits with chain actors

Third form is Farmer-Tourist (FT). FT refers to the relationship in which local farmers supply their agri-products directly to tourists or they do businesses on their own farms based on tourism, known as farm tourism or farm based tourism.

CONCLUSION

The farms on Koh Trong are small-scale and family-oriented farms. Tourism is yet a small market for agri-products from Koh Trong, but implies a future potential one. While conventional supply chain is adequate, there is a barrier to overcome in making the chain more equitable for all market actors. Limited knowledge, limited transportation, irregular supply done by Koh Trong farmers,

limited market access and imbalanced power among the chain actors are the issues affecting the supply chain. Farmers should increase growing crops to supply more regularly and build group for supplying their agri-products so that they can gain more power in negotiating the price of the products with middlemen.

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Research article

Off-Farm and Non-Farm Activities Development in Rural South-Eastern Bosnia

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Abstract Agriculture represents about 9% of the Bosnian gross domestic product and employs almost a fifth of the labor force. Agriculture is no more sufficient to ensure the development of Bosnian rural areas; where lives around 61% of the population. Diversification issue can be considered in terms of resources (land, labor or capital), location (on-farm or off-farm) and output (farm or non-farm). The paper aims at analyzing income-generating activities diversification in rural south-eastern Bosnia with a focus on motivations and barriers. It discusses the main factors affecting off-farm and non-farm activities development, including policies, and provides some recommendations. The paper is based on an extended secondary data analysis and semi-structured interviews, conducted in March-April 2012, with 104 households' heads from Foca, Rogatica, Han Pijesak, Vlasenica, Sekovici, Milici and Bratunac municipalities. Almost a half of the surveyed households characterized themselves as mixed (46.1%), 41.3% as farm, and 12.6% as non-farm. Income is generated mainly from agricultural products sale (76%), off-farm activities (52.9%) and pensions (44.2%). Motivations for engaging in off- and non-farm activities are not always purely financial and also reflect societal changes. In the last five years, 21.6% of the households started new income-generating activities - mainly related to services provision and on-farm processing - but gave up while 22.6% of them still deal with new activities. The main barrier is the lack of financial resources (39.7%) and time (12.1%). Weak business skills are also a limiting factor. Development of new activities raises farmers' income and contributes to a healthy, diversified and viable rural economy. Public institutions need to make sure that policies in place, whether sectoral or broader, do not put obstacles in the way of diversification and improve rural planning and services delivery. Creating an enabling environment for diversification requires the efforts of many public and civil society actors.

Keywords non-farm, off-farm, motivations, barriers, Bosnia

INTRODUCTION

Agriculture share in GDP was 8.1% in 2011 (EC, 2012). According to the Labor Force Survey for 2012, the agricultural sector employs 167,000 persons *i.e*. 20.6% of the total labor force (ASBiH, 2012). Rural areas (81%) lag behind in terms of socio-economic development and still face many problems. Around 61% of the total population can be classified as rural. Agriculture provides a source of income for about 50% of the total population of the country. The Agro-food processing industry is recovering following a decade of under-investment and its share in GDP is increasing (about 8%) (Kurbanova et al., 2011).

Despite its declining gross value added, agriculture continues to have an important influence on the rural economy (OECD, 2006). Generally speaking, as an economy grows the non-farm economy also grows in importance within the rural economy (Valdés et al., 2008).

It is clear that nowadays agriculture is not sufficient to insure the sustainable development of rural areas that's why rural economy should be diversified (Antonelli et al., 2009; Haggblade et al., 2007; OECD, 2006). The framework provided by OECD (2009) considers the issue of farm household diversification by differentiating between activities in terms of resources (factors of production: land, labor or capital), location (on-farm or off-farm) and output (agricultural or non-agricultural) (Fig. 1). The major row differentiation between activities is made on the basis of the location of the activities, either on-farm or off-farm. Within each location, diversification activities are further differentiated as to the type of output, whether: agricultural production (*e.g*. growing crops or raising livestock); continuation (*e.g*. processing of food or providing contracting services to other farmers); or other (OECD, 2009).

OBJECTIVE

The paper aims at analyzing off-farm and non-farm activities development in rural south-eastern Bosnia with a focus on motivations and barriers.

		FACTORS OF PRODUCTION		
		LAND	**LABOR**	**CAPITAL**
LOCATION	**ON-FARM**	Within agriculture, including specialty crops, organic and biomass production	Agriculture-related *e.g*. direct sales and contracting (fencing, crop harvesting, etc.)	Agriculture-related *e.g*. processing of farm products including cheese
		Other *e.g*. forestry, wind-turbine, recreation, and aquaculture	Other *e.g*. handicraft, farm tourism, contracting (snow clearing, etc.)	Other *e.g*. biomass energy generation, wood processing
	OFF-FARM	Agriculture *e.g*. land rented to other farmers	Agriculture-related, *e.g*. employment on another farm	Agriculture, *e.g*. purchase of additional farmland
		Other *e.g*. land rented to others for forestry, wind turbine	Other *e.g*. school teacher, nurse, government official	Other *e.g*. investment income, pensions

Source: Adapted from OECD, 2009.

Fig. 1 A framework for classifying farm household income diversification activities

METHODOLOGY

The paper is based on an extended secondary data analysis and field research. The field survey analyses the diversification of activities by farm households in Bosnia. Semi-structured interviews were conducted in March - April 2012 with 104 households' heads randomly chosen from seven undeveloped and mid-developed municipalities: Foca, Rogatica, Han Pijesak, Vlasenica, Sekovici, Milici and Bratunac. Semi-structured interviews (SSI) were conducted in local languages. The checklist prepared for SSI included 40 questions dealing, among others, with types of households (farm, mixed, non-farm), household structure, employment and income for households' members, microfinance and access to loans and diversification of income-generating activities.

The average age of households' heads is 46.9 (age range: 29-67). Almost all interviewees (93.2%) were men. Average number of household members is 4.3. About a tenth of the household members (8.5%) are illiterate while only 8.85% of them have high education. The highest percentage of the surveyed households have income from 5,000-15,000 BAM (67.3%) while more than 12% have good or quite good income (more than 15,000 BAM, Bosnian Convertible Marks). The general poverty line in Bosnia and Herzegovina (BiH) is 2,857 BAM per capita and per year (ASBiH, 2008). Taking into account this criterion, more than 50% of surveyed households are the under poverty line.

The various factors enhancing or limiting farm household diversification into off- and non-farm activities are discussed in this paper. In the light of available evidence on the role of agriculture and farm household diversification in the Bosnian rural economy, some initial policy implications are drawn and some recommendations provided to speed up the pace of Bosnian rural economies diversification.

RESULTS AND DISCUSSION

Almost a half of the surveyed households characterized themselves as mixed households with diversified income-generating activities. The livelihood strategy for about two fifths of the surveyed households is focused on agriculture. The high percentage of mixed and non-farm households means that rural economy is diversified but the high percentage of farm households clearly shows that agriculture is still important in livelihood strategies of the rural population in south-eastern Bosnia. Mixed households have better education level compared with farm and non-farm households. Furthermore, their members accept easier new technologies and other innovations in rural areas and they are more engaged in social life within the community. In the case of mixed and non-farm households, income is mostly provided from salaries of full time employees that deal with the off-farm sector. Nevertheless, the percentage of households relying on income from farm activities is quite high. In fact, a large number of households indicated primary agricultural production as a main or an additional income (51.9%) while only 15.4% do not have any farm income (Table 1). A large share of income from farm shows that agriculture is still the main activity in rural areas of south-eastern Bosnia and it characterizes households with lower education level and older members. This is at least to a certain extent due to the fact that because of the civil war many big companies - that employed large number of people from rural areas of south-eastern Bosnia - were destroyed or closed so that rural people are obliged to insure their subsistence dealing with agriculture. For the same reason the percentage of pension income is high as many of the rural people were retired after the civil war after engagement in army and also because almost a third of the surveyed household members (29.3%) are over 50 years.

Among the reasons for which many households did not start any new income-generating activities can be mentioned the lack of financial resources or time and the difficulty to find suitable markets. Other barriers include: high taxes, lack of experience, difficulties in finding partners, complicated administration issues, etc. (Fig. 2).

The most frequent businesses that the surveyed households have tried out are related to wild fruit and herbs collection (19.2%) and services provision on equipment and machines (15.4%). Activities related to rural tourism are not enough developed. New processing and packaging

activities regard dairy products, meat, strawberries and cereals. Other new farm income-generating activities include: wood processing, piglet breeding, sheep breeding, beekeeping, dairy products sale and raspberry growing.

Table 1 Types of households, income sources and new income-generating activities

Specification	Percentage of the surveyed households
Type of household	Mixed: 46.1% Farm: 41.3% Non-farm: 12.6%
Income sources	Sale of agricultural products: 76% Off-farm activities: 52.9% Pensions: 44.2% Other: wages, providing services on equipment and machines, social programs and help, family and friends, renting land and property.
New income-generating activities in the last five years	Did not develop any activity or start a new business: 55.8% Started but gave up: 21.6% Still deal with new activities: 22.6%

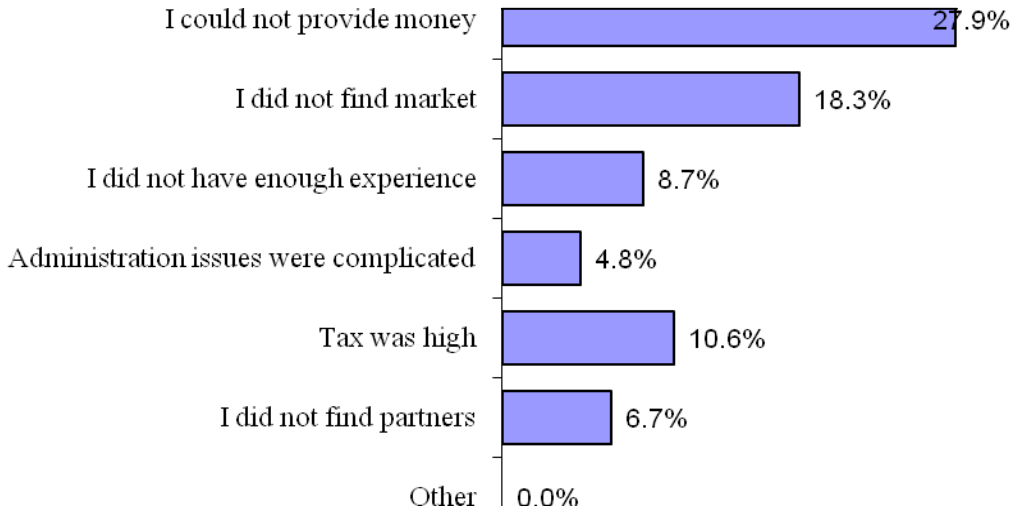

Fig. 2 Main problems and constraints faced by rural households in their attempts to develop new farm, non-farm and off-farm income-generating activities

Financial reasons are key constraints in starting up households' own business activities and diversification of livelihoods. Taking into consideration that money is the main problem, one way to cope with this problem is to get a loan. Almost twenty eight percent (27.9%) of the surveyed households have never applied for a loan mainly for the lack of collaterals. Others applied for loans for many reasons: construction and maintenance of buildings (24.0%), buying animals (12.5%), buying machines and equipments (11.5%), buying seeds and fertilizers (4.8%), etc.

Many factors influence the diversification of farm households into non-farm activities, including government intervention. If governments want to foster diversification, they would need to make sure that policies in place, whether sectoral or broad, do not put unintended obstacles in the way of diversification. Providing the services needed to foster business in rural areas - such as telephone and internet coverage, training and information - also help to create an environment conducive to diversification (OECD, 2009). Prerequisites for encouraging private investments include improving the business climate, and providing business development and financial services

suited to the needs of rural entrepreneurs. Acquiring a labor force with appropriate skills is crucial (IFAD, 2010).

As for human capital, the major part of respondents stated that they possess certain skills, especially in food processing. Some of them mentioned also fruit production, beekeeping, organic production and animal husbandry. Older members of households have more experience in collecting wild fruits and mushrooms and producing medicinal and aromatic plants. Strengthening the rural people's capabilities to take advantage of opportunities in the rural non-farm economy is essential. Education and skills are particularly important (IFAD, 2010).

Motivations for engaging in non-farm activities are not always purely financial, but also reflect societal changes. In terms of the farm household, a financial motivation appears to be the strongest driver for diversification in general, although social motivations are shown to be important for farm tourism. However, it appears that weak business skills are limiting the extent of diversification. Women play a more important role in the diversification of the farm into non-farm activities than in the primary agricultural activities (OECD, 2009).

Differences also appear in terms of the size and type of farm operation. In general, off-farm diversification activities are undertaken by smaller farms, for which they are more financially important. A number of factors would explain this including the existence of less utilized farm resources and greater financial pressure. The location of the farm also plays an important role in determining the extent of diversification activities. In general, the further a farm is away from a urban area, lower is the opportunity to diversify into non-farm activities (OECD, 2009).

The challenges of income diversification have a strong regional character or lie in the characteristics of the farm or farm household. According to the Working Group on Diversification of the British Department for Environment, Food and Rural Affairs (DEFRA, 2007), key barriers to farm diversification include validity of market research, capacity to develop a considered business case, quality of business skills and training, availability of appropriately skilled personnel and regulatory controls, and access to specialist business advice. Access to finance was also identified as a potential barrier.

A range of policy measures have been introduced in various countries to assist farm household diversification into non-farm activities. These measures involve grants, training and facilitation. The diversity of measures reflects not only differences in policy objectives and country approaches but also differences in terms of the barriers that the policy tries to overcome or correct. In some countries, diversification activities appear to reduce access to some types of agricultural support. Regulations governing tax, social security, land zoning and labour markets may complicate diversification in countries where agriculture is not treated the same as other sectors. Farm households, who engage in non-farm activities, may have to maintain two separate registration and declaration systems for tax and social security purposes, and may lose the benefits of being "farmers" (*e.g.* if there is preferential treatment in the social, tax system, or access to some farm subsidies, such as investments) if the income they derive from non- farm activities becomes higher than the income from agricultural activities (OECD, 2009).

The impact of labour regulations and the social security and tax systems on diversification essentially depends on how agriculture is defined under those regulations/systems. Often a broad definition of agriculture is used, allowing many forms of on-farm diversification activities to be classified as agricultural or farming, and thus permitting a continuation of the *status quo* in terms of administration requirements and special concessions (OECD, 2009).

The heterogeneity of farm operators and the variety of non-farm activities mean that, at any one time, there will be sets of circumstances that are highly favourable to diversification and others where there are insuperable obstacles. This has a number of policy implications for countries wishing to encourage farm diversification. The DEFRA Working Group on Diversification recommends modifying rural actor skills as well rural development planning and service delivery systems so that they do not pose such a substantial barrier to diversification (DEFRA, 2007).

CONCLUSION

Rural economies in south-eastern Bosnia are quite diversified but agriculture is still the main economic activity for many households. Many households have started new income-generating activities such as services provision and on-farm processing but they had to tackle many problems and constraints such as the lack of financial resources. Harnessing farm diversification especially in the non-farm economic activities requires improving the environment, thus strengthening incentives and reducing risks for the actors. This involves improving rural infrastructure and services as well as governance and the business climate to encourage private investment. Creating an improved environment for farm activities diversification requires the efforts of many actors. The roles of government actors are often critical.

Diversification of farm households into other activities on and off the farm affects the rural economy, by raising the level of farm income and the viability of farms. However, household livelihoods' diversification depends on the existence of a healthy and diversified rural economy, which provides off-farm work opportunities as well as services. For rural policy to be more effective, small fragmented programmes should be replaced by an integrated rural development policy, that rural farm and non-farm households can benefit from, which requires a strong horizontal coordination effort at all governance levels. In fact, it is necessary to reframe and redesign the rural development policy as agriculture is no more the only way to alleviate poverty and to improve rural living standards. Fully exploiting rural economy diversification potential in Bosnia requires also improving rural governance, upgrading rural people's human capital, strengthening rural social capital and improving physical capital as well as access of the rural population to finance. That requires also a favourable and enabling legal and legislative environment fostering farm activity diversification.

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Research article

Agricultural Extension and Advisory Services in Bosnia

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Received 15 December 2012 Accepted 30 January 2013 (*Corresponding Author)

Abstract Bosnia and Herzegovina (BiH) consists of two governing entities; the Federation of Bosnia and Herzegovina (FBiH) and the Republika Srpska (RS). Agriculture employs almost a fifth of the total labor force. Around 61% of the population lives in rural areas. Easy and timely access to reliable and updated information provided by extension services is crucial for agricultural and rural development. The paper aims at analyzing the public agricultural extension and advisory services (AEAS) in Bosnia. In particular, it analyses governance; human resources; gender; cooperation projects; decentralization; financing; role in building social capacity as well as advisory approaches, methods and media. Some recommendations to improve the AEAS performance are made. The paper is based on a literature review and semi-structured interviews as well as focus group discussions carried out in March 2011 with agricultural advisors in the RS. Modern AEAS started to exist in BiH in 2002 and are organized on entity level: the Agency for Providing Services in Agriculture in the RS and cantonal agricultural extension services in the FBiH. The National Extension Services for BiH project helped establishing cantonal and regional offices. The Advisory Services Agency has five regional offices. Advisors use many group (*e.g.* lectures, seminars, field days) and individual (*e.g.* farm visits, phone calls) extension methods and media (*e.g.* internet, leaflets, posters, brochures, mass media). Advisors focus mainly on crop and animal production, processing and marketing. They also assist producers to gather in cooperatives. Advisory services face many financial, management and technical problems. The traditional top-down approach is still widely used. Bosnian AEAS should be supported by providing them with the necessary means and resources as well as technical, managerial and soft skills to fully assume their crucial role. That is necessary to develop a well performing pluralistic, participatory, bottom-up, decentralized, farmer-led and market-driven advisory system.

Keywords agricultural extension, performance, governance, Bosnia

INTRODUCTION

Bosnia and Herzegovina (BiH) consists of two governing entities *i.e.* the Federation of Bosnia and Herzegovina (FBiH) and Republika Srpska (RS); and a self-governing administrative unit i.e.

Brčko District (BD), under the State sovereignty. During the post-war period, the rural scenario in BiH has changed dramatically. Rural economy in BiH is getting more diversified but agriculture still plays an important socio-economic role. Agriculture share in GDP was 8.1% in 2011 (EC, 2012). Agriculture employs a fifth (20.6%) of the total labor force i.e. 167,000 persons (ASBiH, 2012). Rural areas cover 81% of the country's territory and approximately 61% of the total population can be classified as rural (Lampietti et al., 2009).

Easy and timely access to reliable and updated information is crucial for agricultural and rural development (ARD). The term "extension" was first used to describe adult education programs in England starting in 1867 (Swanson and Rajalahti, 2010). One can simply say that "*extension is getting knowledge to farmers so that they will make a positive change*" (USAID, 2012). Advisory service is commonly used as an alternate term for extension services. Apart from their conventional function of providing knowledge and technology to improve agricultural productivity, agricultural advisory services are also expected to link farmers to markets, promote sustainable production techniques, etc. (Swanson and Rajalahti, 2010).

Good extension is recognized as a key to agricultural development (USAID, 2012). Agricultural extension is the defining metaphor for all technology transfer activities and models. However, too few farmers have access to the extension services they need and extension workers themselves cannot easily tap all the information they need to help farmers (USAID, 2012). According to Leeuwis (2004), extension as a communication for innovation should serve as a "two-way" or "multiple–way process", which may have implications for all involved parties (farmers, researchers, extension agents, policy makers, agricultural industries, etc.). In fact, agricultural and rural extension needs to provide a wider range of services to a more diverse clientele to improve their capacity to access, adapt and use knowledge, inputs and services (World Bank, 2008). For extension to be successful, it needs to include credible content, effective delivery and be relevant to and applicable by clients (USAID, 2012).

In the Western Balkans, current agricultural extension structures have been developed mainly within the last two decades with the help of international donors. Public extension structures exist besides other providers such as NGOs and commercial extension agents (FAO, 2011).

OBJECTIVE

The paper aims at analyzing the public agricultural extension and advisory services (AEAS) in Bosnia and Herzegovina.

METHODOLOGY

The paper is based on a review of secondary data from different sources such as the FAO Regional Office for Europe and Central Asia; Agency for Statistics of BiH; USAID; the European Commission (EC); Arcotrass GmbH; the Institute for Statistics of the RS; the International Bank for Reconstruction and Development (IBRD); the Ministry of Agriculture, Forestry and Water Management of the RS (MAFWM-RS); the World Bank; etc.

Primary data were collected by semi-structured interviews as well as focus group discussions carried out in March 2011 with agricultural advisors in the RS. The prepared checklist dealt with many issues regarding the AEAS in BiH and the RS such as (i) governance; (ii) human resources; (iii) gender; (iv) main cooperation projects; (v) decentralization; (vi) financing; (vii) role in building social capacity; and (viii) advisory approaches, methods and media.

Taking into consideration the problems and weaknesses that were identified some recommendations were made to improve the Bosnian AEAS performance.

RESULTS AND DISCUSSION

Generally speaking, the performance of the agricultural extension system is strongly correlated to that of the research, development, education (formal, non-formal and informal) and training

(including vocational training) systems. As for existing agricultural training and education capacities, seven agricultural (cantonal level in the FBiH and regional level in the RS) faculties provide agricultural studies in BiH (FAO, 2011). The main agricultural research institutes and faculties in BiH are (Arcotrass et al., 2006): Agricultural Faculty in Sarajevo (FBiH); Agricultural Faculty in Banja Luka (RS); Veterinary Faculty in Sarajevo (FBiH); Faculty of Technology in Banja Luka (RS); and Agricultural Institutes in Sarajevo, Mostar (FBiH) and Banja Luka (RS).

Agricultural extension and advisory services, as known in practice worldwide (cf. Swanson and Rajalahti, 2010) started to exist in BiH in 2002. They are organized on entity level: Agency for providing services in agriculture in the RS, cantonal agricultural extension services in the FBiH and the Department of Extension Services in Brcko District. Responsibility for extension activities in the FBiH is in the hands of cantonal ministries in charge of agriculture. In Brcko district, the Office of Agricultural Extension Services operates within the Department of Agriculture and Forestry.

With the strong support of international donor projects the establishment of advisory services in BiH started after the civil war. A World Bank project is still active at national level (FAO, 2011). Within the EU PHARE pilot project (Co-ordination, Institutional Development and Advisory Services to Support Private Farmers; 1998-2000), extension service offices were founded throughout BiH (Arcotrass et al., 2006). In the RS, PHARE project financed the establishment of seven advisory services in Banja Luka region with a central office in Banja Luka. In the second phase (2000-2002), five regional centers have been established covering the entire territory of RS. Funds were provided also through the National Extension Services for Bosnia and Herzegovina (EU-ESP) project (MAFWM-RS, 2010).

In May 2002, the Agricultural Extension Service of the RS (Official Gazette of the RS, No 36, June 21, 2002) was established within the Ministry of Agriculture. Two years later, the Government of the RS established the Agency for providing services in agriculture, as a separate professional and legal organization, with a wide range of activities including agricultural extension services. The Agency is headquartered in Banja Luka and has five regional offices *i.e*. Banja Luka, Doboj, Bijeljina, Sokolac, and Trebinje; where work 21 advisors and administrative staff (about 48% female) for 221,000 rural households in the RS. All regional offices are financed by the government of the RS and each one of them covers from 9 to 21 of municipalities (MAFWM-RS, 2010).

The agricultural extension system in the RS includes municipal based advisers - within the Department for Economic and Social Affairs - supported by a central support unit with specialist adviser capacity, based in Banja Luka (Arcotrass et al., 2006). The number of officers for agriculture in municipalities in each region ranges from 9 (Trebinje) to 28 (Banja Luka) (MAFWM-RS, 2010). The Advisory Services Agency (ASA) in the RS is financed by the Entity budget but can also apply for funds from development projects. Seven municipal offices in Banja Luka area (*i.e*. Kozarska Dubica, Gradiska, Prijedor, Novi Grad, Laktasi, Prnjavor and Kotor Varos), are financed by municipalities. Generally the service appears to be well appreciated and used, though it remains poorly equipped, under-funded and generally under-manned (Arcotrass et al., 2006). The fact that extension is managed by a state agency provides some space for extension management and maintaining distance from day-to-day political decisions (FAO, 2011).

The EU-ESP project helped also establishing cantonal agricultural advisory services in the FBiH. The extension system was established at canton level but the commitment of most cantons was minimal and no central services were established to support the system (Arcotrass et al., 2006). Field advisors are part of the municipal administration (FAO, 2011). With this organizational setup extension superiors in the cantonal ministries of agriculture usually have little say regarding the extension service managed by municipalities. The relative advantage of having advisors who are close to the field and its actors, as well as the apparently positive ratio of farmers to advisors, is quite often counteracted by a deficiency of funds for transport and a great burden of administrative tasks, minimizing the time available to carry out advisory work. This has led to an almost asphyxiation of advisory work since the end of the last EU-funded project (FAO, 2011).

All services provided by the public advisory systems in BiH are free; the work of the advisors is paid for with entity, canton or municipality money (FAO, 2011) (Table 1).

As for agricultural extension methodological procedure, more or less clearly defined individual contact farmer approach has been implemented, focusing the advisory contacts on 40-50 example farms per extension agent (FAO, 2011). Advisors use many group extension and communication methods (*e.g.* lectures, seminars, demonstrations, field days, events, etc.) and individual methods (*e.g.* farm visits, contacts at extension offices, phone calls). The main media used are the internet, leaflets, posters, brochures, and mass media (Table 1).

Table 1 Characteristics and methodological procedure of the public advisory services in the entities of the FBiH and RS

Characteristics	RS	FBiH
Institutional Setup	State agency: Advisory Services Agency	Under responsibility of cantons
Field advisors	Field advisors are agency staff (agriculture administration)	Field advisors are part of municipality administration
Finance	Agency budget (300.000 € in 2009)	Cantonal budget
Resources of field advisors	Office, telephone, PC, Internet access, vehicle	Office, telephone, PC, Internet access
Approach to farm families	Individual contacts (sample farmer)	
Media	Leaflets, brochures, Radio, TV	
Priority setting	No defined procedure/ policy dependent	

Source: Adapted from FAO, 2011

Advisors provide services dealing mainly with agriculture production, processing and marketing (*i.e.* vegetables and fruit growing, animal husbandry, processing and quality of agro-food products, agro-economy). In the RS, most of extension agents are agriculture engineers that have general educational orientation (*e.g.* crop production, livestock production, fruit growing) while the number of specialists *e.g.* plant protection, irrigation, agricultural machinery, is modest. The fact that the majority of the field staff are agricultural experts induces a strong focus on production techniques and a relative preference given to large farms (FAO, 2011). The target group includes mainly farmers eligible for incentives. Extension generally lack market or farm management focus (Arcotrass et al., 2006). According to Swanson (2008), in most developing countries, extension's focus has concentrated on technology transfer for the major food crops. Extension agents also assist agricultural producers to gather in cooperatives and associations, help them to prepare business plans and to apply for credits. However, such an ambitious plan is far from matched by personnel, technical equipment and financial resources.

The Bosnian public agricultural extension service is strongly focused on production techniques, while farm management, markets and marketing, regional rural development and the promotion of producer organizations are only partially served. Extension agents are only able to thinly cover the areas of farm economy and farm development planning. Bosnian farmers' knowledge and skills requirements encompass issues of production, farm management (*e.g.* data recording), marketing and rural development. Rural development is not systematically supported by the public advisory systems due to an overload of work, and to the general lack of knowledge (on projects and programs) and skills (on group facilitation and group management) (FAO, 2011).

Advisory services face many finance, management and technical support problems as well as those related to mentality, low motivation and enthusiasm, overload with non-advisory activities, etc. According to the MAFWM-RS (2010), the main problems faced by the public extension system are: low number of extension agents; limited funding; lack of information flows between the advisory services and the Ministry of Agriculture; weak participation in international projects; confusion about the role and functions of the Agency; low interest of farmers for training; lack of long-term agricultural policy; and lack of specialized research institutions.

Advisors spend most of their working hours doing administrative tasks, first of all those related to incentive measures. According to FAO (2011), the handling and the administration of regional and national support programs dominates part of the activities of the public extension

services (FAO, 2011). Moreover, there is still a strong legacy of the former Yugoslav socialist system and the traditional top-down approach is widely used while the Agricultural Knowledge and Information System (AKIS) (Engel, 1997; Röling, 1996) and, the more recent, Agricultural Innovation System (AIS) (World Bank, 2006; Hall et al., 2006) concepts diffusion is limited.

Besides public extension services, many institutions provide advisory services such as cooperatives, agricultural and veterinary institutes and stations as well as private actors. In general, there are four types of private actors in agricultural extension: input suppliers; agricultural products purchasers; private trainer-advisor-outreach agencies; and mass media (Neuchatel Group, 1999). In BiH, communication and cooperation between the public, semi-public and private actors involved in the agricultural extension system is generally weak and unsystematic. In fact, Bosnian extension agents have no regular cooperation with the applied research institutes, universities, NGOs, and private extension providers. Meanwhile, they have poor cooperation with input suppliers and processors while cooperation with farmers' groups and associations is sporadic (FAO, 2011).

Bosnian extension agents lack systematic offers of professional training as there is no systematically planned and performed in-service training program. However, there are donor projects that provide training on a broad range of agriculture and rural development issues. Nevertheless, these trainings are not coordinated and planned, nor institutionalized at national and/or regional level and are thus potentially not accessible to all agricultural advisors. Agricultural advisors need training regarding the following issues: farming systems approach; extension methodology; farm economy and management; marketing, market development and value chains; environmental impacts of farm production; EU regulations; etc. (FAO, 2011).

In future, the agricultural knowledge system including education, research, extension and agribusiness needs to focus on how to improve the farm household's income, as opposed to just improving production. This requires a much sharper focus on the economics of technology and investments and on risk acceptability to farmers. In the reorganization of the extension services it must be realized that the technologies devised for the social farms are inappropriate for the private farms. A complete reversal of production technologies is now required (Arcotrass et al., 2006). The extension system must be flexible, user-driven, and focused on local problems (World Bank, 2008). Both public and private extension resources should be fully used; accountability to clients increased and more responsibilities transferred to the private sector (Arcotrass et al., 2006).

Linkages between advisory services and public stakeholders as well as research and education institutions dealing with ARD should be strengthened. Agricultural education, training and research systems should be strengthened as well. It is essential that the research system engages universities, private sector research and civil society organizations, and stimulates the scaling-up of innovations (Hall et al., 2006 and World Bank, 2008). Research needs to be more integrated into the agricultural sector transformation by moving from agricultural research and development to Agricultural Research for Development (AR4D). The agricultural education and training system needs to adapt as well to meet the new dynamics of agricultural innovation. Education institutes, both higher and vocational, have to offer more relevant subject matters for agricultural innovation (Daane, 2010).

CONCLUSION

Access to information and knowledge is crucial for the development of Bosnian agriculture and rural areas. Modern agricultural extension and advisory services in BiH are organized on entity level. There are also cantonal (FBiH) and regional (RS) offices. Bosnian advisors use many group and individual extension methods and media. However, advisors focus mainly on crop and animal production. They also assist producers to gather in cooperatives.

Advisory services face many financial, management and technical problems. The traditional top-down approach is still widely used. Funds available for field-level extension activities and in-service training courses for the extension staff are very limited. For all these weaknesses and problems the involvement of other actors in the extension work is crucial if the system is to keep with rural people's expectations and to meet their needs. In the framework of the agricultural innovation system, there is a clear role for public, private and civil society organizations to work

together in providing extension services to rural households.

Higher attention should be paid to modernizing and supporting Bosnian advisory services to allow them to assume fully their role as a main bridging actor in the dissemination of knowledge and the promotion of rural innovation, diversification, multifunctionality and sustainability. It is necessary to develop a pluralistic, participatory, bottom-up, decentralized, farmer-led and market-driven advisory system. The agricultural extension system should use advice, non-formal education and facilitation paradigms not only to achieve food security but also to manage natural resources; improve rural livelihoods; and build rural social capital. Well-performing agricultural advisory services are indispensable for achieving sustainable agricultural and rural development.

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Research article

The Study on Flood's Impact on Rice Production in Sandek Commune Bathay District Kampong Cham

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Abstract Flood is regarded as the most serious natural disaster that affected the economy of Cambodia. As the consequence, flooding has caused the loss of many lives, and has addressed impacts on social welfare and damaged the public and household properties. Livestock and crops were also destroyed. It has caused not only on the economic impact, but also on social and environmental problems of the nation. Seeing this serious problem which is an obstacle for the development of Cambodia, this study have been conducted with three main objectives are (1) to identify the extent of flood's impact on rice yields of farmers, (2) to assess the economic impact of rice production, and (3) to explore the farmer's adaptation capacity on rice pattern to the flood. To achieve those objectives, structured questionnaires were used with 96 who participated in the interview. The Study showed that the major flooding event in the last twenty years, worst flood in history in study site was the flood in 2011. Indeed, all respondents have evaluated there 2000, 2001, 2002 and 2011. Flood causes the most negative impact to their rice and mixed crops productions. The flood of 2011 has badly affected to economic value of farmer's rice production, which total average yield 3.862 tones/ha were lost. Rice crop is the main source of farmer's living, so this is the serious problem to their livelihoods. Low education of farmers was seen as the cause of low adaptation to flood. Most illiterate people (98%) were worst affected among the others in the study site. Recently, around a half of respondents grow dry season rice instead. Migration after that the flood in 2011 has become the popular way to generate more income. Conclusion, flood in 2011 is the worst impact on rice production in the study area. Further adaptation strategy is strongly needed for local people.

Keywords impact, flood, rice production, adaptation

INTRODUCTION

Natural disasters are key factor in rural people becoming poor and destitute in Cambodia and in the persistence of poverty (MoE and UNDP, 2011). The main natural disaster in Cambodia is flood (CRC, 2003a, 2003b). As the consequences, flooding had caused the loss of many lives, impact of social welfare and damaged the public and household's properties. Livestock and crops were also destroyed. Moreover, flooding not only caused of economic impact, but also to social and environmental problems of the nation. Flooding have caused loss of lives, affected social welfare and damaged public and household's properties, livestock and crop. Moreover, flooding make people suffer, afraid and migration. According to (NCDM and MoP, 2008) showed that from 1997 flooding increase and happen almost every years. (NCDM and MoP, 2008) also add that major flooding events affecting a significant population occur in 1961, 1966, 1978, 1984, 1991, 1996, 2000, 2001, and 2002. Although the flood in 2011 damaged rice paddy 267,184 hectares, other crops 17, 264 hectars and 250 people were killed (NCDM, 2012). Agriculture is the source for rural livelihoods, and for Cambodia are relying in rice production (RGC, 2010 and MoE, 2002). But, Cambodia agriculture is extremely affected by climate change. The flood's impact on rice production was cause of food security problems and around 18% of total Cambodia people had

food insecurity almost every year (NGO ESCRMC, 2002). By the ways, flood's impact on rice production is the obstacles and difficulty to achieved the government strategy in order to increase rice yield and rice export 1 million tones in 2015 (ACIAR, 2009). Moreover, it is the obstacle in poverty alleviation program and in achieving the millennium development goals.

METHODOLOGY

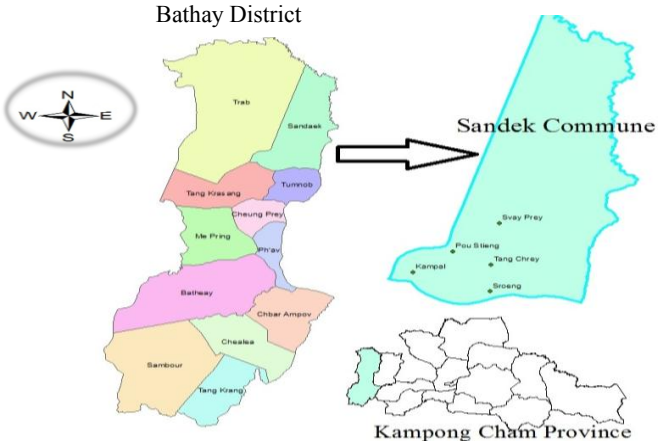

Fig. 1 Bathay district

Household level study was conducted in tree villages: Savay Prey village, Po Stiang village, and Tang Grey village, Sandek Commune, Bathay District, Kampong Cham Province. Major occupations for the people live in the commune who the rice growers. Mapping, seasonal calendar, time line and semi structure interviewer were used in qualitative methodology. There were 96 farmers who participated in the interview for quantitative approach. All data from quantitative were entry into SPSS program for this analysis.

RESULTS AND DISCUSSION

Households' survey and group discussion showed the events flood at the study area in 2000, 2001, 2002 and 2011. The worst floods in the study area's history occurred in 2011. This result is not different from data of (NCDM, 2012) which reveals that in some areas, the flood in 2011 was less severe than the flood in 2000. However, the other areas were worse than the flood in 2000. Table 1 shows 77% of the total respondents (n=96) caused impact and another 21% caused the medium impact. The rest, around 2% got less impact. For the flood in 2000 in the study area 69% got the worst impact. 23% got medium impact and another 6% got less impact. Only 2% of the total of the respondents is normal. Remarkably, the event flood in 2002, only 1% of the total respondents got the worst and medium impact. 11% was less impact and another around 13% normal. Meanwhile, around 17% of the household survey was less impact and around 24% was less potential. The rest, around 33% was the best potential from flood in 2002. Therefore, the event flood in 2001 around of the total of the respondents (n=96) at the study area around 8% got the worst impact by flood. The household's survey shows 24% was less impact and another around 17% normal. Meanwhile, around 7% of the total respondents is less potential and another around 11% mediums potential. The rest, around 33% is the best in the flood in 2001. Flood in 2011 had caused the loss of many lives, impact of social welfare and damaged the public and household's properties. Livestock and crops were also destroyed.

Agriculture is the foundation of farmers' livelihoods in study site, and rice paddy is the core cropping of respondents. It is the most important occupation for their living standard. But flood in 2011 damaged the public and household's properties and damaged on the livestock especially rice production. The survey result showed the rice paddy around 95% of the total respondents (n=96) got the worst impact by flood in 2011. They got nothing of rainy season rice yield because the

farmers growed raining rice at the same time during the flood period and flood in 2011 submerged before harvest 3.1% got medium impact. Most of the respondents got a little of raining rice yield and another 1% got less impact, they lost a little of their rainy season rice yield. The rest, no one in the respondents did not have an impact by flood in 2011 (Table 2). And Flood's Impact on plant around houses was 83.3% of the respondents got the worst impact. 9.4 % got medium impact and 7.3% of them got less impact by flood in 2011. Livestock rearing is a key part of rural livelihood, providing a mean for saving, source of income and food. But, Looking into the flood's impact on livestock of the respondents around 35.4% got the worst impacted by flood in 2011. Moreover, around 43.8% got medium impact and another 7.3% got less impact. Only 3.1% of the total households did not get impact. So, flood in 2011 really affected to their livelihood and saving. Remarkably, only 7.3% of houses of respondents the worst and medium impact. 58.3% got less impacted. The rest, approximately 27.1% was not affected by flood in 2011. During and after flood, the diseases always happen on human and animal. Most of local people have recognized the increasing cases of family's health problems and insect.

Table 1 Flood situation in the last 20 years in the study area

	2011	2000	2002	2001
Worst impact (%)	77	69	1	8
Medium impact (%)	21	23	1	-
Less impact (%)	2	6	11	24
Normal (%)	-	2	13	17
Less potential (%)	-	-	17	7
Medium potential (%)	-	-	24	11
The best potential (%)	-	-	33	33

Source: Households' survey, 2012

Table 2 Flood's impact on livelihood

Level of Impact	Worst (%)	Medium (%)	Less (%)	No Impact (%)
Rice	95.8	3.1	1.0	-
Plant near house	83.3	9.4	7.3	-
Livestock	35.4	43.8	17.7	3.1
Houses	7.3	7.3	58.3	27.1

Source: Households' survey, 2012

The economic impact of rice production

The survey showed that the people in the study site were farmers who grow rice paddy. this result is similar to the commune data book 2011 shows majority occupation of all of people lives in the commune are farmers which growing rice paddy. But, flood in 2011 almost damaged their rice production in the study site. And the total average yield only 0.119 tone/ hector .It was not enough even to home consumption. So, this was the serious problem to their livelihoods. Flood's impact on rice production was the obstacles and difficulty to achieved government strategy (ACIAR, 2009). Therefore, the survey result showed the economic value of rice production 3.682 tones/hectare was loss by flood in 2011. So, it really the obstacles to Achieved government strategy in order to increase rice yield and rice import 1 million ton in 2015.

Local knowledge to flood information

The Information of the water's level is vital for people especially farmers who live in the vulnerable area. Household's survey showed 98% of the total respondents (n=96) do not know the water's level beneficial for cropping matures at Chorlar Sas station. Remarkably, only 2% of the total respondents know the water level matures at Chorlar Sas station that beneficial for cropping. According to households' survey and household's group discussion shows the study area's history events flood in 2000, 2001, 2002 and 2011. Therefore, farmer used to get negative impact by flood.

In contrast, almost respondents in the study area did not make attention to water's level or flood information. It is the serious problems for people who lived in the vulnerable area. We also can say that, do not make attention on water's level or flood information is also another cause of badly impact by flood. In contrast, if they make attention on flood information they can reduce the level of worst impact by flood and they can prepare before flood. So, they have capacity to recover their farm after flood. Flood it is the serious problems and serious concern.

Level impacts of literacy respondents

Survey result showed that 98% of the total literacy respondents in the study place (n=96) was worst impacted by flood in 2011. Looking to the medium impact of the literacy respondents is only 2%. Due to the result shows among literacy respondents all of them were impacted by flood in 2011. The education has play main role in adaptation capacity to flood. Low education may the cause of low adaptation. By the ways, low adaptation is another cause of got worst impacted by flood.

The farmer's adaptation capacity on rice pattern to the flood

Generally, rice farming in the study site takes 7 months which started from June to December. By the ways, flood in 2011 submerged rice paddies about 3 months which started from middle September to middle December (Table 3). Group discussion and the result of interview 96 households showed farmers growing raining rice paddy at the same time during the flood period and flood in 2011 submerged before harvest. Therefore, almost the raining rice paddy of the farmers at the study area was damaged by flood in 2011. The average raining rice yield of the total respondents (n=96) in the year 2011 is only 0.118 tones/hectares. The green color showed the cycle of rice production and yellow color was the period of flooding and the red color was the worst flood. According to the timetable of crop calendar of rice production and flood duration, we can conclude that, the farmer's adaptation capacity on rice pattern to the flood before 2011 is low.

Table 3 Flood duration and rice production cycle

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Set	Oct	Nov	Dec
Rice												
Flood												

Source: Households' survey, 2012

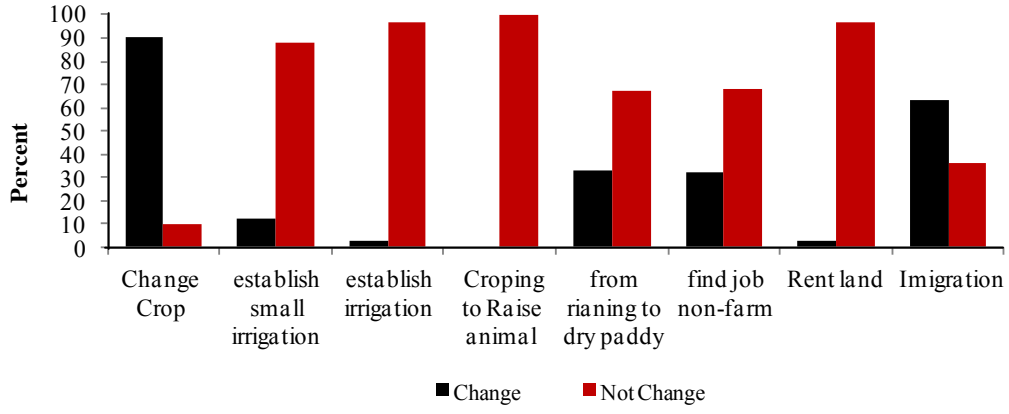

Fig. 2 Farmers' adaptation to flood

Survey result showed that 90% of total interview households has change crop. They changed many kind of rice while only 10% has not. 12% of the total respondents (n=96) was established small irrigations. They build ponds and wells near their farm. According to household's interviews only 3% is establish irrigation. It does not mean that local farmers build new irrigations they all together just rebuilds and clean some irrigation that too old and can not content the water.

Therefore, around 3% has changed rent their land to another. Most of the people do not like this way. However, they still grow rice event they do not know does the flood can damage their rice yield or not. They are farmers so they have no choice and they really want to grow rice two or three times per year, but lack of irrigation. Moreover, around 30% is change from raining to dry paddy and another round 60 % has migrated. Remarkably, there is no respondent change cropping to raise animal (Fig. 2). Agriculture is the foundation of rural livelihoods and rice production is the majority crop for rural people. Flood in 2011 is the worst impact on rice production in the place study is also another cause of blocked the development of Cambodia. Further adaptation strategy is strongly needed for local people.

CONCLUSION

Flooding had caused the loss of many lives, impact of social welfare and damaged the public and household's properties. Livestock and crops were also destroyed. Moreover, flooding not only caused of economic impact, but also to social and environmental problems of the nation. The major flooding event at the last twenty years worst flood in history in particularly study site was the flood 2011. Indeed, all respondents had evaluated there 2000, 2001, 2002 and 2011. The flood was the most negative impact on the rice and mixed crops productions. Particularly, the flood of 2011 had bad impact to economic value of farmer's rice production, which consisted of total average yield 3.862 tones/ha were lost. Rice crop was the main source of farmer's consumption, so this was a serious problem on their livelihoods. Around a half of respondents grow dry rice season instead. Migration to another place becomes the popular way to generate more income. Low adaptation of the farmers is another cause of worst impact especially on rice production. Therefore, the extent of flood's impact on rice yields of farmers is the main consequence. In conclusion, flood in 2011 is the worst impact on rice production in the place study. Moreover, it is the obstacles in poverty alleviation program and in achieving the millennium development goals. Further adaptation strategy is strongly needed for local people.

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Research article

Dietary Exposure Assessment of Benzylpenicillin Residue in Pork Consumed by Age and Gender Groups in the Philippines

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Abstract Exposure assessment is one of the most important key components of the risk assessment process. Dietary intake of significant amounts of residue can lead to adverse health effects and development of antimicrobial resistance in the population. The study was conducted to determine exposure risk to antibiotic drug residues in pork consumed in the Philippines. The specific aim was to estimate dietary exposure of Benzylpenicillin residues by age and gender groups. Parameters such as food consumption, substances residue, body weight, ages, and gender groups were gathered from local and international institutions. Mathematical equations were used to calculate for Dietary Exposure from amount of drug residue multiplied by the mean food consumption and adjusted by body weight. The present study; dietary exposure of Benzylpenicillin residue for children from 1 to <3 years old had the highest exposed followed by adolescents, adults and infants while males were significantly higher than females ($p<0.05$). This is the first attempt to determine risk assessment of dietary exposure to antibiotic residue of different population groups in the Philippines. Improvement of mathematical models used in this study is proposed to better prioritize exposure assessment models for veterinary drug residues to ensure the safety of food produced from farm to table.

Keywords exposure assessment, drug residues, age-gender groups, consumption

INTRODUCTION

The use of risk assessment has gained steadily in importance and recognition as a scientifically-based approach for the development of food safety and quality standards. During recent years there has been increasing use of the word "risk" in connection with food safety (Sumner et al., 2004). Consequently, a risk assessment of the food safety implications (Gehring et al., 2005) may be made on the potential harm or risks of veterinary drug residues to the human consumer. The importance of risk assessment lies not only in its ability to estimate human risk, but also in its use as a framework for organizing data, as well as for allocating responsibility for analysis. As such according to World Health Organization (1995), it is important to understand that risk assessment is a process that can include a variety of mathematical models to estimate risks. Risk assessments also promote international trade by addressing new safety and quality challenges (Graf, 2005).

Exposure assessment is among the components of risk assessment (Codex Alimentarius Commission, 1999). Dietary exposure to veterinary drugs occurs when residues remain in food

products derived from animals treated with a veterinary drug (Health Canada, 2003a). Dietary exposure models have been developed to predict human exposures to chemicals resulting from the consumption of contaminated food and residue levels and also for substances naturally occurring in them (Fryer, 2006). In 2003b, Health Canada primer on "Assessing exposure from pesticides in food" indicated that risk exposure from food can either result in short-term (i.e., acute) or long term (i.e., chronic) effects. In actual risk equations, it is possible that toxicity may be computed utilizing the estimation of consumer intake of drug residues in foods of animal origin, hence, this study on exposure assessment.

Thorough literature search revealed no available study on exposure assessment on veterinary drug residues 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 exposure assessment of antibiotic residues. To date, there is no local study conducted on the exposure risk assessment for residual antibiotics in the Philippines. Thus, this study aims to make a "Dietary Exposure Assessment of Benzylpenicillin Residues in Pork Consumed by Age and Gender Groups in the Philippines".

The overall objective of the study is to determine exposure risk to antibiotic drug residues in pork consumed in the Philippines. The specific aim is to estimate the dietary exposure of Benzylpenicillin residues by ages and gender groups.

METHODOLOGY

The study was conducted using secondary data collected from local and international institutions for estimating dietary exposure assessment. For instance, local data like the report on veterinary drug residue (2003-2008) from National Meat Inspection Service, recommendation on Maximum Residue Limit (MRL) published by Bureau of Aquaculture Fisheries and Product Standard, the report of Food Consumption Survey in 2003 and Recommended Energy and Nutrient Intake in 2002 published by Food and Nutrition Research Institute (FNRI, 2003), the development of antimicrobial resistance from Research Institute for Tropical Medicine, Philippines. 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.

Dietary modelling combines food consumption data with food chemical concentration data to estimate dietary exposure to food chemicals, or intake of nutrients. The Eq. (1) below, the basic dietary exposure model is of the form:

$$Dietary\ Exposure = \frac{Food\ Consumption \times Amount\ of\ drug\ residure}{Body\ weight} \quad (1)$$

where food consumption is the amount of food people eating per capita per day expressed in mg/kg/day and amount of drug residue expressed in µg/kg BW/day.

RESULTS

The benzylpenicillin antibiotic have been test for consecutive years from 2006 to 2008 in the Philippines. The number of violations was determined using Microbial Inhibition Test and was measured using caliper method (NMIS, 2008). Positive benzylpenicillin residue results in NMIS were assumed to equivalent to HPLC LOQ 400 µg/kg (Heitzman, 1995) and dietary exposure was calculated using the following equation (3) which regarded computed using equation (2).

Eq. (2) the Mean Food Consumption Difference Age Groups is as follows;

$$The\ mean\ food\ consumption\ difference\ age\ groups = \frac{average\ weight\ difference\ age\ groups \times the\ mean\ food\ consumption\ per\ capita\ in\ the\ Philippines}{average\ weights} \quad (2)$$

Eq. 3 Dietary Exposure of Benzylpenicillin Residue is as follows;

$$DE_{PEN} = \frac{amount\ of\ benzylpenicillin\ residues\ of\ 3\%\ positive\ results \times mean\ food\ consumption\ difference\ age\ groups}{average\ weights\ differences\ age\ groups} \quad (3)$$

Based on an update as of the 32nd session of the Codex Alimentarius Commission in 2009 first draft prepared by Dr. Macneil, a typical recommended dose by intramuscular injection (IM) in swine, cattle, horses, and sheep of a 300,000 unit/mL formulation is 6,600 units/mL BW. As a feed additive, a typical dosage for swine or poultry is 55 mg/kg in the diet. Intramammary treatment is typically by administration of 100,000 units per quarter. In the studies reported, 1 mg procaine benzylpenicillin is equivalent to 1667 IU (international units).

As at 50th report of JECFA in 1999, the Committee considered residues of procaine benzylpenicillin to be equivalent to residues of benzylpenicillin. Dietary Exposure (DE) was calculated using equation (1) following the mean one-day per capita food consumption in the Philippines and by island groups, food groups and adjusted 55-kg person. The DE of Benzylpenicillin Residue was calculated by the amount of benzylpenicillin of 3% positive results multiplied the food consumption difference age groups and adjusted by average weight difference age groups.

Table 1 shows that DE of benzylpenicillin residue for children from 1 to 3 years old had the highest value at 0.002923 µg/kg bw/day. Such value was calculated as 5 µg/kg of amount residues × mean one-day per capita pork consumption of 0.0076 kg ÷ 13 kg of average children weights. Likewise, average DE for children (0.002913 µg/kg bw/day) was higher than adolescents (0.0029096 µg/kg bw/day), followed by adults (0.002909 µg/kg bw/day) and infants (0.002903 µg/kg bw/day). Also, DE for males was significantly lower than females (p-value=0.034).

Table 1 Dietary exposure of benzylpenicillin residue of 3% of positive results intake of fresh pork in the Philippines

Age Groups	Average Weight (kg)	Amount Residue (µg/kg)	Mean One-Day Per Capita Pork Consumption (g)	Dietary Exposure (µg /kg bw/day)
1. Infants, month				
Birth- <6 (3)	6	5	3.5	0.002917
6-<12 (9)	9		5.2	0.002889
2. Children, year				
1-3 (2.5)	13		7.6	0.002923
4-6 (5.5)	19	5	11.1	0.002921
7-9 (8.5)	24		13.9	0.002896
3. Adolescents, M, year				
10-12 (11.5)	34		19.8	0.002911
13-15 (14.5)	50	5	29.1	0.002910
16-18 (17.5)	58		33.7	0.002905
4. Adolescents, F, year				
10-12 (11.5)	35		20.4	0.002914
13-15 (14.5)	49	5	28.5	0.002908
16-18 (17.5)	50		29.1	0.002910
5. Adults, M, year				
19-49	59		34.3	0.002907
50-64	59	5	34.3	0.002907
65 and over	59		34.3	0.002907
6. Adults, F, year				
19-49	51		29.7	0.002911
50-64	51	5	29.7	0.002911
65 and over	51		29.7	0.002911

DISCUSSION

To determine the risk of dietary exposure of DE_{PEN} residue using mathematical model gives an estimate of the risk of having toxicity among the populations. In the present study is a first step in determining the most important fields for generation new data to estimate more accurately the proportion of the population at risk of toxicity and development of antimicrobial resistance due to a given the amount of antibiotic residue of dietary intake in pork consumption.

Exposure was calculated for the populations in the Philippines based on the consumption per capita (as a major factor), followed by the amount substance residue and body weight. For instance, Steve (2009) and Kroes et al., (2002) where dietary exposure assessments have been taken, relevant food consumption data have been utilized. E.g., Ock and Hee (2002) reported estimation of dietary pesticide risks, following the setting up of food consumption and pesticide residue levels in the calculation of toxicological risk. E.g., assessment on dietary melamine exposure based on the maximum consumption of melamine and the median levels of melamine detected in the most contaminated food (Xu et al., 2009). This dietary modeling combines food consumption data with food residue concentration data to estimate dietary exposure level to contaminants heavy metal (Haeng et al., 2005).

The present study found that DE_{PEN} residue for children from 1 to 3 years old is the highest exposed followed by adolescents, adults and infants whilst males are significant for females in the Philippines. For instance, Kroes et al., (2002) reviewed on children, because of its higher food consumption rates per kg bw, is generally expected to have a higher exposure level and is therefore higher risk of the population. In this respect, children may be of special interest because of their higher intake level per kg bw due to growth processes (Kroes et al., 2002). A similar study on dietary exposure of children and teenagers to benzoates, sulphites, butylhydroxyanisol and butylhydroxytouen found that between 2 groups of students the younger subjects are more exposed when the exposure is expressed in kg of bw ($p<0.01$) (Soubra *et al*., 2006). Another possible example was conducted on cumulative risk assessment of the exposure to organophosphorus and carbamate insecticide in the Dutch diet by Boon et al., (2008). For children the exposure (57 vs. 25 µg/kg BW/day) was higher than the total population (18 vs. 23 µg/kg BW/day). The resulting in exposure levels equal to 11% and 25% of the acute reference dose for the total population and young children respectively. Another similar study, Caldas et al., (2006) found that children exposure to acetylcholinesterase (AChE) inhibition pesticides is also of additional concern, as this population might be more sensitive to these compounds than adults. For children, the exposures were, on average, 2.4 times higher than the exposure found for the general population. Since the determination of dietary exposure to antibiotic residues in the present study shows no zero risk, i.e., there is a risk for possible adverse effects on the population. Another concern for use of antibiotics in agriculture and aquaculture is the risk for development of antimicrobial resistance. Currently, an antimicrobial resistance surveillance reference laboratory has been prepared with 435 isolates by the Antimicrobial Resistance Surveillance Program of Research Institute for Tropical Medicine. It is clear that the percentage of penicillin resistance is 25% Salmonella sp. (RITM, 2009).

CONCLUSION

Based on the finding of the present study, dietary exposure of benzylpenicillin have been detected in pork which children from 1 to 3 years old is more exposed and more risk, because of their higher food consumption rates per kg body weight, is generally expected to have a higher exposure level due to physical activity.

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Research article

The Difference of Agricultural Land Use in Watersheds and Long Term Fluctuation on the River Water Quality

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Abstract This study was conducted to determine the relationship between the characteristics of fluctuations in river water quality at the normal water level and the proportion of agricultural land in watersheds of Eastern Hokkaido that have different agricultural land use, based on the 20 years observations. The investigations were carried out during late August to early September in 1992, 2003 to 2006, and 2012 at 35 watersheds in two areas, and NO_3-N, EC of river water and river discharge were measured. The Tokachi area (24 watersheds) is located in the northwestern part of the Tokachi General Subprefectural Bureau, the main land uses are upland and dairy farming. The Nemuro area (11 watersheds) is located in the western part of the Nemuro Subprefectural Bureau, the main land use is large-scale dairy farming. In the 20 years since 1992, NO_3-N concentration and EC have shown increasing tendency in some of the investigated river watersheds. The river water quality in some watersheds investigated in 2004, immediately before the full implementation of "The Law on Animal Waste Regulation", greatly differed from the observation results of several years before and after 2004. When the two areas had the same proportion of agricultural land, the NO_3-N concentration in the river water tended to be higher in Tokachi area than in Nemuro area. This is attributed to the proportion of upland fields, which require large inputs of chemical fertilizer in the Tokachi area. EC, however, tended to be high in the Nemuro area, even for watersheds with similar proportion of agricultural land. This suggests that the river water in the Nemuro area contains many materials of geological origin, in addition to containing NO_3^-.

Keywords NO_3-N concentration, EC value, agricultural land use, long-term fluctuation

INTRODUCTION

Large-scale farming under harsh climatic conditions has long prospered in Eastern Hokkaido, whose natural environment differs from those of other Asian monsoons regions. In recent years, water contamination including nitrate pollution of river water and groundwater has been pointed out (Tabuchi et al., 1995; Matsumoto and Tou, 2006).

In the Tokachi district, large-scale upland and dairy farming were established early years before World War II. In the Kushiro and Nemuro districts, however, agricultural land has expanded only since the 1960's, with the large-scale reclamation of wilderness to grassland. As the land development expands, the varieties of cultivated crops have been reduced and agricultural land use has been unified for grassland. Several studies have conducted to determine the influence of the drastic land use changes on the river water quality there since the 1990's (Kuramochi et al., 1994; Nagasawa et al., 1995; Inoue et al., 1999; Muneoka et al., 2001). In the Tokachi district, however, studies on agricultural land use and river water quality have only just begun (Okazawa et al., 2011; Muneoka et al., 2012).

Tabuchi et al., (1995) conducted investigations of the river water quality at the normal water level in watersheds of an extensive area of Eastern Hokkaido in the summer of 1992. They had shown that there was a positive correlation between the nitrate nitrogen concentration in river water and the extent of agricultural land use in each investigated area. Based on this study, the authors have conducted investigations in the Tokachi and Nemuro areas during the same periods at normal water level. There has been no similar research anywhere in which to weigh the river water quality in two large areas with the different agricultural land use over a long period.

Thus, the objective of this study was to evaluate the impact from the different agricultural land use of watersheds on the river water quality at the normal water level, based on a 20-year observation.

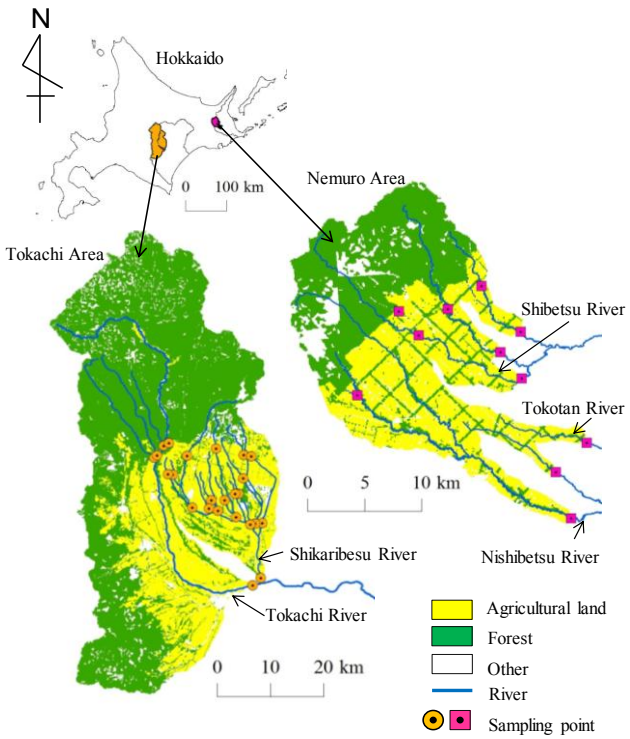
METHODOLOGY

The outline of this study sites are shown in Fig. 1. The Tokachi area, which consists of 24 watersheds on the Tokachi River system and the Shikaribetsu River system (No. 1 to 24), is located in the northwestern part of the Tokachi General Subprefectural Bureau, and it is an area with upland and dairy farming. The Nemuro area, which consists of 11 watersheds on the Shibetsu River system, the Tokotan River system and the Nishibetsu River system (A to K), is located in the western part of the Nemuro Subprefectural Bureau, and it is an area mainly of dairy farming. In both of these areas, large-scale farming has been operated, and there have been no considerable changes in agricultural land use in either area since 1985.

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

The investigation of the river water quality was conducted at the normal water level at 35 sampling points. Electric conductivity (EC) and water temperature were measured at sampling points. And discharge was also measured on the rivers in small watersheds (varied between 22 and 25 by year). The indices and the methods used for water quality analysis varied with each year, nitrate nitrogen (NO_3-N) concentration and EC as indices in this study. The investigations were carried out during late August to early September in 1992, 2003 to 2006, and 2012.

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



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

Fig. 1 Outline of the Tokachi and Nemuro areas

RESULTS AND DISCUSSION

The characteristics of long-term fluctuations at the 35 locations in the two areas, which are indicated by using the NO_3-N concentration and the EC of the river water as indices, are shown in Fig. 2.

The NO_3-N concentration in 1992 were <0.1 to 3.9 mg/L for Tokachi area and <0.1 to 2.0 mg/L for Nemuro area. In and after 2003, a tendency of year-on-year increase in the maximum value of NO_3-N concentration was observed for both areas. The maximum NO_3-N concentration was 7.2 mg/L in Tokachi area and 2.6 mg/L in Nemuro area.

The tendency of increase in NO_3-N concentration was noticeable at four sampling points in Tokachi area (No. 10, 11, 12 and 17) and at three sampling points in Nemuro area (G, H and K). These seven points were distinctive that they were small watersheds of 5 to 28 km^2 in area and they had high proportions of agricultural land (49 to 95%). It is worth noting that the NO_3-N concentration showed drastic decreases in 2004 at six points (No. 7, 8, 14, 15, 23 and 24) in Tokachi area and at three points (C, G and J) in Nemuro area, irrespective of the watershed size and the proportion of agricultural land (Fig.2 (a), (b)).

The EC in the two areas in 1992 were 5.1 to 23.3 mS/m in Tokachi area and 5.8 to 18.6 mS/m in Nemuro area. However, the maximum values of EC tended to show slight increases in both areas in the 20-year period. The maximum EC was 26.8 mS/m in Tokachi area and 20.4 mS/m in Nemuro area for the period from 2003 to 2012. EC showed drastic increases at one point (No. 8) in Tokachi area and at three points (D, E and G) in Nemuro area in 2004 (Fig.2 (c), (d)).

Based on these data, it can be assumed that the fluctuations in river water quality, which are indicated by the decrease in NO_3-N and the increase in EC in 2004, reflect the changes in the behavior of farmers, including the management of livestock manure, that resulted from the full implementation of "The Law on Animal Waste Regulation" in November 2004.

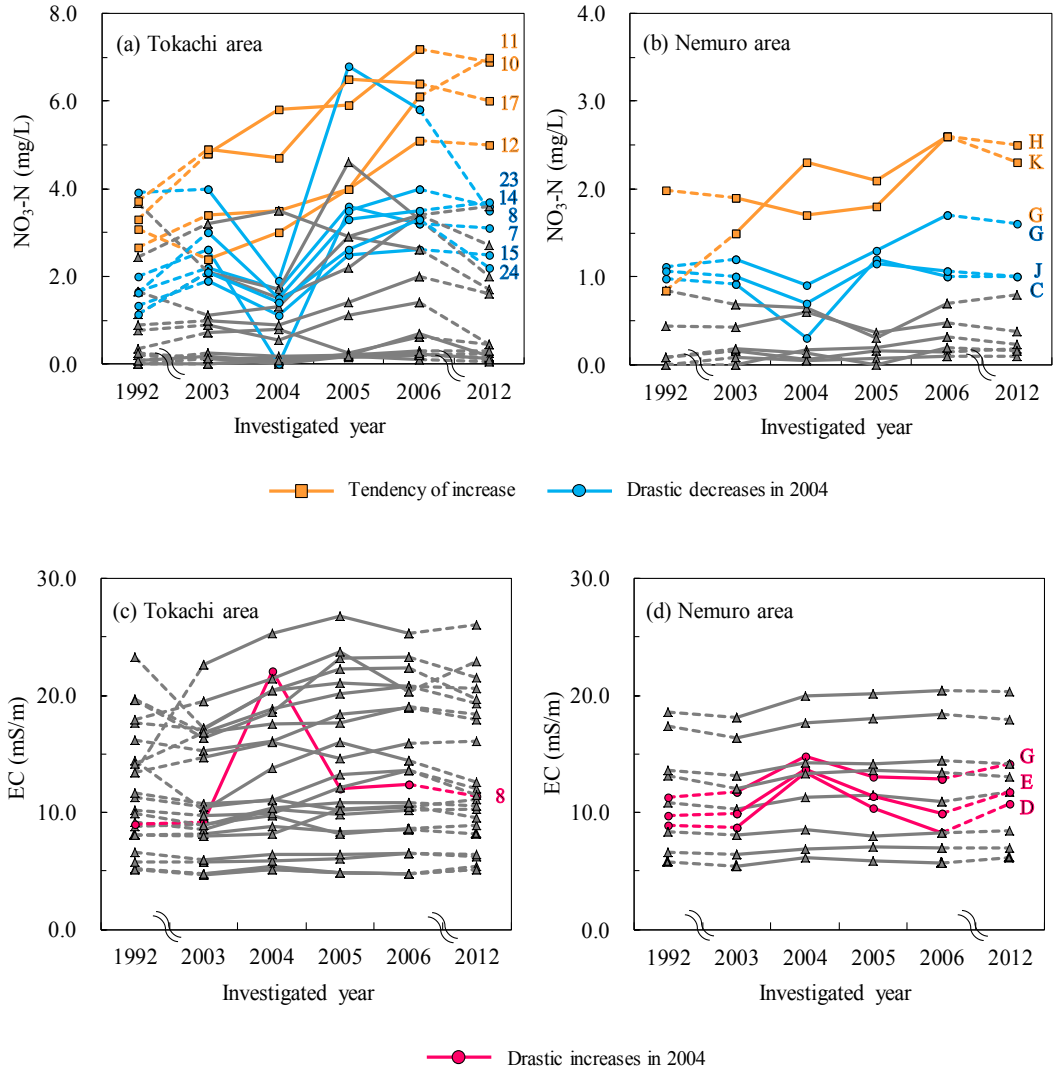


Fig. 2 Long-term fluctuation on the NO_3-N concentration and the EC of the river water in the Tokachi and Nemuro areas

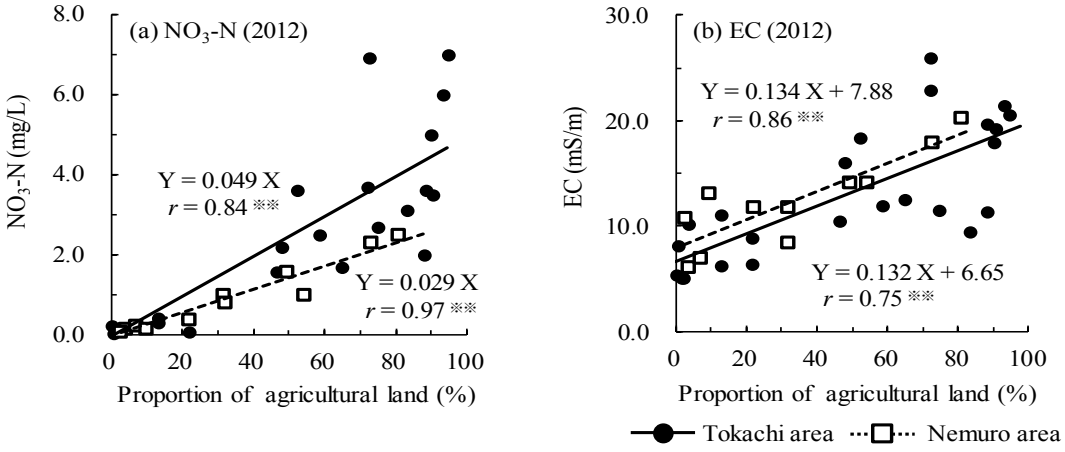
Fig. 3 shows the regression lines and the results of calculation for the coefficients of correlation *r*, which indicate the relationship between the NO_3-N concentration of the river water and the proportion of agricultural land and that between the EC of the river water and the proportion of agricultural land in watersheds at the two areas.

From the relationship between the NO_3-N concentration (Y) and the proportion of agricultural land (X) in the watershed is expressed as Y = a X. The slopes "a", which indicates impact factor (IF) values, were 0.030 to 0.055 in Tokachi area and 0.020 to 0.031 in Nemuro area during the period. When two watersheds, one from the Tokachi area and the other from Nemuro area, that had similar proportions of agricultural land were compared, the NO_3-N concentration in the river water tended to be higher in Tokachi area. In the Tokachi area, land use was for dairy farming and the farming of various upland crops. In addition to livestock manure, the loading source includes chemical fertilizers that were applied in large quantities to the upland fields. It is assumed that the use of chemical fertilizers contributed to the higher concentration of nitrogen in river water.

From the relationship between the EC of the river water (Y) and the proportion of agricultural land (X) in the watershed is expressed as Y = a` X + b`. The slopes "a`" were 0.102 to 0.150 in Tokachi area and 0.119 to 0.149 in Nemuro area during the period. The intercepts "b`" of the areas were 6.11 to 6.65 for Tokachi area and 6.81 to 8.78 for Nemuro area. As shown above, when the watersheds in Tokachi area had the same proportion of agricultural land as that in the Nemuro area,

the EC of the river water tended to be higher in Nemuro area. It is assumed that the river water in the Nemuro area contains considerable amount of dissolved ions derived from geologic material, in addition to the nitrate ions (NO_3^-) from farmland.

When the coefficient of correlation *r* was examined by using NO_3-N concentration as the index, *r* for Tokachi area was 0.65$^{※※}$ to 0.89$^{※※}$, and *r* for the Nemuro area was 0.85$^{※※}$ to 0.97$^{※※}$. When EC was used as the index, *r* for Tokachi area was 0.70$^{※※}$ to 0.82$^{※※}$ and *r* for Nemuro area was 0.77$^{※※}$to 0.89$^{※※}$. As described above, *r* for Nemuro area was constantly higher during the period. A factor contributing to this result could be that the agricultural land in Nemuro area is unified into grassland, whereas the agricultural land uses in Tokachi area are more diverse.



Investigated year	NO_3-N (mg/L) [Y = a X] Tokachi area a	*r*	Nemuro area a	*r*	EC (mS/m) [Y = a` X + b`] Tokachi area a`	b`	*r*	Nemuro area a`	b`	*r*	N.B
1992	0.031	0.88 **	0.020	0.85 **	0.111	6.29	0.76 **	0.127	7.09	0.86 **	
≈											
2003	0.036	0.84 **	0.022	0.96 **	0.102	6.39	0.70 **	0.124	6.81	0.88 **	
2004	0.030	0.65 **	0.022	0.93 **	0.133	6.63	0.77 **	0.119	8.78	0.77 **	
2005	0.051	0.89 **	0.024	0.95 **	0.150	6.11	0.80 **	0.132	7.73	0.84 **	
2006	0.055	0.89 **	0.031	0.96 **	0.148	6.28	0.82 **	0.149	6.85	0.89 **	
≈											
2012	0.049	0.84 **	0.029	0.97 **	0.132	6.65	0.75 **	0.134	7.88	0.86 **	(a), (b)

**significance of 1%

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

CONCLUSION

Fluctuations in river water quality at the normal water level were investigated during a period of 20 years at 35 sampling points in two areas in Eastern Hokkaido, with a focus on the differences in agricultural land use between the watersheds. This study evaluated that, in the Tokachi area, upland-field-derived NO_3-N constantly flowed into the rivers in high concentrations at the normal water level. As a result of the long-term observation, the concentration of river water quality hasn't drastically decreased in spite of the full implementation of "The Law on Animal Waste Regulation" in November 2004. Toward improving the river water quality in extensive agricultural areas from the standpoint of conserving the water environment, it is necessary to evaluate and review the management of livestock manure by individual farms as well as examining the relative positions of farmland and rivers and the land in between these.

ACKNOWLEDGEMENTS

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Research article

E-Learning Solution on Good Agricultural Practices (GAP) for Students of Higher Learning in Cambodia (Focus Vegetables)

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Abstract Food security is one of the critical development issues faced by several developing countries. One avenue of yielding quality crops is by ensuring that good agricultural practices are followed throughout the entire farming cycle. This research focuses on educating students of higher learning on good agricultural practices associated with growing vegetables. Research target are students who are currently pursuing tertiary education in the field of agronomy and agroindustry, as it is expected that upon graduation, they will represent the frontlines of various agricultural concerns. As such, students form the basis for sustainable education as they can replicate knowledge gained and impact farmers on good agricultural practices through proper education, as well as enforcement. For the purpose of this research, students from Royal University of Agriculture, Cambodia are identified as participants. The electronic learning method (e-Learning) is deployed to expose students to new mechanisms of teaching and learning, as well as to encourage students to be more active in independent studying. As teaching material, interactive multimedia videos canvassing the general farming guidelines, production and post harvest practices pertaining to the cultivation of vegetables are produced and distributed to students through workshops. A web portal is also developed to form an online community of students and promote interaction through forums, live chats, news updates and social networking platforms.

Keywords good agricultural practices, e-learning, sustainable education, safe vegetables

INTRODUCTION

Food security remains as one of the critical development areas faced by many developing countries all over the world. Food security is said to be a country's capacity to provide and ensure people have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Reduced and inadequate food supply versus increasing demand from a growing population is the simple imbalanced equation to today's global issue of food shortage, with developing countries worst hit in spite of agriculture contributing a rather significant percentage to their respective GDPs.

While there are many undergoing efforts and research to improve agricultural produce, effective educational efforts at grass root levels is necessary to ensure the success of these improvement efforts. One of the measures to improve food security is by adhering to good

agricultural practices or commonly known as GAP. GAP involves taking all possible procedures recommended before, during and after the growing period to ensure that optimum quality and quantity of yield can be produced. The procedures cover a wide spectrum of farming activities, ranging from soil management, irrigation and fertilization to harvesting as well as packaging and storage.

There are several benefits of implementing GAP as highlighted by the Caribbean Agricultural Research and Development Institute (CARDI) and Food and Agriculture Organization (FAO):

- The appropriate adoption and monitoring of GAP helps improve the safety and quality of food and other agricultural products
- By improving the quality and quantity of yield, farmers are able to increase their income and living conditions. In the long run, poverty levels can be reduced
- It may help reduce the risk of non-compliance with national and international regulations, standards and guidelines, regarding permitted pesticides, maximum levels of contaminants in food and non-food agricultural products
- Adoption of GAP helps promote sustainable agriculture by preserving the environment (no contamination of water and soil)

Good agricultural practices is a very wide field and its application differs depending on the type of crop. For the purpose of this project, vegetables are selected as the focus area because they are easily susceptible to diseases which either damage the crop or render it unsafe for consumption. As such, complying with GAP for this type of crop is crucial.

Case Study: Cambodia

The Kingdom of Cambodia, is a developing country located at the southern section of Indochina in Southeast Asia. From its population of 11.5 million people, 84% are working in the agriculture sector. Cambodia's main produce include rice, cereal grains, vegetables, fresh fruits and sea products.

For the purpose of this project, Cambodia has been chosen as the country of study due to its deep involvement in agriculture activities. Additionally, University Kuala Lumpur (UniKL) and Royal University of Agriculture, Phnom Penh (RUA) have been collaboration partners on various projects pertaining to Information Technology and student exchange programmes. For these reasons and familiarity, both universities are collaborating on this project to develop e-Learning materials for students of RUA to educate them on GAP.

PROJECT BACKGROUND

Education on GAP has been implemented in developing countries for many years. The traditional approach (for developing countries) has been top-down, where agencies involved in formulating the practices train extension staff, and the latter is deployed to agricultural farms to educate farmers. Methods of teaching could be verbal, written literature and demonstrations. Literature suggests that with this traditional approach of educating farmers from some developing countries such as Cambodia have some limitations and the results of growing by adhering to GAP procedures takes a long time. This may be due to several challenges, such as the ones mentioned as follows.

Poor lteracy levels

In Cambodia, 77% of adults either have no education or only have primary school level education. In fact, 47% did not even have the opportunity to complete primary education (*www. cambcomm.org.uk*). As GAP generally involves specific procedures, measurements and instructions, one would require written manuals for reference. However, with low literacy levels, farmers in developing countries such as Cambodia may have difficulty reading and following all practices outlined.

Lack of expertise to monitor farmers

Implementing and complying with GAP procedures on a day-to-day basis is not an easy feat as there are many different guidelines to follow at different stages of a crop's growth cycle. GAP is the result of much scientific research and development activities performed by agricultural experts to continuously improve the quality and quantity of yield. Nevertheless, actual execution is at farm level and in the hands of the farmers. Sufficient specialists from agricultural ministries and agencies trained in GAP must be deployed to provinces and farms to not only educate farmers, but be available to provide hands-on assistance and monitor the cultivation activities of the farmers.

Difficulty in reaching farmers

Most farms and farmers are wide spread all across Cambodia and physically reaching out and communicating with them can be a challenge. In 2010, based on the ASEANGAP, the Ministry of Agriculture, Forestry and Fisheries of Cambodia issued Proclamation No. 099 MAFF on GAP in the Production of Fresh Fruit and Vegetables. However, until today, it's unclear how many farmers have heard of this initiative and implemented it. More manpower and effort is required to not only reach the farmers, but constant follow up is required to ascertain that they follow the GAP guidelines.

Farmers' reluctance to change

Very often, farming is a livelihood inherited from one generation to another and over the generations, farmers are accustomed to their legacy farming habits which may not be the best approach in today's conditions due to changes in agricultural inputs, climate and land conditions. GAP will help farmers deal with these changes and perform farming in a more contemporary way. However, because these farmers are acclimatized to ancient farming habits, they may not be willing to learn the latest farming methodologies.

Educating students of higher learning on good agricultural practices

Instead of directly coaching farmers at ground level, this project focuses on educating students of higher learning on good agricultural practices associated with growing vegetables. The project targets students who are currently pursuing tertiary education in the field of agronomy and agroindustry for two reasons. Firstly, upon graduation, these students will be attached to various agricultural agencies and they can be sent out to the ground level to train and monitor farmers closely on the implementation of GAP. Secondly, these graduates can be empowered as enforcement officers. After a period of learning, the Ministry of Agriculture can impose regulations to compel farmers to adhere to GAP procedures. Subsequently the enforcement officers (who have been educated on GAP since tertiary studies) can supervise farms and farmers under their jurisdiction to ensure GAP-based regulations are followed.

SOLUTION: e-LEARNING FOR AGRICULTURAL STUDENTS

Aside from contriving an alternative approach to strengthen GAP implementation efforts in Cambodia that is to expose university students to good agricultural practices, the purpose of this project is to expose these students to new mechanisms of teaching and learning via e-Learning and assess their acceptance of such teaching and learning systems.

E-learning is referred to as instructional content or learning experience which is delivered through electronic technologies. Delivery methods can be as advanced as satellite broadcast or interactive TV or even more practical such as through the Internet or CD-ROMs. E-learning models for higher learning were initially introduced to facilitate distance learning to allow

individuals in remote areas to gain access to higher education. However, in present times, e-Learning has been manipulated to inject variety in teaching as well as to expose students to independent studying.

According to Abdon, Ninomiya and Raab, e-Learning is increasingly being adopted in developed countries, however, it is still relatively unknown and unused as an educational approach in developing countries. e-Learning is emerging as the next explosion in teaching and learning for some of these reasons:

- Portability – students are not confined to the classroom to learn, instead by just owning a PC or a laptop, they can learn anytime, anywhere or even while on-the-go.
- Improves comprehension – e-Learning content can be developed with rich videos, graphics and audio elements and this improves a student's ability to understand.
- Consistent – An unavoidable weakness of humans is inconsistency. With e-Learning, content is standardized and regardless the number of students, everyone receives the same information in the same manner.
- Flexibility – Students are able to learn at their own pace and not at the pace of the fastest or slowest learner in class. They can spend more time on topics they are weak in or even skip topics which are known or not required.

Components and methodology

The e-Learning solution developed will comprise of two components – web portal and multimedia interactive CD. Figure 1 gives the framework summary of this solution. As this project focuses on GAP pertaining to the cultivation of vegetables, the entire e-Learning solution will cover the following categories and modules.

Web portal

The web portal is being developed using Joomla Content Management System (CMS), a free and open source CMS for publishing various content. Joomla is written in PHP and supports MySQL database. Joomla is selected as it has a variety of web templates available for selection. Various content, from text, photos, music, video and documents can be conveniently placed within the template and managed. Another advantage of using Joomla is that it requires almost no technical skill or knowledge to manage. Once the project is complete, it can be handed over to web administrators of RUA and they will easily be able to administer and update the website regularly.

The web portal will be developed based on the rapid application development (R.A.D) methodology, which uses minimum planning in favor of quick prototyping. With RAD, the portal's planning stage is interleaved with the coding process, thus making development faster and easier to change requirements. The process can also be turned back if changes are required prior to testing and implementation. Feedback from users and testers can be incorporated without changing too much of the template design. Figure 2 shows the home page of the web portal.

Table 1 Categories and modules

General Guidelines	Production	Harvest	Post Harvest
Planning Practices	Planning the Garden	Harvest Handling	Curing
Soil Management	Sowing	Containers	Pre-packaging (cleaning,
Irrigation Practices	Watering	Tools	disinfection, artificial waxing)
Fertilization Practices	Fertilizing	Packing	Packaging
	Pest Control		Cooling methods &
	Disease Control		temperature
	Weeding		Storage
			Pest Control & Decay

E-LEARNING SOLUTION ON GOOD AGRICULTURAL PRACTICES		
Deliverables	Web Portal	Multimedia Interactive CD
Content	General Guidelines, Production, Harvest & Post-Harvest	
Features	Home Page Latest News Online Tutorials FAQs Forum Live Chat Box Social Media Plug-ins	Modular videos developed using video footage, still images, 2D animation and 3D animation Background voice-over to explain topics
Language	English	
Development Platform	Joomla (PHP & MySQL)	Adobe Flash using Action Script 3.0 Adobe Photoshop Adobe Premiere Final Cut Pro Adobe After FX

Fig. 1 Framework for e-Learning Solution on Good Agricultural Practices

Fig. 2 Screen shots of the Web Portal Homepage (left) and one of the videos from the interactive CB (right)

Multimedia interactive CD

The multimedia interactive CD will hold individual videos/animations for each module covered under GAP. From the home screen, students will be able to select which module's video/animation they wish to view (for example 'Fertilizing' under 'Production'). At the end of the video/animation, they can attempt available questions to test their understanding.

The development of the CD content involves three phases, as outlined below:

1. Pre-production - This phase involves idea generation and brainstorming activities on how to turn information gathered on GAP into suitable graphical content. This is done through sketches formulating layout with flowcharts and storyboards.
2. Production - Production involves execution from the pre-production phase with the design ID of the user interface (UI) using creative designing software and programming.
3. Post-implementation - This stage involves system testing on CD Rapid Prototyping to test the application/system functions and rectify errors.

CONCLUSION

This project is currently in development phase and is expected to be implemented in RUA in March 2013. This is the first time an e-Learning solution for GAP is developed for students of higher learning in Cambodia. As such, upon successful implementation, students' acceptance levels will be gauged and their feedback will be gathered for further improvement.

One of the drawbacks of this solution is that it is fully developed in English and language can be a barrier to the students fully understanding the content. At the point of writing this paper, due to lack of funding, we are not able to translate and develop this solution in Khmer, which is the Cambodian national language.

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Research article

Utilization of Inoculated Eri Cocoon for Water Pollutant Removal

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Abstract The eri cocoon may have the potential to immobilize effective microorganisms although it needs to be tested in order to be used as a method to remove pollutants from water. *Lactobacillus acidophilus* has proven to be capable of removing up to 60% of Arsenic (III) from water within 3 hours. The main objective of this study was to quantify the amount of glucose absorbed by inoculated eri cocoon as an indicator of the capacity for pollutant removal. *Lactobacillus* spp. was incubated at 37 ^{o}C for 48 hours. By microscopic observation, structures were described. The rate of inoculation was calculated as colony forming units (cfu) in the eri cocoon divided by cfu of the inoculation solution times one hundred. An absorption trial was set up. The absorption rate was calculated as final glucose concentration minus initial divided by time. The untreated (UT) eri cocoon presented nano-tubes where bacteria can easily penetrate. By soaking eri cocoons in distilled water (WS), cavern-like structures appeared within the silk fibers. When the eri cocoon was autoclaved (AC), the cavern structures were more frequent. The twisted yarn (TY) showed almost no difference with the fibers in the UT eri cocoon. The sample counts gave no statistical differences between UT and AC. Eri cocoon has the natural structures to accommodate microorganisms within its fibers. In the inoculation rate there was no difference between UT and AC treatments. The consumption of glucose showed no difference between UT, AC and WS; but there was a significant difference between the first three and TY. TY had the lowest glucose consumption.

Keywords pollutants, eri cocoon, lactobacillus, glucose, absorption

INTRODUCTION

Sericulture is defined as the breeding and raising of silk worms for the production of silk. There are different species of silk worm used for this purpose. This study will be focused on the eri silk worm (*Samia cynthia ricini*). The eri culture, as is called the rearing of eri silk worm, takes place in different areas of Asia and India.

In the North-East region of India, eri farmers adopt various traditional indigenous practices for rearing (Sarmah et. al., 2010). Eri culture has different uses such as a poverty alleviation strategy (Ramalakshmi, 2009) and the use of the eri pupa as a food for human consumption (Sarmah, 2011). But the main purpose of eri culture is for the production of silk.

Some studies on the structure of the silk fiber have been conducted. However, these studies have focused on the protein structure rather than the physical structure (Asakura and Nakazawa, 2004). In another study the eri cocoon was analyzed in an aqueous solution and dry-frizzed to obtain a fibroin powder to be used for its thermal properties and protein structure study (Yaowalak et. al., 2009). Asakura and Nakazawa (2004) concluded that the silk fiber has a spiral protein structure focusing in poly-Alanine chain and Glycerine areas with a Carbon and Nitrogen terminals.

Structural studies of the filaments have been done by Akai and Nagashima (2001, 2002) on different silk moths. Porous and compact filament formations are caused or regulated by continued lysosome releases which are affected by the progress of silk gland degradation (Akai and Nagashima, 2001). These porous structures and shell holes, as described by Akai and Nagashima (2001, 2002), can supposedly be present in other Saturniids as well and used as a niche for effective microorganisms.

The use of different methods for water pollutant removal has been considered one of the important actions taken to protect the environment. There have been some experiments to immobilize microorganisms and used for bioremediation (Krumme et. al., 1994; Arango, 2004; Hosseini et. al., 2007; Singh and Sarma, 2010). Most of the substrates used to immobilize effective microorganisms are non-biological porous materials. The eri cocoon has the potential to immobilize effective microorganisms and from there be used as a method to remove pollutants from water. A study with *Lactobacillus acidophilus* has proven that this bacteria is capable of removing, at a concentration of 2 mg dry wt/ml biomass, up to 60% of Arsenic (III) from a 1000 ppb water solution at pH 7 within 3 hours (Singh and Sarma, 2010). In another experiment, *Lactobacillus* spp. isolated from shrimp farm water samples was capable of simultaneous removal of pathogenic bacteria and nitrogen (Ma et al., 2009).

OBJECTIVE

The main objective of this study was to quantify the amount of glucose absorbed by inoculated eri cocoon as an indicator of the capacity for pollutant removal. Secondary objectives were: to describe the structures that eri cocoon present in order to be a niche for microorganisms; to observe the effects of different treatments on the physical structures of the cocoon fiber; and to determine the ability of eri cocoon to allocate *Lactobacillus* spp. within its structure.

METHODOLOGY

The experiment was done in a two stages stile. Stage one the description and inoculation, and stage two the glucose consumption. When analyzing the inoculation the treatments was cocoon treatments only and when analyzing the glucose consumption the statistical differences were calculated based on cocoon treatments and glucose concentration levels.

Physical description: Microscopic images were taken from different treatments of eri cocoon. From the images, physical description and differences were observed to determine the space that microorganisms could inhabit. The treatments were untreated cocoons (UT); the pupa was removed and only the silk cocoon was utilized. 1 week soaked in water (WS); the cocoon was soaked in distilled water for seven days without stirring at 25 ^{o}C. Autoclaved (AC); the eri cocoon were immersed in destilled water and autoclaved at a temperature of 110 ^{o}C and at a pressure of 152 kPa. Twisted yarn (TY); an already processed silk yarn was used.

Inoculation: *Lactobacillus* spp. was incubated and inoculated to calculate the ability of the treatments to allocate bacteria by the cocoon. The inoculation solution was added directly to the treatments by 6 ml per sample in order to cover half of the sample and allowing the other half to absorb by capillarity. The inoculated eri cocoon was incubated for 72 hours at 37 ^{o}C. Five count repetitions were made to get an average of colony forming units (cfu) per milligram of eri cocoon in order to observe the differences between treatments.

Glucose consumption: Two levels of glucose solutions were used: a high concentration of 15 g of glucose dissolved in 100 ml of distilled water; and 5 g of glucose dissolved in 100 ml of distilled

water, which equals 15% glucose solution and 5% glucose solution respectively. The inoculated eri cocoon treatments were placed in 60 ml of glucose solution and sampled at 3, 24, 48, 72, 120, 192, 288, 360, 408, 480 hours. The four treatments had four repetitions and two repetitions of control. The control treatment was distilled water instead of the glucose solution. The glucose consumption was recorded and analyzed by the SPSS 15 for windows system in a two factorial analysis. The treatments resulted in UT15%, UT5%, WS15%, WS5%, AC15%, AC5%, TY15%, and TY5%.

RESULTS AND DISCUSSION

Physical description

The UT presented entrances and nanotubes where bacteria can easily penetrate (Fig. 1a). After using a filter to observe the spaces within fibers the nanotubes were easily observed (Fig. 2). After treating the cocoon by soaking it for seven days cavern like structures began to appear within the silk fibers (Fig. 1b). Although no entrances where observed, these cavern-like structures present more suitable and larger spaces than those on the normal nanotubes present on the UT. When the eri cocoon was autoclaved the cavern-like structures were more frequent and entrances to them were observed. These cavern-like structures presented more space within the fiber and also were longer that those present on the WS treatment (Fig. 1c). The twisted yarn showed almost no difference to the fibers in the untreated, the only difference was the order that they aligned with each other making a lower exposure area (Fig. 1d).

Inoculation

In Fig. 3, the inoculation data are shown. The inoculation solution showed an average of 1.15 x 10^{16} colony forming units (cfu) per milligram of cocoon. UT and AC were not statistically different and had the higher inoculation count in cfu per milligram of cocoon. WS and TY had the lowest inoculation and were statistically different from AC and UT.

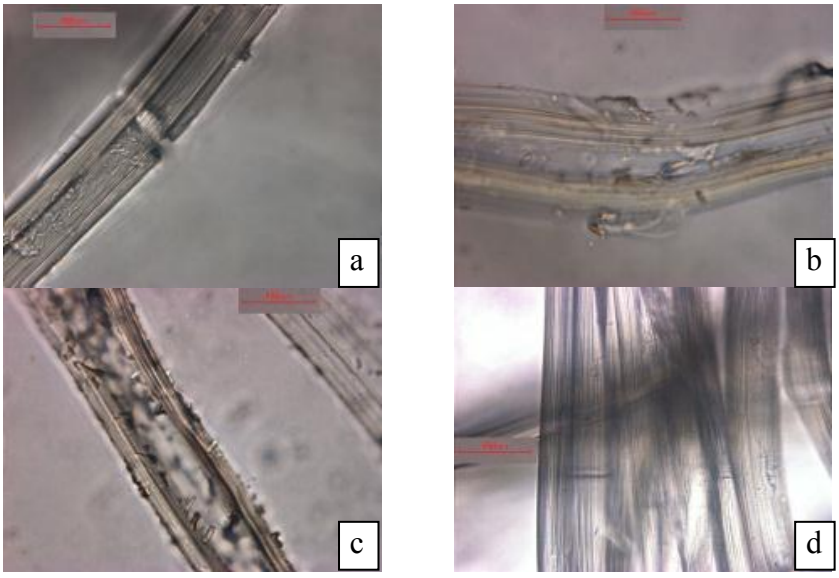

Fig. 1 Fig. 1 Microscopic cross-sectional views of eri-cocoon
(*a untreated, b 1week soaked in water, c autoclaved, d twisted yarn)*

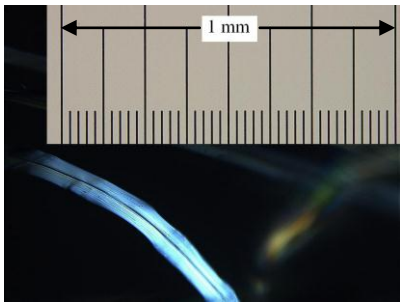

Fig. 2 Negative light filter fiber picture

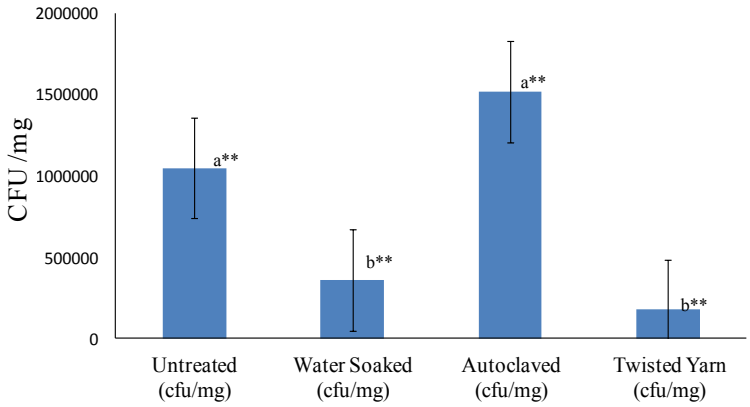

Fig. 3 Average colony forming units per milligram of eri cocoon

The alignment in TY and the treatment that it received beforehand may be the cause of such low cfu/mg count. It is also possible that if the TY was soaked in water before the inoculation this might have given a similar result to WS. WS and TY were not statisticalyl different; nevertheless, they both have the capacity to allocate a certain amount of *Lactobacillus* spp. within their structures.

Glucose consumption

The glucose consumption was taken and corrected against the control samples. There was a statistical difference in glucose consumption between UT15%, AC15%, WS15% and TY15%, UT5%, AC5%, WS5%, TY5%; TY15% was statistically different from UT5%, AC5%, WS5%, TY5%. There was no statistical difference between UT15%, AC15%, and WS15%. Within the UT5%, AC5%, WS5%, TY5% there was no statistical difference. Fig.4 shows the net consumption of glucose per treatment over time.

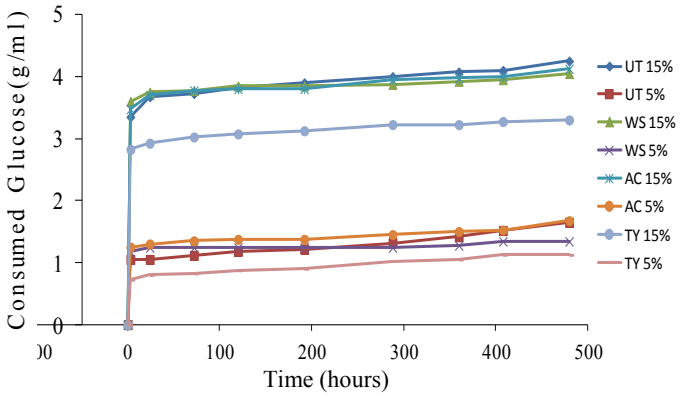

Fig. 4 Net glucose consumption by *Lactobacillus* spp. inoculated eri cocoon

CONCLUSIONS AND RECOMMENDATIONS

Eri cocoon has the natural structures to accommodate microorganisms within its fibers. Application of treatments such as soaking the eri cocoon in distilled water, or using an autoclave can improve the structures. Creation of yarn appeared to reduce the ability of eri cocoon fiber to accommodate bacteria. Eri cocoon inoculated with *Lactobacillus* spp. is able to absorb up to 29% of glucose out of a glucose solution at 15g/100ml or 15% glucose solution within 450 hours; and up to 26% within the first 3 hours.

Comparing physical structures, as the amount of space observable by microscopic imaging, and inoculation rate, the AC treatment presents the best structures and the highest rate of colony formation. Regarding inoculation rate there was no statistical difference between UT and AC which infers that the cheapest and best option for inoculation is the UT.

When comparing glucose consumption, the treatments AC15%, UT15%, and WS15% present the highest consumption. Nevertheless, using the inoculation rates as a reference point, the most effective treatments are AC15% and UT15%. Even though AC presents all the advantages for a filtering system, the use of UT is recommended to make a nitrogen absorption trial replacing glucose in the solution. The combination of UT and TY may give a better result when used together to make a net for water pollutant removal.

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Research article

Management of Municipal Sewage Sludge by Vermicomposting Technology: Converting a Waste into a Bio fertilizer for Agriculture

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Abstract This paper reports on the feasibility of utilization of vermicomposting technology using the earthworm *Eudrilus eugeniae* for managing municipal sewage sludge by conversion into beneficial bio-fertilizer. Sewage sludge was used at various concentrations 1, 5, 10, 15, 20, and 25% to test for avoidance behavior of the earthworm. The mix of sewage sludge with cassava wastes and cow dung was subjected to compost treatment with and without earthworm treatment for 30 days. During the study period data was collected on the surviving earthworms, biomass together with chemical analysis of wastes before and after treatment. The results indicate that 5% concentration of sludge mixed with cassava waste was ideal for *Eudrilus eugeniae* to treat. There was a decrease in pH, organic carbon concentration, C:N ratio, and an increase in electrical conductivity (EC), nitrogen, potassium and phosphorus concentrations in all the vermireactors. Total Kjeldhal nitrogen (TKN), available phosphorus and potassium concentrations were increased compared to compost without earthworm treatment at 50, 24, and 10% respectively. The heavy metal concentrations (Cr, Cu, Cd, Pb and Hg) in final vermicomposts were lower than in initial feed mixtures. The earthworm biomass was increased 40-90% and could survive 60% from the beginning. Therefore, the present study showed that vermicomposting of municipal sewage sludge into bio-fertilizer is feasible and provides a safe, simple, economic and practical alternative method to resolve the problem of management of sewage sludge.

Keywords waste management, safe fertilizer, agriculture

INTRODUCTION

In Thailand, municipal sewage sludge from domestic wastewater treatment is generated in large quantities, is hazardous and creates problem for safe disposal due to the presence of certain soil contaminants, such as organic compounds, heavy metals, and human pathogens. Sewage sludge generated in huge quantities has led to indiscriminate and inappropriately timed application of untreated sludge to agricultural fields as fertilizer because of its nutrient content, especially nitrogen and phosphorus. The problem of sludge disposal and management exists in other developing countries and probably prevails also in other parts of the world. Indiscriminate disposal of sewage sludge on agricultural fields induces soil and plant toxicity and creates depressive effects on the metabolism of soil microorganisms by drastically modifying physico-chemical and

biological environments of soil. Therefore it is absolutely essential for sewage sludge to undergo additional stabilization treatment prior to agricultural use (Hait and Tare, 2011).

The organic matter and high nutrient contents of municipal sewage sludge have promoted its application to agricultural land as an organic fertilizer. However, heavy metals in domestic and industrial wastewater are concentrated in sewage sludge at high levels with the total content ranging from 0.5 to 2% on a dry weight basis and at 6% in extreme conditions (Gupta and Garg, 2008). Therefore, concerns for the safe application of sewage sludge are mainly focus on the heavy metal contamination that can arise. Copper and cadmium often have high concentrations in sewage sludge and may affect the health of people and animals through the food chain if sludge is applied improperly. Methods for decreasing the contents and bioavailability of these elements in sewage sludge are worthy of research. Unlike organic compounds, metals cannot be degraded (Lasat, 2000). To decrease the contents and bioavailability of heavy metals usually requires their removal. Such an approach can be prohibitively expensive. Also, the metal removing process often employs stringent physicochemical agents, which can dramatically inhibit soil fertility with subsequent negative impacts on the ecosystem. Another method is to use chemical immobilization amendments to reduce metal bioavailability. The addition of chemical immobilization amendments may only immobilize lethal levels for restricted periods of time and introduce other harmful chemicals. Phytoremediation is recognized as the most commercially and environmental friendly technology available (Lasat, 2000), but up to now, only a limited number of plants have been found to have the phytoaccumulation ability and much less can be used for field phytoremediation because of low biomass production. There is a need for ecologically as well as economically sustainable technologies which enable recovery of recyclable constituents from sewage sludge as it is rich in nutrients and has high organic matter content. Vermicompost technology is ecologically and economically sustainable and has been widely used for processing of sewage sludge over the years (Sinha et al., 2010). Therefore, this study aimed to assess the feasibility of utilization of vermicomposting technology by using the earthworm (*Eudrilus eugeniae*) for ameliorating the municipal sewage sludge by conversion into beneficial bio fertilizer.

METHODOLOGY

Earthworms and substrate: Earthworms, *Eudrilus eugeniae*, were randomly obtained from stock cultures maintained in the earthworm culture laboratory at Khon Kaen University. Stock earthworms were cultured in the laboratory on partially decomposed cow dung mixed with cassava waste. Sewage sludge with approximate water content of 75-85% was taken directly from the Si-Phaya Wastewater Treatment Plant in Bangkok, Thailand. The sludge was shade dried in the laboratory to remove excess water. The chemical characteristics of the sewage sludge and bulking materials are shown in Table 1.

A study of the toxicity of sewage sludge on the survival of earthworms: The study of the toxicity of sewage sludge on the avoidance behavior of earthworm was performed with different concentrations of sewage sludge at 1, 5, 10, 15, 20 and 25% using 10 earthworms in a plastic containers containing 100 g of (dry weight basis) substrate material; avoidance behaviour of earthworms was observed every day.

A study of the survival and the growth of earthworms affected by sewage sludge mixed with cassava industrial wastes: This study included 4 sub-experiments; 1. Vermicompost mixed with cassava pulp 2. Vermicompost+ 5% sewage sludge mixed with cassava pulp 3. Vermicompost with cassava peel 4. Vermicompost + 5 % sewage sludge mixed with cassava peel. This experiment used a "Completely Randomized Design" (CRD) with three replications. Ten earthworms were released into plastic pot containers containing 100 g (dry weight basis). The weight of earthworms was recorded before and after 30 days. After 7 days, the survival rate of earthworm was measured. Cassava waste was chosen in this study because cassava industry is main industry in this area and produces a considerable amount of waste per day.

Vermicomposting process

Experiment design: The vermicompost (VCP) (with earthworm) and compost (without earthworm) experiment was conducted in plastic buckets (35 cm diameter and 40 cm depth) and used cassava pulp, cassava peel and 5% sewage sludge in the process. The experimental design was CRD with 3 replications with the mixture at a rate of 75%: 25% (cassava industrial wastes: soil mixture). The 25% in soil mixture was composed of Nampong soil and cow manure. The moisture content in the mixture was adjusted to 70-80% of WHC (Water Holding Capacity) by water and 10 earthworms/1 kg were added to the mixed material which was covered with a dark net to prevent earthworm escape and direct exposure to light (Wang et al., 2012). The time of study were 0 and 30 days at room temperature between 28±2 ^{O}C

Chemical analysis: The weight of the system and chemical parameters of substrate were measured in all treatments before introducing earthworms and after vermicomposting for 30 days. The earthworms were separated by hand at the end of the period. The growth rate of composting earthworms in this system was then analyzed according to the method described by Suthar (2009).

(1) Analysis of sewage sludge and earthworms; A total of 40 g compost and vermicompost was collected from each container using multi-point sampling at random. The samples were homogenized, dried at 40°C in a ventilated oven, and then passed through 100-mesh sieves after grinding into small pieces. The pH of compost (CP) and vermicomposting (VCP) was measured using a digital pH meter in 1/2.5 (w/v) deionized water. Total organic carbon was determined by the partial-oxidation method (Walkley and Black, 1934). Total N (total nitrogen) was measured by the micro Kjeldahl method (Jackson, 1973; Bremner and Mlvaney, 1982). Total P (TP) was determined by digestion with acid (HNO_3: H_2SO_4:$HClO_4$ (5:2:1). The sample used 1:10 mixed acid (w/v). Water-soluble P (WSP) was measured in Deionized water extraction ratio VCP and CP 1:25 (W/V) and shaken for 2 hours. Exchangeable phosphorous (Exch. P) was determined using the Bray II extraction method (Schroth et al., 2003). The totals from P solutions were determined using the ascorbic acid molybdenum blue method by UV spectrophotometer (Murphy and Riley, 1962).

(2) Heavy Metal Analysis; Total heavy metals (Cr, Cu, Cd, Pb and Hg) concentrations were determined by the HF-HNO_3-$HClO_4$ digestion method and HNO_3-H_2SO_4 digestion method, respectively. The heavy metals were extracted using the diethylene-triaminepentaacetic acid (DTPA) extraction method. The heavy metal concentrations of all extracts were determined by atomic absorption spectrophotometry (AAS). About 20 g of initial earthworms in stock cultures and final earthworms at each treatment with equal weight were separated from containers and then kept in culture dishes in the dark for two days to empty their gut content, after which they were washed in distilled water to remove excess material from their bodies. Next, the earthworms were sacrificed by freezing and dried at 105 °C for 24 hours in a ventilated oven. Prior to analysis, the earthworms were cooled to room temperature, then ground and passed through a 20-mesh sieve. The metals concentrations (Cr, Cu, Cd, Pb and Hg) in earthworm tissue from different treatment groups were analyzed using the same method as described for sludge metal contents.

Statistical Analysis: One-way ANOVA was used to analyze the significant differences among different vermicomposters for studied parameters. Tukey's test was performed to identify the homogeneous type of vermicomposters for the various parameters. The probability levels used for statistical significance of tests were $p < 0.05$.

RESULTS AND DISCUSSION

Sewage sludge had negative impact on earthworm. Avoidance behavior of the earthworm *Eudrillus eugeniae* (% avoidance) when exposed to different concentrations of sewage sludge was showed in Table 2. However, when mixed sewage sludge with cassava waste, earthworms could survive in vermicompost at 5% sewage sludge and also increased weight. After 30 days, vermicompost with cassava pulp could increase nutrients and reduce Cr, Cu, Pb and Hg concentrations in sewage sludge by 2.31, 14.03, 1.80 and 33.75% , respectively and vermicompost with cassava peel could reduce Cu and Hg by 34.270 and 14.504%, respectively. The results are shown in Tables 1-6.

Cassava peel could help to reduce heavy metal by addition to vermicomposting and was better than cassava pulp. Vermicomposting resulted increase in total N (TN), total P (TP) and total K (TK) as compared to the initial compost material depending on different bulk material. The study showed that the vermicomposting significantly improved the availability of nutrients in sewage sludge. Moreover, vermicomposting considerably reduced the availability of heavy metal presumably by forming organic-bound complexes. The environmental conditions and characteristics of each material in general showed significant effect on the transformation and availability of nutrients and heavy metals (Hait and Tare, 2012). Cassava pulp is acidic with low electrical conductivity (EC) and is distinct from Cassava peel which has higher pH and EC (Table 1) and cow dung had both high pH and EC together with high available-P (Table 1).

Table 1 Physico-chemical characteristics of primary sewage sludge and bulking material for vermicompost

Material	pH	EC (μS/cm)	Avail-P (%)
Cassava pulp	4.21 ± 0.11	328.33 ± 22.30	0.002 ± 0.00
Cassava peel	6.72 ± 0.08	666 ± 26.66	0.010 ± 0.00
Soil	7.76 ± 0.03	543.33 ± 7.57	0.002 ± 0.00
Cow Dung	8.09 ± 0.12	5263.33 ± 234.59	0.033 ± 0.00
Sludge 100%	6.13 ± 0.03	1446 ± 44.51	0.020 ± 0.00
Sludge 5%	6.81 ± 0.06	553 ± 95.82	0.011 ± 0.00

Material	TP (%)	TN (%)	OM (%)	K (%)
Cassava pulp	0.083 ± 0.001	0.205 ± 0.008	70.072 ± 3.50	0.174 ± 0.006
Cassava peel	0.208 ± 0.006	0.133 ± 0.016	8.552 ± 0.45	0.213 ± 0.006
Soil	0.034 ± 0.002	0.044 ± 0.002	0.585 ± 0.07	0.038 ± 0.000
Cow dung	0.080 ± 0.001	0.927 ± 0.012	32.092 ± 3.90	1.719 ± 0.081
Sludge 100%	0.191 ± 0.001	2.710 ± 0.020	26.908 ± 0.95	0.088 ± 0.000
Sludge 5%	0.044 ± 0.003	0.119 ± 0.007	1.713 ± 1.31	0.048 ± 0.003

Table 2 Avoidance behavior of earthworm, *Eudrillus eugeniae* (% avoidance) exposed to different concentrations of sewage sludge

Concentration of sewage sludge (%)	% Avoidance of *Eudrillus eugeniae*
1	20
5	100
10	100
15	100
20	100
25	100

Table 3 Earthworm weight in different vermicomposting treatments

Treatment	Earthworm weight (g/earthworm)		
	0 day(g)	30 day(g)	Increased weight (%)
Vermicompost + cassava pulp	0.413	0.000	0.00
Vermicompost + cassava pulp +5% sludge	0.499	0.765	34.76
Vermicompost + cassava peel	0.433	0.475	8.83
Vermicompost + cassava peel +5% sludge	0.482	9.005	94.65

Table 4 Earthworm survival in different vermicompost treatments

Treatment	% survival
Vermicompost + cassava pulp	100
Vermicompost + cassava pulp +5% sludge	98
Vermicompost + cassava peel	96
Vermicompost + cassava peel +5% sludge	100

Table 5 Physico-chemical characteristics of initial waste mixtures, compost and vermicompost obtained from different vermicomposters (g/kg) by earthworm after 30 days

Treatment	pH			EC (μS/cm)		
	Initial 0 day	CP* 30 day	VCP** 30 day	Initial 0 day	CP* 30 day	VCP** 30 day
Vermicompost + cassava pulp	8.06 B	8.91 B	9.26 A	1712.67 A	2660.00 A	2019.00 D
Vermicompost + cassava pulp +5% sludge	8.31 A	9.06 A	8.96 B	1446.00 C	2666.67 A	2630.00 B
Vermicompost + cassava peel	8.07 B	8.38 C	7.62 D	1434.33 C	2306.67 B	2830.00 A
Vermicompost + cassava peel +5% sludge	8.00 B	8.12 D	7.79 C	1598.33 B	2280.00 B	2176.67 C

Treatment	TN (%)			OM (%)		
	Initial 0 day	CP* 30 day	VCP** 30 day	Initial 0 day	CP* 30 day	VCP** 30 day
Vermicompost + cassava pulp	0.160 C	0.310 B	0.210 D	12.872 A	21.148 A	6.219 C
Vermicompost + cassava pulp +5% sludge	0.351 A	0.524 A	0.343 B	14.016 A	17.364 AB	12.835 B
Vermicompost + cassava peel	0.136 D	0.206 C	0.261 C	9.590 BC	5.740 D	6.193 C
Vermicompost + cassava peel +5% sludge	0.207 B	0.300 B	0.594 A	7.974 C	5.934 D	11.814 B

Treatment	Avail-P (%)			TP (%)		
	Initial 0 day	CP* 30 day	VCP** 30 day	Initial 0 day	CP* 30 day	VCP** 30 day
Vermicompost + cassava pulp	0.012 D	0.023 A	0.018 C	0.015 B	0.575 D	0.496 C
Vermicompost + cassava pulp +5% sludge	0.017 A	0.023 A	0.024 B	0.036 A	0.978 A	0.819 A
Vermicompost + cassava peel	0.016 B	0.002 C	0.015 D	0.009 C	0.590 C	0.497 C
Vermicompost + cassava peel +5% sludge	0.015 C	0.019 B	0.025 A	0.034 A	0.699 B	0.785 B

Treatment	K (%)		
	Initial 0 day	CP* 30 day	VCP** 30 day
Vermicompost + cassava pulp	0.375 B	0.426 B	0.396 C
Vermicompost + cassava pulp +5% sludge	0.411 A	0.541 A	0.524 A
Vermicompost + cassava peel	0.304 C	0.280 C	0.332 D
Vermicompost + cassava peel +5% sludge	0.280 D	0.401 B	0.449 B

**CP = Compost without earthworm **VCP = Vermicompost with earthworm*
Mean values followed by different letters in the same column are statistically different (ANOVA; Tukey's test, $p < 0.05$)

Table 6 Heavy metal concentration (mg/kg) in initial sewage sludge and compost, vermicompost and earthworm after 30 days

Heavy metal	Heavy metal in initial sewage sludge (mg/kg)	[2/]S1		[2/]S2		[2/] Earthworm	
		CP*	VCP**	CP*	VCP**	S1	S2
Cr	73.533	9.736	9.516	9.680	5.237	2.051	2.351
Cu	667.628	40.242	35.290	36.798	27.406	7.746	4.815
Cd	1.189	0.088	0.108	0.079	0.086	0.172	0.172
Pb	113.904	11.249	11.050	7.724	7.884	2.351	1.786
Hg	4.450	0.321	0.240	0.150	0.131	0.038	0.048

**CP = Compost without earthworm **VCP = Vermicompost with earthworm*
S1= Vermicompost with cassava pulp *+5% sludge*. *S2=* Vermicompost with cassava peel *+5% sludge*
[1/]Test method*: In house method based on EPA 3052* [2/] *Manual on Fertilizer Analysis, APSRDO.DOA; 4/2551*

CONCLUSION

This study indicates that sewage sludge at 5% could be managed by earthworm treatment through vermicompost technology, which could be a potential technology to convert toxic organic waste into nutrient rich biofertilizer. The feasibility of using earthworms to mitigate the metal toxicity and to enhance the nutrient profile in sludge might be useful to improve the sustainability of land restoration practices on a low-input basis.

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Research article

The Role of Organic Farming in Providing Ecosystem Services

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Abstract Ecosystem Services (ESS) are defined as the benefits humans derive from ecological processes and the ecosystem functions (MA, 2005). The functionality of agro-ecosystems is strengthened through ES like pollination, biological pest control or hydrological services provided by natural ecosystems (Sandhu et al., 2010). Agro-ecosystems also produce several ESS such as carbon sequestration, regulation of soil and water quality and support for biodiversity (Power, 2010). On the other hand agriculture may have a negative impact on neighboring natural ecosystems. Organic farming is the most sustainable and environmentally compatible way of agricultural land use, by using biological methods for regulation of pest and diseases instead of chemically-synthesized pesticides and mineral fertilizers. Thus organic agriculture minimizes negative impacts on nature-related ecosystems while simultaneously providing positive ESS like biodiversity.

Keywords ecosystem services, agro-ecosystems, organic farming, sustainability

INTRODUCTION

Stable ecosystems are required for a functioning natural balance. That is necessary for nature-related as well as for anthropogenically influenced systems. Essential goods like food, forage, fuel and fiber are provided by agricultural ecosystems (Power, 2010; Porter et al., 2009). For a sustainable production of these products fertile agro-ecosystems are needed, especially to cover the increasing demand due to a growing world population.

There are several interactions between natural and agro-ecosystems which can be illustrated and also valuated by the concept of ecosystem services (ESS). ESS is defined as the benefits humans obtain from ecosystems and their functions (MA, 2005). With regard to agro-ecosystems it is necessary to take both aspects into account: consumption as well as provision of ESS. This document research deals with the description of these interactions and especially with the effect of different land use intensities (conventional vs. organic farming). Unlike conventional agriculture, the use of chemically-synthesized pesticides and mineral nitrogen fertilizers in organic farming is excluded. For this comparison the concept of ESS is used (Swinton et al., 2006).

ECOSYSTEMS

The term ecosystem includes i.a. both natural and agricultural systems. They have basically a comparable structure, consisting simplified of producers, consumers and destruents with close interactions to each other (Fig. 1). The system is self-regulating and in the long run in equilibrium (Fig. 1a). Depending on the intensity of use, agricultural systems have various effects on different groups. In conventional farming the biomass production increases strongly (producer) through the

intensive use of synthetic chemical fertilizers and pesticides, the biomass of consumers (pests etc.) is selective decreased (Fig. 1b). Organic farming as a sustainable form of agriculture is an intermediate position, by using biological cycles for the regulation of the agro-ecosystem instead of chemicals (Fig. 1c).

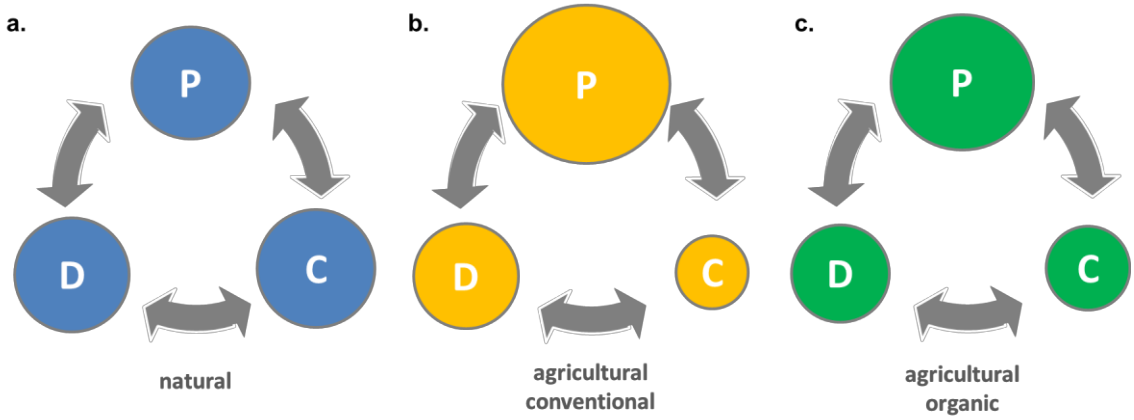


Fig. 1 Schematic types of ecosystems with their different dimensions of producer (P), consumer (C) and destruents (D)

THE THEORY OF ECOSYSTEM SERVICES

Defined as the benefits people obtain from ecosystems, ESS includes supporting, provisioning, regulating and cultural services (Figure 2, left side; MA, 2005). Supporting services are i.a. pollination, biological control, soil formation, carbon sequestration or nutrient cycling, which are all vital for supplying food and other raw materials (Sandhu et al., 2010) and mentioned as provisioning services. Regulating services affects e.g. hydrological flows, floods, water quality, climate conditions or diseases. There is also a cultural dimension of ESS that provides aesthetic, recreational or spiritual benefits for the people.

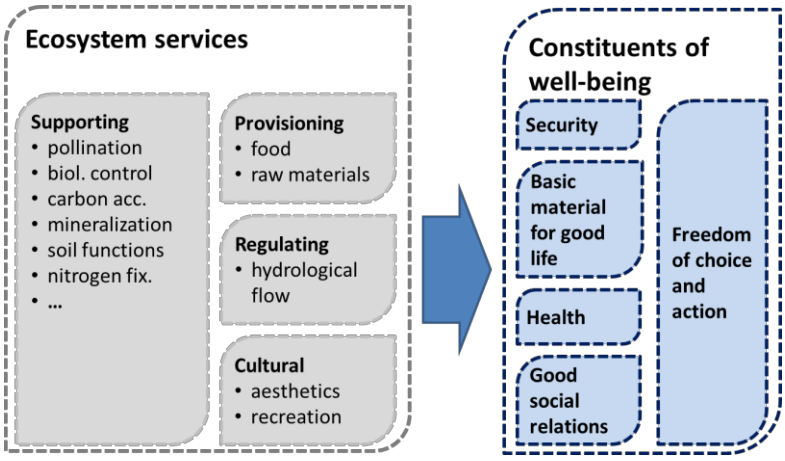


Fig. 2 Ecosystem services and their connections to human well-being
Source: adapted from (MA, 2005)

Well-being of human species is fundamentally dependent on the flow of ecosystem services (MA, 2005). People's well-being is assumed to have multiple constituents, including security, basic material for a good life, health, good social relations and freedom of choice and action (Fig. **2**, right side). Security means secure access to natural and other resources, personal safety as well as safeness from human-made and natural disasters. Aspects like adequate and secure livelihoods, enough food at all times, shelter and access to goods like clothing etc. are understood as the basic

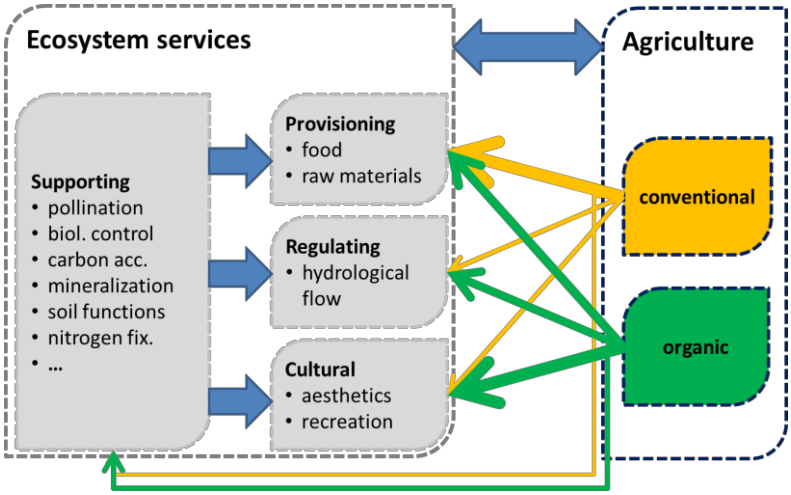
material for a good life. Under health factors like feeling well and having a healthy physical environment and access to clean air and water are summarized. Good social relations include mutual respect, social cohesion and the ability to help others and provide for children. Freedom of choice and action means the opportunity to achieve what an individual values doing and being. It is influenced by all other constituents of well-being and is also a precondition for achieving other components (MA, 2005).

ECOSYSTEM SERVICES AND AGRICULTURE

Agriculture represents humankind's largest engineered ecosystem which is embedded into a web of natural ecosystems (Zhang et al., 2007). The effects and direction of the strong interactions between managed an untouched ecosystems depend on the agricultural production system. Adapted management practices are able to diminish many of the negative impacts of agricultural land use without reducing the provisioning services (Power, 2010). Otherwise utilizes intensive agriculture large quantities of fertilizers and pesticides and acts as a major driver for land uses change and degradation of ecosystems (Sandhu et al., 2010). By using the concept of ESS it is possible to get an indicator for long-term sustainability of agricultural production balancing between ESS demand and supply (Björklund et al., 1999).

Conflicts through agriculture

In particular, under intensive conventional management practices neighboring natural ecosystems may be damaged, also known as ecosystem disservice, which can lead to increasing production costs or reduced productivities (Zhang et al., 2007). For example the biodiversity of unmanaged ecosystems provides important services to agriculture while extensive application of fertilizer and pesticides have adverse effects. Also the groundwater related to intensive agricultural usage often contains high concentrations of nutrients and pesticides which affects human's well-being (Tilman, 1999). Furthermore unsustainable farming practices encourage problems like soil degradation, meaning a reduction of nearly all ESS for the future.



Thickness of the green and orange arrows symbolize the significance
Source: adapted from (Sandhu et al., 2010)

Fig. 3 Interaction between ecosystem services and different agricultural systems

Services from agriculture

Of course the main ESS from agro-ecosystems is the provision of classical products (food, fuel, fibre etc.). But farmers also help to maintain several other services that make agriculture productive (Fig. 3).

Regulating and cultural services flows from agro-ecosystems vary greatly depending on the management system. Besides there are also supporting ESS such as pollination, biological pest control, carbon sequestration or soil nutrient renewal supported by agricultural usage (Swinton et al., 2006; Power, 2010).

Benefits from organic farming

Even if the amount of provisioning services in terms of yields per acreage is smaller than under conventional regimes, the balance of all services and disservices is better in organic managed agro-ecosystems (Fig. 3). Especially the damage of neighboring natural systems is less pronounced. Thus supporting ESS can increase by promoting the nature cycle through organic farming. Also the regulating and cultural services within organic production systems are higher due to wide and more diverse rotations, no monocultures and often more small-scaled structures.

CONCLUSIONS

As shown, agriculture does not only have negative impacts on nature-related ecosystems but also generates own positive ESS. Particularly favorable becomes the balance in agro-ecosystems under organic farming practices. For a secured worldwide food supply long term productive ecosystems are needed. Organic agriculture fully matches these conditions as the most sustainable way for production of food and other raw materials.

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Research article

Pre-Planting Treatments of Stem Cutting with Vermicompost Tea Affecting Rooting and Growth Yields of Different Cassava Varieties

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Abstract This study investigated the effects of the pre-planting treatment of stem cutting with different vermicompost tea concentrations on the rooting, budding, and root biomass of cassava. The completely randomized design (CRD) was used with three replications. The stem cutting of three cassava varieties (Rayong 7, Rayong 9 and Kasetsart 50) were soaked into the different solutions consisting of un-treated (control), 0% VM tea (distilled water), 50% VM tea, and 100% VM tea. Root and bud number and root dry weight were monitored at 7, 14 and 21 days after planting. Results showed that the numbers of cassava root pre-treated with vermicompost tea treatments were significantly increased compared to control. The number of cassava root grown in soil amended with 50% and 100% of the original vermicompost tea concentration were increased by 41.69% and 36.56%, respectively and the buds were increased by 44.09% and 44.18%, respectively compared to the control. The dry weights of root were also increased significantly average 213% and 292%. Therefore, this study indicated that pre-treating cassava stem cutting of three varieties with vermicompost tea before planting had a positive effect on initial root development, bud and root growth. Because of vermicompost tea had organic substances: humic acids, fuvic acids and plant- growths regulators hormone and plant nutrients on cassava growth.

Keywords budding and rooting of cassava, pre-planting treatment, root growth, vermicompost tea

INTRODUCTION

Cassava is an important economic crop of Thailand, which this crop occupies the largest planting area in northeastern part accounting for approximately 54.7% of those of the whole amount of the country (Ministry of Agriculture and Cooperatives, 2008). Productivity and commercialization targets of this crop contribute to concentrate uses of many kinds of chemicals, e.g., pesticides, herbicides, and plant growth promoting compounds. These chemicals may accumulate in cassava stem. Additionally, they may lead to negative effects on the environment and also physical, chemical, and biological properties of soil (Warburton and Pillai-McGarry, 2002).

Vermicompost (VM) tea is known to have positive effects on plant growth as it contains plant essential elements (including both macro- and micronutrients) and growth regulators (e.g., indole acetic acid, gibberellins, and cytokinins) (Arancon et al., 2005). A number of soil scientists found that there were abundance of microorganisms which promoted plant growth and yield. Additionally, humic acid contained in VM tea can improve soil properties (Atiyeh, 2001).

OBJECTIVES

Objectives of this study were to evaluate effects of pre-plating treatments of cassava cutting with different VM tea concentrations on their rooting, budding, and root growth.

METHODOLOGY

Vermicompost tea preparation: The VM tea was prepared from soil:cattle manure:cassava pulp mixture (2:1:7 ratio). Total amount of the mixture was equal to 1000 kg. One hundred individuals of earthworm (*Eudrillus eugeniae*) were fed in a 1 m^2 cement tank. After 30 days of the composting, liquid solution, extracted from the vermicompost, was collected as VM tea, and was pH (8.11), EC (0.69%), OM (0.08 %), Total N (0.0045%), Total P (0.0058%), Total K (0.14 %) and C/N (10.71 %) in VM tea.

Experimental design: A pot experiment was conducted under greenhouse conditions. A factorial treatments structure was used with three cassava varieties (Rayong 7 (RY7), Rayong 9 (RY9), and Kasetsart 50 (KU50)) and four pre-planting treatment media (un-treated (control), 0% VM tea (distilled water), 50% VM tea, and 100% VM tea). The 12 treatment combinations were arranged in a completely randomized design (CRD) with three replications for a total of 36 experimental units.

Statistical analysis: All data were analyzed by two-way analysis of variance using Statistix 8 program (Analytical Software, 2003). The treatment means were compared using Fisher's least significant difference (LSD) for the main effects of cassava varieties, pre-plating treatment media, and their interactions. The significant difference was accepted at $P \leq 0.05$.

RESULTS AND DISCUSSION

Influences of vermicompost tea on cassava budding

There was significant difference of cassava bud number between all pre-planting treatments (i.e., 0%, 50%, and 100% VM tea) and control ($P \leq 0.005$) since 7 days after cassava planting (DAP) (Table 1). At 7 DAP, bud numbers of all cassava varieties which were treated with 50% VM tea (7, 5, and 4 buds for RY7, RY9, and KU50, respectively), were significantly higher than the controls (1, 0, and 0 bud for RY7, RY9, and KU50, respectively). VM tea contained plant available nutrients, organic acids, and plant growth regulators (Edwards et al., 2006) as well as humic and fulvic acids (Arancon et al., 2005), which these compounds might accelerate budding and increase bud number of these cassavas. During 14 – 21 DAP, no significantly different bud number among the varieties, which were treated with all pre-planting treatments, were observed. Because, the stem cutting lengths (25 cm length) and nod numbers (4-7 nods) of all studied varieties were equivalent so that the maximum bud number per each stem cutting of these cassavas were already obtained at 14 DAP. However, these treatments were still significantly higher than the controls.

Influence of vermicompost tea on cassava rooting

No significant difference of cassava root number among all treatments were found at 7 DAP (Table 2). However, the root numbers of the three cassava varieties treated with 50% and 100% VM teas significantly higher than 0% VM tea and the control were observed at 14 DAP and 21 DAP. At these growth stages (14 DAP and 21 DAP), root numbers of RY7, RY9, and KU50 were significantly higher than their controls. These can be explained that the germination of cassava root generally appears at approximately 2 - 3 weeks after cassava planting (Montaldo, 1972). Increases in cassava root number when treated with VM tea is confirmed by Edwards et al., (2006) who found that VM tea had positive effects on plant growth (including root) at the early stage. However, the rooting period depends substantially upon cassava stem cutting quality and varieties (Department of Agriculture, 2002).

Table 1 Bud number of cassava with different varieties

(Rayong 7 (RY7), Rayong 9 (RY9), and Kasetsart 50 (KU50)) treated with four pre-planting treatment media (un-treated (control), 0% VM tea (distilled water), 50% VM tea, and 100% VM tea) at 7, 14, and 21 days after planting

Pre-planting treatment	Bud number								
	RY7			RY9			KU50		
	7 DAP	14 DAP	21 DAP	7 DAP	14 DAP	21 DAP	7 DAP	14 DAP	21 DAP
Control	1 e	2 d	2 d	0 e	2 d	2 d	0 e	1 d	1 d
0 % VM tea	4 cd	4 c	4 c	3 d	4 c	4 c	3 cd	4 c	4 c
50 % VM tea	7 a	7 a	7 a	5 bc	6 ab	6 ab	4 b-d	5 bc	5 bc
100 % VM tea	6 ab	6 ab	6 ab	3 d	5 bc	5 bc	4 b-d	5 bc	5 bc
F- test (cassava variety; a)					*				
F- test (pre-planting treatment; b)					*				
F- test (a × b)					ns				
CV (%)					23.94				

**significantly different at P ≤ 0.05; and ns: not significantly different (P > 0.05)*
DAP = day after cassava planting

Table 2 Root number of cassava with different varieties

(Rayong 7 (RY7), Rayong 9 (RY9), and Kasetsart 50 (KU50)) treated with four pre-planting treatment media (un-treated (control), 0% VM tea (distilled water), 50% VM tea, and 100% VM tea) at 7, 14, and 21 days after planting

Pre-planting treatment	Root number								
	RY7			RY9			RY7		
	7 DAP	14 DAP	21 DAP	7 DAP	14 DAP	21 DAP	7 DAP	14 DAP	21 DAP
Control	2 a-c	23 ab	23 c-e	2 a-c	12 f	15 f	1 c	10 f	12 f
0 % VM tea	2 a-c	17 c-e	17 e	2 ab	15 de	18 de	1 bc	17 c-e	20 de
50 % VM tea	3 a	28 a	34 a	2 ab	17 c-e	20 de	2 a-c	21 b-d	28 a-c
100 % VM tea	3 a	23 a-c	30 ab	2 ab	15 e	25 b-d	2 a-c	15 de	25 b-d
F- test (cassava variety; a)					**				
F- test (pre-planting treatment; b)					**				
F- test (a × b)					**				
CV (%)					22.72				

***significantly different at P ≤ 0.01; *significantly different at P ≤ 0.05;*
DAP = day after cassava planting

Table 3 Root fresh- and dry biomasses of cassava with different varieties

(Rayong 7 (RY7), Rayong 9 (RY9), and Kasetsart 50 (KU50)) treated with four pre-planting treatment media (un-treated (control), 0% VM tea (distilled water), 50% VM tea, and 100% VM tea) at the harvest day (21 days after planting)

Pre-planting treatment	Root fresh biomass (g pot^{-1})			Root dry biomass (g pot^{-1})		
	RY7	RY9	KU50	RY7	RY9	KU50
Control	2.29 b-c	1.55 d	1.09 d	0.15	0.12	0.09
0 % VM tea	1.17 d	1.11 d	1.53 cd	0.09	0.09	0.23
50 % VM tea	2.77 b-c	3.13 bc	5.99 a	0.44	0.37	0.47
100 % VM tea	5.96 a	3.91 b	2.47 b-d	0.57	0.59	0.44
F- test (cassava variety; a)		ns			ns	
F- test (pre-planting treatment; b)		*			*	
F- test (a × b)		*			ns	
CV (%)		41.89			59.47	

**significantly different at P ≤ 0.05; and ns: not significantly different (P > 0.05)*

Influences of vermicompost tea on root biomass

No significant difference of root dry biomass among treatments was found. Nevertheless, root fresh biomasses of RY7 treated with 0% (1.17 g pot^{-1}) and 100% (5.96 g pot^{-1}) VM teas were significantly higher than the control (2.29 g pot^{-1}) (Table 3). Meanwhile, root fresh biomass of RY9

treated with 50% (3.13 g pot^{-1}) and 100% (3.91 g pot^{-1}) VM teas significantly increased relative to the control (1.55 g pot^{-1}). In KU50, only 50% VM tea (5.99 g pot^{-1}) was significantly higher than the control (1.09 g pot^{-1}). Significant decrease in root dry biomass in KU50 treated with 100% VM tea suggests that this VM tea might has plant diseases and toxic compounds which exerted the negative effects on root growth. Frederickson (2002) found that VM tea decreased seed germination and plant growth. Therefore, dilution of VM tea for pre-planting treatment of cassava stem cutting should be critically considered. However, this practice may decrease plant nutrients, and hence cassava root biomass.

CONCLUSION

Pre-treatment of cassava stem cutting with VM tea before planting could accelerate rooting and budding of all three cassava varieties (RY7, RY9, and KU50). This was due to VM tea containing plant essential elements and growth regulators which promoted cassava rooting within 7 DAP.

We recommend that 50% VM tea is the optimum concentration for pre-planting treatment of the cutting as this concentration contributed to the highest cassava root and bud numbers compared to others. Therefore, use of VM tea is an alternative choice for stem cutting pre-treatment, which can substitute chemical uses, and also accelerate rooting and budding of cassava.

ACKNOWLEDGEMENTS

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Research article

Water Quality Preservation Effect of Riparian Forests in Watersheds with Dairy Farming Areas in Eastern Hokkaido

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Abstract The effects of riparian buffer zones consisting of forest and wetland on water quality functions were investigated by comparing the river water quality in two watersheds with dairy farming grassland in a large-scale dairy farming area of Eastern Hokkaido. The nitrogen, phosphorus and suspended solids (SS) components from the two watersheds, one without riparian buffer zones (MB) and the other with riparian buffer zones (HY), were compared at normal flow and at rainfall runoff periods. Total nitrogen (T-N) and NO_3−N concentrations were lower in the water from the river with riparian buffer zones. For the water sampled during the rainfall runoff period, all the water quality indicators showed lower concentrations for the river with riparian buffer zones than for the river without riparian buffer zones. The amount of nitrogen that flowed out of land into the river (nitrogen load) in the watershed with riparian buffer zones was 70% of that of the watershed without riparian buffer zones. The differences in water quality between the two watersheds are assumed to have resulted from water purification by the riparian buffer zones on one of the rivers. It is assumed that the riparian trees adsorbed nitrogen and that the riparian wetlands removed nitrogen and captured suspended solids, both of which contributed to purifying the runoff water. Based on the above findings, it can be determined that the conservation of riparian buffer zones is effective in preserving the river water quality on a watershed-wide scale in watersheds consisting of dairy farming grassland.

Keywords riparian, forest, river, nitrogen, phosphorus

INTRODUCTION

In Japan, measures against river water contamination caused by pollutants including nitrogen (N), phosphorus (P) and suspended solid (SS) from upland fields and dairy farming grassland has been called for since the 1980s. The authors have been examining water quality conservation measures based on land use by conducting studies on the relationship between river water quality and land use in watersheds with upland fields and grassland in Hokkaido, Japan (Okazawa et al, 2010, 2011 and 2012). We have reported that a major factor in river water contamination is the expansion of farmland in agricultural watersheds, that the location and scale of farmlands and forests influence the nitrogen concentration of river water, and that forests and wetlands along rivers, which are called riparian buffer zones, are effective in conserving the quality of river water.

The ability of riparian buffer zones to conserve the water environment has attracted attention in the US and Europe since the 1980s (e.g. Lowrance et al., 1984; Hill et al., 2000). It has been clarified that the nitrogen concentration of runoff from farmlands in the shallow groundwater decreases when it passes through riparian buffer zones. In Japan, Hayakawa et al. (2001) and Kanazawa and Hayakawa (2001) examined the relationship between the topographic linkage and the nitrate nitrogen concentration in groundwater, and clarified that the nitrate nitrogen concentration in runoff water from upland fields decreases when that water passes though grasslands. Nakamura and Ishida (2001) examined the effectiveness of riparian buffer zones in conserving the water quality on a watershed-wide scale in a small watershed with dairy farming grassland in Eastern Hokkaido, and they clarified the relationship between the changes in the water environment by ground freezing and the water quality conservation of buffer zones. In Japan and other regions that experience Asian monsoons, few studies have addressed the functions of riparian buffer zones, and proposals for measures for conservation and restoration of riparian buffer zones are not easily accepted. Even though riparian buffer zones have been recognized as conserving the water quality, few studies have evaluated the phenomenon on a watershed-wide scale.

OBJECTIVE

This study investigated the influence of riparian buffer zones on the water environment of a watershed by examining a dairy farming area with grassland in Eastern Hokkaido, where relatively natural riparian buffer zones consisting of riparian forests and wetlands are found. The river water at the normal flow and rainfall runoff periods was investigated in two watersheds with different conditions of rivers and surrounding areas: The river in one watershed was artificially modified and the areas along it was mainly grassland, and the river in the other watershed was natural, with forests and wetlands along it. By comparing the river water quality of the two watersheds using statistical method, the effects of riparian buffer zones on water quality functions were clarified on a watershed-wide scale.

METHODOLOGY

The subject area

The survey was done in Hamanaka Town (E145°13′, N43°07′), which is in a dairy farming area of Eastern Hokkaido. Hamanaka is located in hills at Konsendaichi in the Nemuro-Kushiro Tableland, which has a geological basement of pyroclastic deposits and a thick surface layer of black volcanic ash soil. The daily mean temperature in Hamanaka averages 4.9 °C; it is -12.3 °C in February and 19.8 °C in August 2003. The annual precipitation in 2003 was 1,178 mm, and rain frequently falls in the period from August to October. The snowfall season is from November to April. On the Konsen Plain (Nemuro-Kushiro Plain), where Hamanaka Town is located, large-scale pilot farms with pasture that are mainly for dairy farming were established during the period from 1950 to 2000. The main agriculture in this area is livestock and dairy farming, with upland cultivation also done in some parts.

The surveys were done on the two tributaries of the Furen River, which flows through Hamanaka Town (Fig. 1, Table 1). The watersheds are indicated as MB and HY. The watersheds are similar in area and in proportions of land uses. The locations of grassland and forest relative to the rivers and the degree of river modification differed between the watersheds. In MB, the grassland comes very close to the riverbanks and 71% of the river has been modified, which is relatively high compared to HY. The riverbed and riverbanks are covered with concrete blocks. In HY, riparian forests of Japanese ash (*Fraxinus mandshurica*) and alder trees (*Alnus japonica*) and wetlands are found along the river. This river remains in its natural, unmodified state. The riparian forests are 30 - 100 m wide. There are livestock barns scattered in both watersheds. The cattle densities are 91 head/km^2 for MB and 85 head/km for HY. The livestock manure is spread on the grasslands after being composted or processed as slurry.

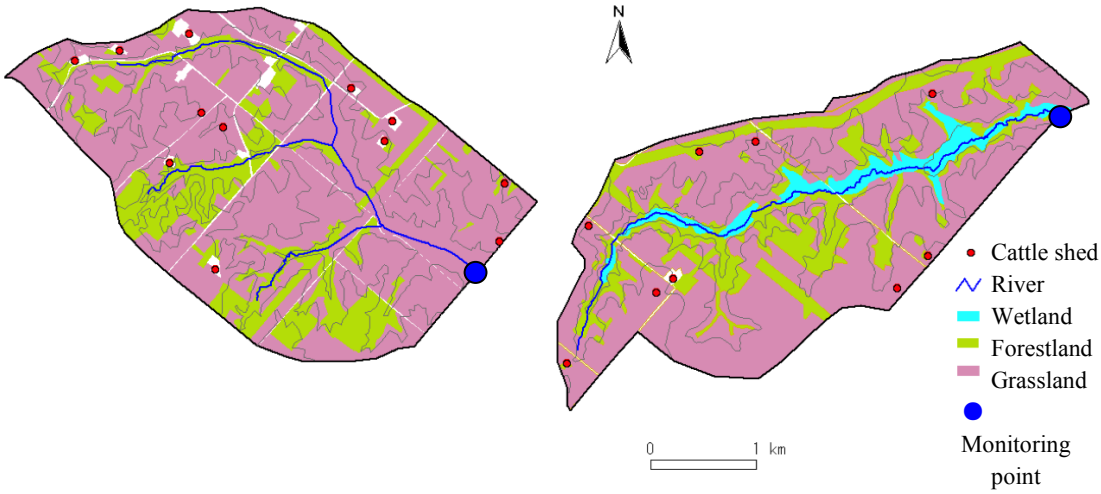

Fig.1 Landuse map of the MB watershed (Left) and the HY watershed (Right)

Table 1 General description of the two watersheds

Name of the watershed	MB	HY
Watershed area (km^2)	10.9	8.9
Land use percentage in the watershed		
Grassland (%)	72	70
Forestland (%)	23	23
Wetland (%)	0	6
Others (%)	5	1
Length of river (km)	8.26	6.23
River density ($km \cdot km^{-2}$)	0.76	0.70
Percentage of improvement length (%)	71	0
Stocking density of cattle ($Head \cdot km^{-2}$)	91	85

Survey technique

The survey periods were from September 5 to November 16 2002 and from June 6 to November15 2003. Continuous monitoring was done for precipitation, river water level and water quality indicators by installing a rain gauge, a water-level gauge and an automatic water sampler at each monitoring point.

River discharges were determined from an H-Q equation obtained from the relationship between the measured discharge (Q) and the water level (H). The continuous values for water levels collected at 10-minute intervals were converted into discharges. The survey periods were classified into that with normal flow (during clear weather) and that with rainfall runoff.

River water was collected using automatic water samplers. Two samples per week were collected from June 6 to August 4 in 2003, and one sample per day (at 12:00 noon) was collected in the survey period in 2002 and from August 5 to November 15 (a period with frequent rainfalls) in 2003. In addition to the regular water sampling, 24-hour continuous sampling at 1-hour intervals was done whenever the rainfall reached 5 mm/h or more. The number of samples collected during the survey periods were 119 (MB) and 109 (HY) for the normal flow period; and 290 (MB), including 10 for flooding, and 340 (HY), including 12 for flooding, for the rainfall runoff period.

The water quality indicators analyzed were T-N (total nitrogen), TON (total organic nitrogen), NO_3-N, NO_2-N, NH_4-N, total phosphorus (T-P), PO_4-P and SS (suspended solids). Ion components were analyzed by ion chromatography, and SS was analyzed by suction filtration. TON was determined by subtracting NO_3-N, NO_2-N, and NH_4-N from T-N.

Calculation method of nitrogen load

The area-specific load of nitrogen flowing out into the rivers in the two watersheds during the period from June 2 to November 14 in 2003 was determined for the normal flow period and the rainfall runoff period (Fig.2). The area-specific load is expressed by Eq. (1).

$$L = (Q \cdot C) / A \quad (1)$$

where L is the Area-specific load ($g \cdot s^{-1} \cdot km^{-2}$), Q is the river discharge ($m^3 \cdot s^{-1}$), C is the concentration (mg/L) and A is the area of watershed (km^2). The area-specific load of nitrogen expresses the flux of nitrogen that flows out of a watershed.

As the changes in nitrogen concentration were smaller during the normal flow period than the rainfall runoff period (see Table 2 and 3), the area-specific load for the normal flow period was obtained by multiplying the average nitrogen concentration of river water at the normal flow period by the discharge. The area-specific load during the rainfall runoff period was obtained based on the water quality data collected every hour and the discharge data collected during the rainfall runoff period. For rainfall events for which water sampling using the automatic water sampler was not done, the load was estimated by obtaining an equation for the relationship between the river discharge (Q) and the load (L) (L-Q formula) from existing data (Fig.2).

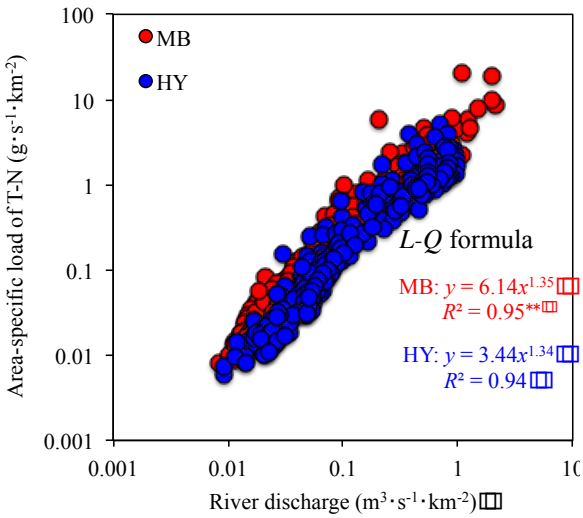

Fig.2 Relationship between specific load of T-N (L) and river discharge (Q) during rainfall runoff period

RESULTS AND DISCUSSION

Characteristics of river water quality at normal flow and rainfall runoff periods

The concentrations of water quality indicators (discharge-weighted average) for the two watersheds during the normal flow period and those during the rainfall runoff period are shown in Tables 2 and 3. During the normal flow period, statistically significant by using t-test statistics differences between the watersheds were found in the concentrations of T-N and NO_3-N, and these concentrations were lower in MB than in HY. For other water quality indicators, the differences in their concentrations between the two watersheds were small, and no significant differences between the two watersheds were found.

Based on the above findings, it can be thought that NO_3-N, which readily eluviates from the grassland soil at normal water level, was purified in the riparian forests, and made the concentrations of water quality components in MB low.

During the rainfall runoff period, the concentrations of all the water quality indicators were higher in MB than in HY. The difference in concentrations of TON, NH_4-N, T-P and SS, which readily flow with the suspended components, were great between the watersheds. During the rainfall runoff period, soil erosion occurs in grassland, and contaminants are adsorbed by sediments and flow out into rivers. That the concentrations of water quality indicators were lower in HY than in MB was attributed to the catching, by the riparian forests and wetlands, of contaminants generated during the rainfall runoff period, which thus kept them from flowing into the river.

Table 2 Mean concentration in normal flow period

MB watershed	T-N	TON	NO_3-N	NO_2-N	NH_4-N	T-P	PO_4-P	SS
M.C.	1.14	0.30	0.80	0.02	0.02	0.08	0.03	12
S.D.	0.35	0.30	0.16	0.02	0.03	0.05	0.02	12
C.V.	31	99	20	122	165	66	52	99
HY watershed	T-N	TON	NO_3-N	NO_2-N	NH_4-N	T-P	PO_4-P	SS
M.C.	0.79	0.30	0.46	0.01	0.02	0.09	0.04	10
S.D.	0.41	0.24	0.30	0.02	0.04	0.06	0.03	11
C.V.	52	80	65	120	181	74	75	109

M.C.:Mean concentration (mg/L), S.D.: Standard division (mg/L), C.V.: Coefficient of variation (%)

Table 3 Mean concentration in rainfall runoff period

MB watershed	T-N	TON	NO_3-N	NO_2-N	NH_4-N	T-P	PO_4-P	SS
M.C.	4.66	3.63	0.63	0.04	0.35	0.61	0.30	204
S.D.	3.05	2.88	0.36	0.06	0.41	1.23	0.20	274
C.V.	66	79	57	139	117	200	68	135
HY watershed	T-N	TON	NO_3-N	NO_2-N	NH_4-N	T-P	PO_4-P	SS
M.C.	2.52	1.89	0.47	0.03	0.14	0.58	0.22	107
S.D.	1.50	1.45	0.15	0.04	0.16	0.53	0.15	110
C.V.	59	77	31	159	118	91	70	103

M.C.:Mean concentration (mg/L), S.D.: Standard division (mg/L), C.V.: Coefficient of variation (%)

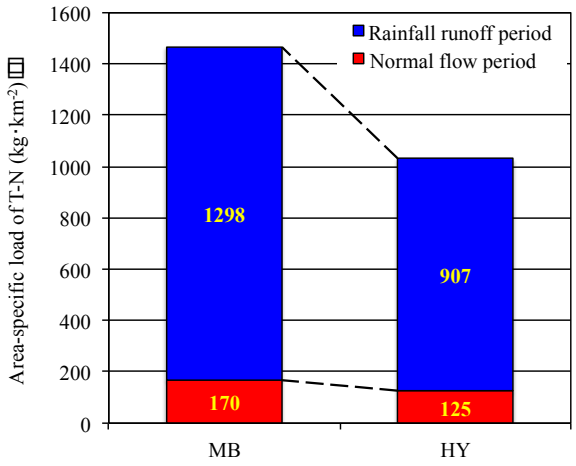

Fig.3 Specific load of T-N during 3 June to 14 November 2003

Nitrogen loading reduction by riparian buffer zones

Figure 3 shows the relationship between area-specific load of T-N in the MB watershed and the HY watershed. The area-specific load of T-N showed lower values in HY than in MB for both the normal flow period or the rainfall runoff period. The two watersheds differed in whether they had

riparian forests and wetlands or did not have these. Therefore, the difference in the area-specific T-N between the two watersheds can be attributed to reduction of nitrogen by the riparian forests and wetlands. It can be assumed that the low levels of nitrogen concentration were the result of purification by the riparian forests and wetlands. Because, many researchers reported that the surface water, which contained nitrogen components flowing out from grasslands into the riparian forests and wetlands, was purified when the trees adsorbed nitrogen components and the wetlands removed nitrogen components (e.g. Takahashi et al., 2003). The area-specific load of T-N in HY for the normal flow period was 125 kg･km^{-2}, which is 74% that in MB, and for the rainfall runoff period it was 907 kg･km^{-2} which is equal to 70% that in MB. This result clarifies that the riparian forests and wetlands reduced the nitrogen load by 26% during the normal flow period and 30% during the rainfall runoff period.

CONCLUSION

The water conservation effects of riparian buffer zones (riparian forests and wetlands) were examined by comparing the water qualities of rivers in two similar dairy farming grassland watersheds that had different degrees of artificial modification of the rivers and different riparian environments. Data suggest the concentrations of river water quality indicators, including nitrogen, phosphorus and SS, in the water of the river with such zones to be lower than in the water of the river without such zones. The zones were found to significantly reduce such load from grasslands, particularly during the rainfall runoff period. It was clarified that about 30% of the nitrogen load in runoff was reduced by the riparian buffer zones.

This study was able to clarify the water quality conservation effect of riparian buffer zones on a watershed-wide scale. It also clarified that the water quality functions of riparian buffer zones differed for every water quality component by flow regime (normal vs. rainfall runoff).

In recent years degradation of the water environment in agricultural watersheds has been a concern in Hokkaido. It can be said that including the conservation of riparian forests and wetlands in environment improvement plans is effective in conserving the water environment of rivers.

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Research article

Integrating Plant Genetic Resources Conservation and Management into the State University's Mandates: An Initiative for Sustainable Development

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Abstract Plant genetic resources (PGR) are plant materials of actual or potential value for the present and future generations. (Borromeo, 2007). Its conservation, management and sustainable utilization are important in environmental protection, crop improvement and food security. In the Philippines, the National Plant Genetic Resources Laboratory, ensures that a number of accessions of crops species are secure and accessible. (Hautea, 1998); Philippine Coconut Authority, Davao National Crop Research and Development Center, Bureau of Plant Industry (Bautista, 1994); and International Rice Genebank Collection (IRRI, 2012) also maintain germplasm collections. Foregoing institutions are non-academic. Hence, Bohol Island State University (BISU) in Bohol, Philippines with South-East Asia Regional Initiative for Community Empowerment (SEARICE) worked on PGR conservation through Farmers Field School (FSS) and Agriculture Curriculum Enrichment (ACE) Projects purposely to mainstream the principles of sustainable agriculture and development through conservation, improvement and utilization of PGR in the communities. Participatory basic needs assessment; FFS curriculum formulation; ACE following protocol and networking with Local Government Units, Department of Agriculture line agencies, non-government and peoples' organization were employed. As a result, 16 FFS were conducted while ACE project successfully integrated Plant Genetic Resources Conservation and Management (PGRCM) into the two Agriculture curricular programs of BISU. Seventy-five students passed the PGRCM course who also graduated from FFS with 290 farmers, five faculty-trainers and nine agricultural technician-trainers with skills in participatory varietal trials, selection and plant breeding that raised rice diversity in villages by 25-33 percent, produced three stable rice accessions, 25 selections and 18 breeding lines at F_3 today apart from a number of bonus accomplishments. These developments are realities justifying that PGRCM can be successfully integrated into the state university's mandates: instruction, research, extension and production and be capitalized as valuable initiative for sustainable development in the communities which the academe serves.

Keywords plant genetic resources, plant genetic resources conservation and management, farmers field school (FFS), state university, mandate, sustainable development

INTRODUCTION

The Philippines is one of the mega diverse countries in the world both at ecosystem, species and genetic level. Nevertheless, it is also one of the hot spots. For this reason, agencies responsible on the Philippine fragile super-diverse ecosystem that houses animal and plant genetic resources are calling to pool in efforts on its conservation and management. Like other government entities, higher education institutions like BISU unifies with other agencies on this noble task of managing life indispensable reserves.

For relevance to local and global trends on sustainable development, BISU has collaborative endeavors with SEARICE, an institution advocating Sustainable Agriculture (SA) and Community Biodiversity Conservation and Development (CBDC). From this partnership emerged the initiative

of integrating plant genetic resources conservation and management into the state university's functions empowering is faculty and students on this very important task commonly carried out by non-academic institutions.

The objective of this initiative was to mainstream the sustainable agriculture principles and approaches into the curricular, research and extension programs of the academe, hence, this reality project on the integration of PGR conservation, improvement and utilization at the BISU-Bilar, Bohol, Central Philippines since 1998 to the present.

OBJECTIVE

The main purpose of the project is to mainstream the principles of sustainable agriculture and development particularly on the conservation, development and utilization of plant genetic resources into the university's mandates.

The initiative has the following specific aims:

1. To integrate the course PGRCM into the Bachelor of Science in Agriculture (BSA) and Bachelor in Agricultural Technology (BAT) curricular programs of BISU;
2. To produce Agriculture graduates with knowledge and skills in PGRCM;
3. To organize and implement a research program on PGRCM at BISU;
4. To empower farming communities in Bohol on rice PGRCM; and
5. To document the issues and lessons learned during the project implementation.

METHODOLOGY

The project was planned and implemented in partnership with SEARICE. To attain its objectives, the project team utilized a combination of strategies.

PGRCM integration into the instruction mandate through ACE was made by reviewing and revising the BAT and BSA Curricular Programs in coordination with the Curriculum Committee of BISU following the Guidelines on Curriculum Enrichment of the university and the Circular Memorandum Order (CMO) of the Commission on Higher Education (CHED). Implementation in BISU-Bilar where the programs are offered followed after its approval and preparation of its syllabus. Class enrolment and activities were monitored and recorded.

PGRCM integration into the research mandate was organized through the genetic diversity conservation (GDCon) project implementation. Center-based and on-farm research projects on PGRCM were conceptualized and conducted like the Participatory Varietal Selection (PVS) and Participatory Plant Breeding (PPB) along with FFS. Experimental research techniques, data collection and analysis were employed for completed studies while monitoring was made for on-going activities.

For the extension function, FFS on Community-based Organic Rice Diversity and Development (CORD) was conducted by the team in selected rice farming communities of Bohol. On-farm experiments were utilized for the hands-on activities of the FFS. The BISU-SEARICE dual collaboration was also expanded for a better and wider implementation.

Issues and lessons from the integration were also documented. Most of the data collection and documentation were prepared by a team member teaching and implementing the PGRCM research and extension activities. This has been done for six year years now.

RESULTS AND DISCUSSION

BISU envisioned to be a premier Science and Technology university for the formation of a world-class and virtuous human resource for sustainable development in Bohol and the country. Attaining this requires the university to operate its mandates along with this vision. This endeavor had conceptualized initiatives which partly generated results that manifest its realization.

ACE Initiative

Based on the curricular review conducted in 2003, BISU offered BAT major in Crop Production Technology and Animal Production Technology and BSA with specialization in Crop Science, Animal Science and Crop Protection. The BAT curriculum was introduced by the Agricultural Technology Education Program of the government since 1990 while the BSA was based on certain DECS and CHED Memorandum Orders. Both programs contained important courses but short of those related to sustainable agriculture and development which are the cry of the times since the late 80s. Hence, Sustainable Agriculture and PGRCM were recommended for integration to make the programs relevant to the needs.

Following the university protocol on curricular changes, the integration was approved by the Board of Trustees in 2004 placing PGRCM as an elective subject in the fourth year Crop Science and Crop Production Technology specialization. The course was offered and Table 1 shows its successful takers. By this, BISU manifested support on the international concerns like environmental health, biodiversity conservation for food security and sustainable development through its flagship program in Agriculture.

Table 1 Population of Agriculture student-enrollees and passers of the PGRCM course and its percentage from the roster of graduates, AY 2007-2012

Academic Years	Total Agriculture (BAT & BSA) Students		Total (BAT & BSA) PGRCM Students*		% Agriculturists with PGRCM Knowledge & Skills
	Enrolled	Graduated	Enrolled	Passed	
2007-2008	83	83	21	21	25.30
2008-2009	54	53	22	22	41.50
2009-2010	37	37	8	8	21.62
2010-2011	31	29	16	16	55.17
2011-2012**	63	62	1	1	1.61
2012-2013**	53	53***	11	10	18.87 ***
TOTAL	321	317***	79	78	24.61 ***

** BSA - Crop Science major, BAT-Crop Production Technology major students* ****projected*
***year when BAT was revised into a generalist program* *Source: Office of the Registrar*

PGRCM research projects

Apart from the rice PVS and PPB, the FFS participants were exposed to the projects established and sustained by BISU-Bilar to level up their PGRCM knowledge and skills in industrial and other economic crops. Table 2 shares data on these projects.

The FFS manifests the super-imposing services in research, instruction and extension. Before the FFS, a benchmark study on the diversity of rice in area was done, then a monitoring activity through the local technicians. Table 3 reveals the seed increase at the FFS sites for a period of six years implying a considerable increase in rice diversity in the areas.

The FFS participants were able to produce "rice selections" and breeding lines from their PVS and PPB activities. The teaching-learning exercises of FFS partakers have already developed rice breeding lines at F_3 as initial products of participatory research as presented in Table 4.

FFS- on community-based organic rice diversity and development (CORD)

BISU organized with the Bohol-Provincial Agriculture Office (PAO) a season-long FFS-CORD for villages that need it. This was tapped as the laboratory field for PGRCM students. The 14-session FFS provided a shared experiential learning opportunity among students, partners like farmers, LGU technicians, faculty-trainees on PGRCM, SEARICE staff and BISU traineers on actual PVS, PPB, vrietal rejuvenation, characterization and other field demonstration on ecological pest management and soil fertility management using organic fertilizers. Table 5 presents the venues and number of FFS participants.

Table 2 Functional PGRCM research projects at BISU-Bilar, Zamora, Bilar, Bohol, Philippines useful for instruction, extension and income generation

PGRCM Projects	No. of Species	No. of Accessions	Year Established	Utilization
Clonal Nursery	22	35	2012	Source of planting materials for the National Greening Project of the Philippines; instruction, research
Sweet Sorghum	1	6	2010	Tourism, instruction, research Show-window for enterprise development
Abaca Nursery	1	3	2009	Instruction, research, source of planting materials for farmers
Molave Provenance cum Progeny Trial	1	5	2008	Instruction, research, source of planting materials for farmers
Fruit Genebank	11	27	2005	Source of gene/seeds; source of planting materials for the clonal nursery; income
Anthurium	2	33	2003	Instruction, research, show-window for enterprise development
Rice Seedbank	2	240	2001	Back-up supply of organic rice seeds for farmers & breeders; Agro-eco-tourism, instruction, research Show-window for farmers for income-generating project (IGP); Source of organic rice seeds for farmers & breeders
Timber Genebank	60	65	1998	Source of genes/seeds; source of planting materials for the clonal nursery
Coconut Genebank	1	5	1983	Instruction; research; source of gene; income
TOTAL	105	229		

Source: Project In-Charge

Table 3 Rice seed increase in the FFS-CORD and PGRCM laboratory/demo sites in Bohol, Philippines, Academic Years 2007-2013

Years/ Season	Locations in Bohol, Philippines	No. of Varieties/ Accessions			% Seed Increase
		Used Before FFS	On-Trial	Used After FFS	
2007-2008	Campagao, Bilar	16	20	11	145.45
2008-2009	San Miguel, Dagohoy	8	25	10	80.00
2009-2010	Untaga, Alicia	9	25	10	90.00
2010-2011	BISU-Bilar, Zamora	15	160	21	71.43
2011-2012	Poblacion, San Isidro	10	30	12	83.33
2012-2013	BISU-Bilar & Loboc	11	45	9	122.22

Source: RDE Library, 2012

Table 4 Number of rice breeding lines produced by FFS participants and facilitators during the PPB activities in Bohol, Philippines, Academic Years 2007-2013

Academic Years	FFS Sites in Bohol, Philippines	Number Involved			No.of Breeding Lines/Selections
		Students	Farmers	Trainers	
2007-2008	Campagao, Bilar	21	10	3	6
2008-2009	San Miguel, Dagohoy	22	25	3	4
2009-2010	Untaga, Alicia	8	10	3	2
2010-2011	BISU-Bilar, Zamora	16	0	1	13
2011-2012	Poblacion, San Isidro	1	28	3	6*
2012-2013	BISU-Bilar & Loboc	11	17	4	18*
	TOTAL	**79**	**90**	**17**	49

Source: RDE Library, 2012 **breeding lines at F_3*

Table 5 Venues and partners/graduates of the off -campus PGRCM activities with the FFS-CORD in Bohol, Philippines, Academic Years 2007-2013

Academic Year/Crop Ping Season	Locations in Bohol, Philippines	Number of Partners/Graduates					
		Students	Farmers	Technicians		Faculty-Trainees	GO &NGO Trainers
				LGU	PAO		
2007-2008	Campagao, Bilar	21	10	0	0	2	3
2008-2009	San Miguel, Dagohoy	22	25	1	2	2	3
2009-2010	Untaga, Alicia	8	10	1	2	2	3
2010-2011	BISU, Zamora*	16	0	0	0	0	1
2011-2012	Poblacion, San Isidro	1	28	3	3	1	3
2012-2013	BISU-Bilar & Loboc	11	17	3	3	0	4
TOTAL		**79**	**90**	**8**	**10**	**7**	**17**

Source: RDE Library, 2012

**- The batch decided to have the in-campus activities only due to conflicting schedules with the farmers*

Issues and lessons learned

Despite the significance of PGRCM to food security, it is only recognized as an Elective subject where only limited number of Crop major students will enroll, thus the need for it become a basic subject so all Agriculture students will take. The non-production of stable materials by the students due to too many activities they have for a limited time was noted. Besides, space and seed bank facilities are inadequate for the very delicate work of growing and handling selections and breeding lines, hence, the need for a wider handling area.

A highly appreciated observation was the great synergy that developed among the young inquisitive students vis-as-vis the adult, experienced practical farmers as well as the technical experts which provided scientific basis on the practices and beliefs that demand for it.

FFS participants also automatically become partners in the disseminating the planting materials, thus, diversifying their farms in dispersing information on sustainable organic farming techniques including indigenous repellents for pest management.

CONCLUSION

1. The PGRCM was successfully integrated into the BAT and BSA curricular programs of BISU as an Elective subject of the students with major in Crop Production Technology and Crop Science respectively;
2. For a period of six years, BISU has produced 78 out of the 317 equivalent to 24.61% of the Agriculture graduates major in Crop Production/Crop Science with knowledge and skills in PGRCM;
3. BISU was able to organize and implement one research program with eight component projects that advocate PGRCM;
4. Through the FFS initiative, the university was able to empower six farming communities in Bohol with 90 farmer-graduates on rice PGRCM apart from training eight LGU technicians, 10 PAO staff and seven faculty; and
5. The most important issue noted during the project implementation was the recognition of the subject PGRCM as an Elective where only few will enroll and the lesson learned during the project implementation was the synergy of the FFS participants advocating PGRCM.

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facilitators and the collaborating institutions of the project for their technical and financial support; the BISU administration for the all-out support in the project implementation.

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Research article

Development of Organic Animal and Crop Production in Bosnia

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Abstract About 35 million hectares of agricultural land are managed organically worldwide by 1.4 million producers. Bosnia has a big agro-ecological potential and natural capital for organic production (OP) as traditional small-scale agriculture can be easily converted to organic. Agricultural land covers 50% of the total area. The paper aims at giving an overview of the current situation of the Bosnian organic sector especially potential, animal and crop production, governance, legal framework and market. Some solutions to overcome the main barriers to OP development are discussed. The paper is based on a secondary data review and exploratory semi-structured interviews - dealing mainly with reasons for converting to organic; marketing channels; problems; impacts; access to agricultural extension - conducted in July 2012 with 20 organic producers from Sarajevo, Banja Luka, Mostar, Bihac, etc. Organic area represents less than 1% of the total agricultural area. Plant production - mainly cereals - is more significant than animal production. Wild collection plays an important role. The complex political structure renders organic sector governance difficult. There is no national action plan and no national law on OP was enforced. Only the Republika Srpska entity has a law on OP. Organska Kontrola is the first local certification body. The organic movement is experiencing new dynamics, pushed by farmer and consumer associations and market actors. Organic market is relatively young and small. Supply chains are generally short. Two marketing channels grow slowly: direct selling (on-farm, farm gate, green/farmer markets) and conventional retail. Certified organic products are exported primarily to the European Union. Further organic sector growth is more than likely. OP represents a valid instrument for sustainable natural resources management and rural development. For allowing organic farming to express all its potential domestic market should be developed; legal framework and governance enhanced; and institutional and financial support secured.

Keywords organic farming, extension, organic market, Bosnia

INTRODUCTION

Thirty-five million hectares of agricultural land are managed organically by almost 1.4 million producers especially in Oceania (12.1 million ha), Europe (8.2 million ha) and Latin America (8.1 million ha) (Willer and Kilcher, 2010). In Western Balkans Countries (WBC) the debate on organic agriculture development is taking place, with the involvement of public and private actors, within various cooperation projects and consultation networks operating at different levels (MAIB, 2008). Organic markets in the WBC in general and in Bosnia and Herzegovina (BiH) in particular are, compared to some of the organic markets in Western Europe, relatively young, very small and in an early stage of market development (Renko et al., 2010). During the last years, domestic market actors and their associations as well as foreign market actors and policy makers often pushed the organic sector evolution with regard to different aspects: official regulation, certification and labeling of organically produced and processed products. Significant influence on organic movements in most WBC countries comes from the legal framework of the EU (Renko et al., 2010).

Bosnia and Herzegovina consists of two governing entities namely the Federation of Bosnia and Herzegovina (FBiH) and Republika Srpska (RS). Agriculture share in GDP was 8.1% in 2011 (EC, 2012). Agriculture employs a fifth (20.6%) of the total labor force *i.e*. 167,000 persons (ASBiH, 2012). Agricultural land covers 50% of the total area (MoFTER, 2009). Bosnia and Herzegovina has good preconditions for organic animal and crop production and wild collection (Dimitrije and Tomic, 2010; Renko et al., 2010) but a series of problems hinder further development of the sector.

OBJECTIVE

The paper aims at giving an overview of the current situation of organic farming in Bosnia and Herzegovina.

METHODOLOGY

The work is based on a secondary data review and exploratory semi-structured interviews. The main secondary data sources were ministries, specific organic statistics, certification bodies, professional organizations, the International Federation of Organic Agriculture Movements (IFOAM), the Mediterranean Organic Agriculture Network (MOAN), etc.

Semi-structured interviews (SSI) were conducted in July 2012 with 20 organic producers randomly chosen from nine cities/municipalities all over BiH: Sarajevo, Banja Luka, Mostar, Bihac, Ribnik, Petrovac, Kozarska Dubica, Knezevo and Konjic. The checklist prepared for SSI included 33 questions dealing mainly with: reasons for converting to organic farming; organic animal and crop production as well as beekeeping; main marketing channels; problems and constraints; main economic, social and environmental impacts of organic agriculture; access to agricultural extension and subsides; main sources of information about organic agriculture; involvement in organic agriculture projects and initiatives; social capital of organic producers; collaboration and contact with other institutions and actors (*e.g*. certification bodies; public institutions; research institutes; donors); etc. Some solutions and recommendations to overcome the main barriers to organic production development provided by the interviewed organic operators are discussed.

The average age of the interviewed organic operators is 46.4 (age range: 27-80). Almost all interviewees (90%) are men. Among the interviewees there are no illiterate, half of them (50%) have secondary education while 20% of them have high education. The surveyed rural households generate income mainly through farming, pensions and salaries from the public sector. Farm surface ranges from less than one to about 100 hectares. Land use is dominated by arable land and permanent grassland and grazing land while land surface dedicated to organic permanent crops, aquaculture and apiculture is quite limited.

RESULTS AND DISCUSSION

Bosnian agricultural production is more traditionally oriented, and the use of pesticides is lower than elsewhere in Europe (Stanojcic-Eminagic, 2010; EC, 2009). There are also few industrial polluters (Stanojcic-Eminagic, 2010). In fact, only 20% of BiH's agricultural surface is suitable for intensive farming (EC, 2009). Because of the low consumption of fertilizers and pesticides, BiH's traditional small-scale agriculture can quite easily convert towards organic farming (Renko et al., 2010). The average farm size is 3 ha. Large parts of the country are uncultivated land or forests while two thirds of the territory are considered mountainous or hilly. Wild collection of fruits, herbs and mushrooms is an important traditional activity (Dimitrije and Tomic, 2010). Additional advantages are the relatively low labor costs (EC, 2009).

The exploratory field survey showed that the main reasons for converting to organic farming are: economic profit; personal satisfaction; environmental protection; and healthy production. The interviewed organic operators believe that organic agriculture bring multiple benefits. Some of the interviewees (15%) consider that organic agriculture has not brought about any economic impacts. They very likely refer to their household's financial situation. Nevertheless, most of the interviewees consider that organic agriculture has generated multiple economic benefits to their rural households and communities. These include higher prices (premium prices) and income, lower production costs and local economy revitalization. The main social impacts of organic agriculture are social capital strengthening; better relationship with neighbors; and increased membership in cooperatives and associations. The main environmental impacts are reduced soil and water pollution and the conservation of biodiversity (*e.g.* local and traditional varieties).

Organic agriculture is at an early stage of development in BiH and there are no national standards yet being enforced. A national Law on Organic Farming is in the phase of adoption. The law is fully harmonized with the new European Union's regulations on organic farming (834/2007 and 889/2008). Currently only in the Republika Srpska a Law on organic food production exists. Organska Kontrola (OK) is the first certification body in BiH, established in 2004 by the "OK Association". OK has developed organic certification standards in accordance with the IFOAM's basic standards and EU regulations (Dimitrije and Tomic, 2010). The certification bodies mentioned by the interviewees are OK, ECON, ECOline and BeHaBioCert.

In BiH, organic area is 200-400 ha which represents less than 0.1% of the total agricultural area. The number of organic farmers is about 300. The average organic farm size is 1.2 ha. More than 440,000 ha are certified as surfaces for wild collection of medical and aromatic plants, and mushrooms. Wild collection makes up a significant share of total organic sector. Production is geographically concentrated in Sarajevo region, central Bosnia region, Herzegovina region and north-western Bosnia. These regions are suited for wild collection (Dimitrije and Tomic, 2010).

All the interviewed organic operators were crop and animal producers. Nevertheless, some of them deal also with other activities such as beekeeping or over other part of the supply chain *e.g.* processing and direct sale. There was also a fish producer. The field survey showed that a wide range of crops is grown organically in BiH. The most common organically grown crops are: pepper, onion, potato, tomato, linseed (common flax), rye, maize, buckwheat and barley. As for livestock, the most important reared species are pigs, bovines, sheep and chicken. The interviewed organic operators have about 80 beehives.

A relatively well-organized supply chain already exists for export high-value organic products such as medicinal herbs, honey, berry fruits and wild collection products; that are sold on European markets (MAIB, 2008). The major exported Bosnian organic products are tea, dried mushrooms, dried forest fruits, essential oils and raw plant material (sage for teas). Approximately 50-60 products of different kinds of herbs and tea are also being produced and exported, mostly to western European markets. The main imported organic products in BiH are Kiwi, biscuits, juices, various flours and meals, and pasta (Dimitrije and Tomic, 2010).

Organic food processing started in 2001 mainly based on essential oil production, forest fruit processing (mushrooms, berries, cranberry, blueberry, rose hip, etc.). The sector is still under development and involves some 20 small and medium enterprises (Dimitrije and Tomic, 2010). The main processing activities of the surveyed organic operators include flour production (rye,

wheat, maize, buckwheat); production of wine (blackberry), liqueur (blackberry) and *rakija* (blackberry); oil extraction; jam and fruit juice production; bakery; etc. Some of them deal also with bottling and packaging.

The organic market in BiH is very small mainly because of the low purchasing power of the population. It is estimated that only around 3% of the population can afford buying organic products (Stanojcic, 2004). In some cases producers sell their certified organic products at conventional prices. This is foremost the case for all unprocessed items of agriculture and wild collection. Furthermore, the so-called healthy food is often misinterpreted as organic food. The organic sector production is still very small and therefore the supply chains are not developed. The organic market represents only about 0.4% of the total food market value. However, according to some sources, the organic market in BiH is growing at an annual rate of 10 to 20%. Organic wholesale is at the beginning of development. Specialized outlets for organic products do not exist. Generally, the distribution channels for organic products in BiH are: conventional supermarket chains (Mercator, Tempo); drugstores; pharmacies (herbal teas); green markets in Sarajevo, Banja Luka and Mostar; and direct selling (Dimitrije and Tomic, 2010). The main marketing channel used by the interviewed organic producers is on-farm direct sale. However, also farmers' market and wholesale to processors are relevant. Other marketing channels include box schemes.

Most of the interviewed organic operators (75%) think that the decision to convert to organic was appropriate as production of healthy food is a good way to increase household income and to make agricultural production more sustainable. Nevertheless, it is important to consider that 15% of the interviewees answered that they regret that decision. That is, according to them, mainly due to the current conditions in BiH making organic agriculture not sustainable. The main problem faced by the interviewed organic operators is the lack of support from municipalities and other public institutions. They mentioned also other constraints such as very rigid regulation; high prices of organically allowed inputs; high certification costs; difficulty to find organically allowed inputs on the market; marketing/sale difficulty; pollution and negative externalities caused by neighbors; lack of training on organic farming; and low prices of organic products. Other problems include lack of financial resources and difficult access to credits; market insecurity and demand volatility; weak organization at the state level; irregular and delayed payments; and problems with pests and climatic disasters. Organic prices are only about 20% higher than prices paid for conventional products; which does not allow covering higher production costs.

A series of major problems still constitute hindering factors for further development of the organic sector: lack of information about organic products; the distrust to the information on the label; lack of promotional activities; little acceptance of paying price premiums for organic products; low availability of the organic products; and lack of domestic supply chains. Hindering factors include as well the strong export-orientation of the supply chains, insufficient domestic infrastructure, lack of expertise among farmers and processors, and costly and complicated certification (Renko et al., 2010).

According to the organic operators, institutions that should make more efforts to solve the problems they face are: the State, municipalities/cantons, entities, cooperatives, and the extension service. Other interviewees pointed out that it is necessary to increase engagement of scientific-research institutions to demonstrate the benefits of organic farming in order to attract relevant institutions and foreign investors. It is clear from the provided answers that a concerted effort of many institutions is necessary.

All organic operators in the RS declared that they received subsidies. In the FBiH only some organic producers have access to subsidies and incentives. The main subsidies and incentives needed by the interviewed Bosnian organic operators change from an entity to another. In the FBiH they are mainly related to easier access to funds and loans with low interest rates. Also in the RS the same type of incentives is needed. However, additional requests concern support for getting financial subsidies; supporting organic farms mechanization (cf. weed management); and support for storage, processing and irrigation facilities. They also insisted on the fact that the new Law on organic farming should be enforced as soon as possible.

As for the social capital of organic operators, 70% of the interviewees are members either of associations (*e.g.* Animal Husbandry Association) or cooperatives (*e.g.* Ecoline, ECON, Sunce,

Tresnja). It should be highlighted that 15% of the interviewed organic operators are members of both of them. Some organic producers are also members of other participatory and civil society groups or organizations such as hunting associations.

Two fifths of the interviewees do not have any ongoing collaboration with other institutions. The remaining deal with many institutions depending on where they operate (FBiH or RS). All in all, organic operators deal with the following institutions: municipalities; entities' ministries of agriculture; cooperatives (*e.g*. Ecoline, ECON, Sunshine and Cherry Product); research institutes (*e.g*. Agricultural Institute at Butimir (Sarajevo); Agro-Mediterranean Faculty (Mostar); Institute of Agriculture in Bihac; Institute for Agriculture in Unsko-Sanski canton (FBiH); Agricultural Institute of the Republic of Srpska); certification bodies (*e.g*. OK; BeHaBIOCert); extension service; etc. Some of them have contacts with organic producers from other countries *e.g*. Croatia.

The interviewees get information about organic agriculture through attendance of courses and conferences or via the Internet; TV; trips and visits to other organic farms; magazines and newspapers; and the radio. Other information sources include friends and professional advisers. The high percentage of organic producers that rely on these alternative information sources can be explained by the fact that only less than a fifth on the interviewed organic producers (15%) has contact with the agricultural extension staff and uses services provided by them. Used extension services and information are related to production methods, optimal sowing and planting time, agro-technology and animal husbandry. According to MAIB (2008), most organic producers and processors in the WBC complain about the lack of adequate extension and advisory services which are crucial for the well-functioning of the whole supply chain. The creation and improvement of supporting structures and services for production and market development is crucial.

Almost a third of the interviewees (30%) do not know anything about organic agriculture programs and projects while only 15% of them have been involved in previous ones. Donors, governmental and non-governmental organizations have been active in supporting the organic sector. Currently, a project called the "Development of Organic Agriculture in BiH" is being supported by the Swedish International Development Agency (SIDA) (Dimitrije and Tomic, 2010).

The interviewed organic producers provided many recommendations for fostering the development of OA in BiH: better organization at the state level; improving protection of organic producers' interests; increasing state and public institutions' assistance and support; better access to markets; better market control; increasing organic producer income through guaranteed premium prices and subsidies; increasing awareness about the safety and quality of organic food products; increasing availability of organic inputs; simplifying certification procedures and reducing certification costs; and increasing involvement of public and civil society organization in the organic sector. In particular, agricultural research and scientific institutes should help organic farmers by exploring new possibilities of application of various plant-based pesticides, in order to reduce the use of harmful chemicals, as well as the selection and breeding of crop varieties that are more adapted to local conditions (climate, soil, pests, etc.). These can include also autochthonous varieties thus contributing to biodiversity conservation.

In BiH there is a need to enhance understanding and provide more information on the whole concept of organic agriculture production and also to secure institutional and financial support to develop the sector. There is also a need to raise public awareness to appreciate the positive externalities of organic farming. This should be done through media promotion, and farmers' fairs and local markets organization (Dimitrije and Tomic, 2010). Options and solutions to overcome the main barriers to the development of organic agriculture include as well (Renko et al., 2010): organizing producers in associations and cooperatives; know-how transfer; teaching organic farming in schools and universities; encouraging vertical and horizontal integration in the supply chain; fostering aggregation; clarifying labeling and certification procedures; and providing online information. Strengthening intra-WBC cooperation, exchange and networking is also a highly appreciated area of intervention. Better and thoughtful synergy in policy-making processes could foster the mainstreaming of organic agriculture and integrate its future development trajectories into the wider rural development context and dynamics. The role of the state as well as national movements is important in the development of the organic sector (MAIB, 2008).

CONCLUSION

Further growth of the organic sector is more than likely as Bosnian organic producers are highly motivated and committed. BiH has all the natural prerequisites for organic food production but very important is farmers' willingness to produce organic food and consumers' willingness to pay premium prices. Bosnian organic market is relatively young and small but is dynamic and linked up internationally. The scope of production is very wide, with a lot of different products, but often small quantities. Wild collection plays an important role in the overall organic raw material production, mostly dominating the agricultural production. Furthermore, plant production is more significant than animal production. Organic food processing sector has been improved in terms of quantity and quality. Supply chains are generally short, with much direct selling on the domestic market. Domestic supply chains do often still have pioneer character and are still in an early stage of development. Producers and consumers are often aware of organic farming benefits and consumption trends are in favor of the sector. However, the development of the organic sector is hindered by many problems. Due to the complex politico-administrative situation of the country, a harmonized national legal framework for the organic sector still does not exists.

There is a need to enhance understanding of the whole concept and philosophy of organic agriculture and also to secure the state institutional support as well as domestic and foreign technical and financial assistance. In order to raise public awareness the concept of organic food production needs to be promoted amongst general public especially women and young people. The practices of organic production, handling and processing and the quality of products have still to be improved. Diffusion of organic good practices requires innovative ways for organic-specific knowledge generation and dissemination and long-term investments especially in the agricultural education-research-development-extension system. Moreover, organic product diversification and structuring of related supply chains is needed to foster further development of organic agriculture.

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Research article

The Study on Conventional Farming Practice - A Case Study of Farmers' Practice in Samroung Village, Cambodia

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Abstract Agrochemicals application has been rapidly popularized in Cambodia due to agricultural development technologies. Although agrochemicals utilization has significantly increased crop production, it has negative impact on human health, sustainability of land use and ecosystem. Therefore, this study has been focused on conventional farming practice in Samroung village of Kampong Cham province, Cambodia. The main objectives of this study are 1) to understand current situation of farming practices in the village and 2) to identify the condition of agrochemicals applied at farmlands. To access the objectives of this study, various participatory researches, both quantitative and qualitative have been conducted. Semi-structured interviews, in-depth interviews, focus-group discussion were conducted, and secondary data were used in this study. Data was summarized and analyzed to observe the significant difference and high confident correlation of these variables by using One-way ANOVA and Regression Analysis. The result of the study showed that rice and vegetable production is main sources of farmers in Samroung village. In addition, chemical fertilizer and pesticide are applied for increasing crop production. The amounts of chemical fertilizer and pesticides applied did not correlate with the level education of famers, also with the size of farmland as well ($P > 0.05$). In addition, the amounts of pesticide applied did not correlate with the total annual household income. However, the amounts of chemical fertilizer applied showed slight correlation with the total annual household income from agriculture ($P < 0.05$). Also, increasing expenses of agrochemicals application, especially chemical fertilizer application, affects to the farmer's annual income. Moreover, it affects to their life that depends on low income from their agricultural products. Furthermore, the survey indicated that 92% of farmer in the village want to change their practice to sustainable practice in the future. Therefore, agricultural education such as providing technical training, workshop is necessarily required for promoting sustainable use of agrochemicals as well as alternative ways based on organic farming practices and farming practice with low chemical input.

Keywords conventional farming practice, agricultural education, agrochemical application, Cambodia

INTRODUCTION

Cambodia is located in the Southeast Asia region, and its topography has enormous potential for agriculture development. Agriculture is vitally important for economic growth and eradicating poverty of the people. According to the statistics of Ministry of Agriculture, Forestry and Fisheries of Cambodia in 2009, agriculture productions share 34.4% of total GDP, in which rice and vegetable represented 54% and 8% of total annual crop production. Increasing crop productivity is

a main factor that increases farmer's income as well as national economy. In view of this, farmers apply agricultural chemicals, such as chemical fertilizers, herbicide or pesticide, to maintain high levels of crop yields. In 2001 chemical fertilizer and pesticide were imported into Cambodia, which represented 45,335 tons and 200 tons respectively (MoE, 2004). The tendency of agrochemicals application has been rapidly popularized in the country. In 2010, 245,854 tons of chemical fertilizer was imported into the country (MoE, 2010).

Kampong Cham province is a main agricultural development zone in Cambodia. The major activity of the people in this area is agriculture, mainly cultivating rice and vegetable. Agricultural history of this area tends to change from traditional farming to conventional farming, and the amounts of agricultural chemicals applied to farmlands are increasing every year. According to Ngo and Siriwattananon (2009) more than 60% of farmers in Prey Chhor district, Kampong Cham province, have applied agricultural chemicals without understanding their impact. Although agrochemicals utilization has significantly increased crop production, it has negative impact on human health, sustainability of land use and ecosystem.

This study has been focused on conventional farming practice in Samroung village of Kampong Cham province. The main objectives of this study are 1) to understand current situation of farming practices in the village and 2) to identify the condition of agrochemicals applied at farmlands.

METHODOLOGY

Study site

The study was focused in Samroung village consisting of 196 households in Samroung commune, Prey Chhor district, Kampong Cham province about 17 km from Prey Chhor Centre. Samroung commune consists of 11 villages with 8,111 people in 1,714 households which account for 93 % of total population, all of whom depends on agricultural sector, mainly on rice cultivation and cash crops for living (CDB, 2010). Most farmers in Samroung village cultivate rice and vegetable. The agriculture situation in the village converted from traditional practice to conventional farming system.

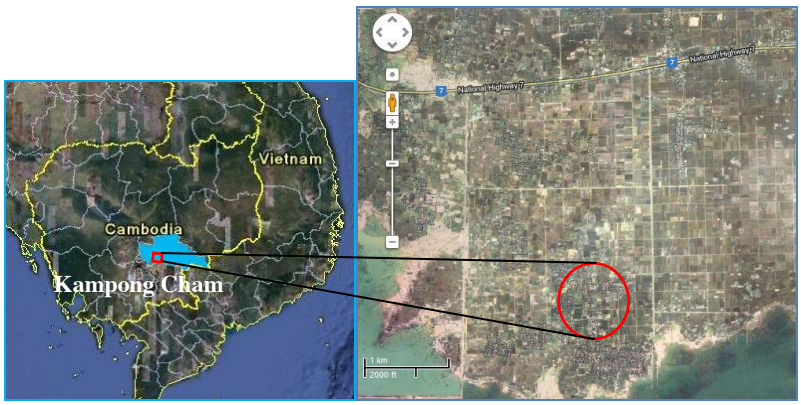


Fig. 1 Location of Samroung village

Data collection and analysis

Secondary data collection: Existing relevant documents were collected from research institutions, journals and reports of experts who had carried out studies in the project area to better understand the issues involved.

Primary data collection: Two steps were used in primary data collection. Firstly, focus group discussion was carried out among7 key persons from the village. A semi-structured questionnaire (a) was used for key informant interviews; a structured-questionnaire (b) was designed for a

household survey on 51 farmers who were selected randomly for interview. This method focused mainly on socio-economic and agricultural situations of the households, cultivation techniques and farmers' perception on the tendency of converting from conventional farming to sustainable farming practices.

Data analysis: The data was summarized; and descriptive statistics, including percentages, mean and standard deviations were used to analyze the data. Also, inferential statistic, including One-way ANOVA and Regression Analysis were used to analyze the significant difference and high confident correlation of these variables.

RESULTS AND DISCUSSION

The current situation of conventional farming practices in Samroung village

According to the result of focus group discussion, it was included that rice is a main crop in Samroung commune and is cultivated 2 to 3 times a year. Besides rice cultivation, cash crops are cultivated rotationally for the whole year depending on the water sources. The main cash crops in the village are cultivated for additional income (Table 1).These vegetables are planted in 4 rotations at upland fields all year round, and a peak season of harvest is from August to October.

The results of the household survey showed that 63% of the households cultivate rice, 34% cultivates rice and vegetable, and 3% does not conduct farming. The average total paddy fields and vegetable fields are 1.5 ha (SD = 1.05) and 0.04 ha (SD = 0.08), respectively.

Table 1 Crop calendar in Samroung village

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1) Rice												
2) Onion												
3) Lettuce												
4) Chinese Kale												
5) Cucumber												
6) Chinese cabbage												
7) Bitter melon												
8) Long bean												
9) Tomato												
10) Eggplant												
11) Chili												

Source: ERECON, 2012

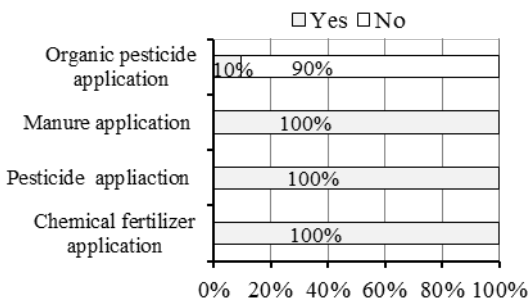


Fig. 2 Percentage of farmer's applying agrochemicals and organic materials

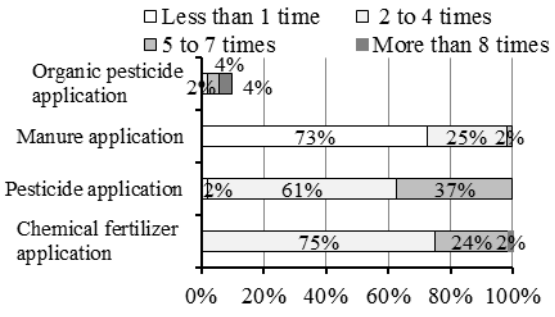


Fig. 3 Time of applying agrochemicals and organic materials

The result of study also showed that cow manure, compost, and waste from bio-gas are applied to improve soil condition as well as agrochemicals, fertilizers and pesticides to increase crop production. According to the result of the survey, 100% of famers in the village have applied chemical fertilizer, pesticide, and manure on both paddy fields and vegetable fields. Also, 10% of the respondents applied organic pesticide, and 90% does not apply organic pesticide (Fig. 2).

Besides, organic materials have been applied on their farmland such as manure with 8510 kg a year and only 10% of farmers applied organic pesticide with 44000ml a year. In addition, 75% of respondents applied chemical fertilizers with 2 to 4 times a year and 61% of farmers applied pesticide 2 to 4 time a year (Fig. 3). However, organic fertilizer and bio-pesticide is limited source for the farmers to apply on their farmlands. In addition, most farmers said organic pesticide is less effective than chemical one.

Markets of agricultural products in Samroung village

Main agricultural products, especially rice and vegetable are sold to the markets through middlemen who come from inside or outside the commune. The middlemen come to buy some kinds of vegetables almost all day. Some middlemen sell vegetables to local market such as Skun market, Prey Torteng market and Kampong Cham market or other markets in Siem Reap province. Before selling vegetable to the middlemen, farmers clean and sort their produce without grading by size and classification. In addition, some vegetable farmers are collecting the vegetable from their village and neighboring villagers and selling it to the local market.

The results of the survey showed that 98% of farmers in the village sell their rice production to the middlemen, and 93% of vegetable growers also sell the vegetable to the middlemen; only 7% bring their vegetable production to the local market directly (Fig. 4). In addition, price of the products depend on middleman.

The survey also indicated that price information sources of farmers in the village are obtained from the middlemen, farmers in the village, mobile phone, radio/TV and NGO officers, representing 62%, 16% and 10%, 6% and 4%, respectively (Fig. 5)

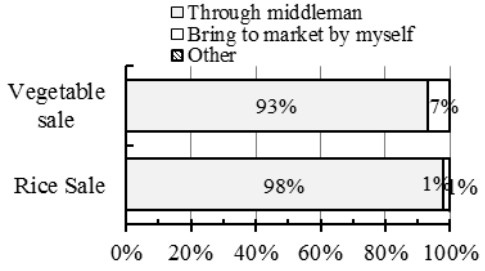


Fig. 4 Percentage of farmers' selling the agricultural products to market

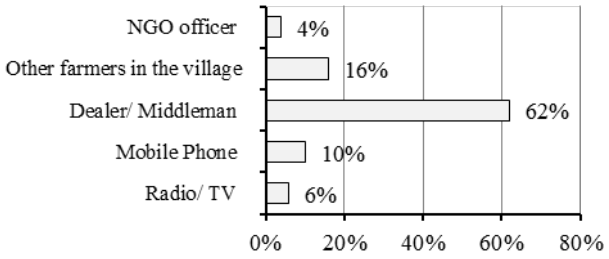


Fig. 5 Farmers' sources of price information for selling the products

Linkage between socio economic conditions and agrochemical application

The main indicators of socio economic such as the level of education, the size of farmland, and the total annual household income were selected to determine the sinificant differnce of amounts of chemical fertilizer and pesticide application by using one-way ANOVA. Also, the relationship of each variable were analyzed by regression analysis.

An annual total household income is 606.93 USD (SD=55.20), and annual average of chemical fertilizer and pesticide application is 321.76 kg (SD=154.81) and 1.12 L (SD= 0.95) respectively. The result of analysis indicated that the amounts of chemical fertilizer and pesticides applied did not have significant difference between each level of farmer's education as well as size of farmland and total annual household income ($P > 0.05$). Moreover, the amounts of chemical fertilizer and pesticide application did not correlate with the level of education of farmers and with

the size of farmland as well (R^2=0.0926, P > 0.05). However, the amounts of chemical fertilizer application correlated slightly with size of farmland (R^2=0.1913, P < 0.05) as well as with total annual household income (R = 0.1913, P <0.01) (Figs. 6, 7).

Fig. 8 showed that the total income from agriculture is not significant difference between each group of farmers' expense on chemical fertilizer application**.** As a result, it could be concluded that farmers need to buy chemical fertilizer very year to increase their crop production. Therefore, the annual household income from agriculture will be low if the farmers increase expense of agrochemical application every year.

Possibility of changing from conventional farming practice to sustainable farming practice

According to the result of the survey, 53% of respondents did not know about sustainable agriculture, and 39% knew less about sustainable agriculture (Fig.9). In addition, responding to the question "do you want to convert conventional farming to sustainable farming practice?" The results indicated that 92% of the farmers want to change to sustainable farming practice (Fig.10).

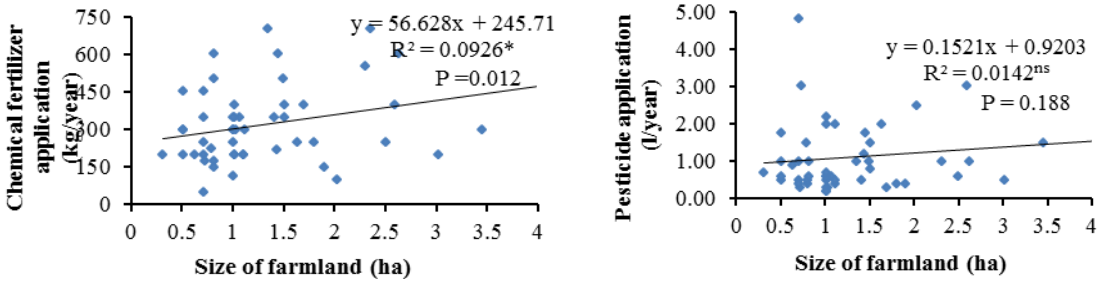


Fig. 6 Correlation of size of farmland with chemical fertilizer and pesticide application

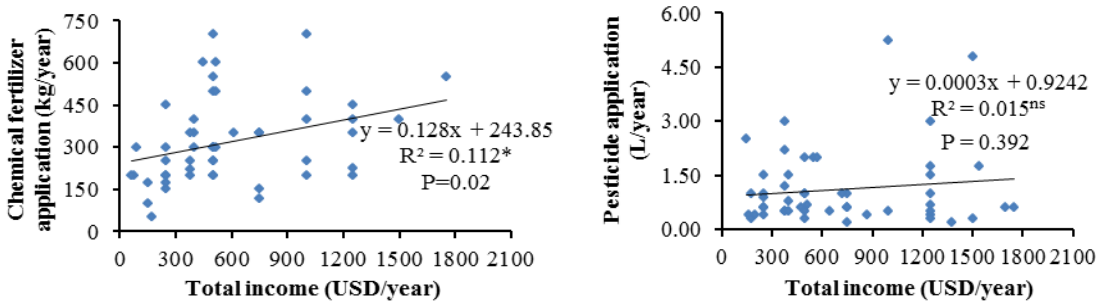
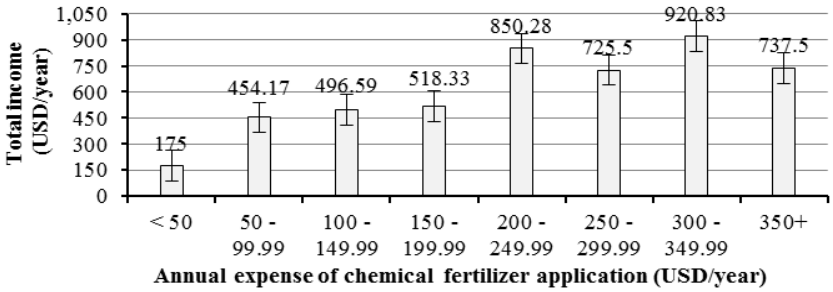


Fig. 7 Correlation of household income with chemical fertilizer and pesticide application



Non-significant difference between each group of annul expenses of chemical fertilizer application (P>0.05)

Fig. 8 Comparison of annual expense of chemical fertilizer application and total income

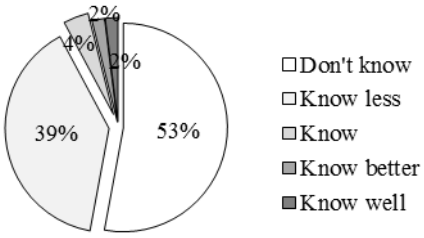


Fig. 9 Percentages of farmers know about sustainable agriculture practice

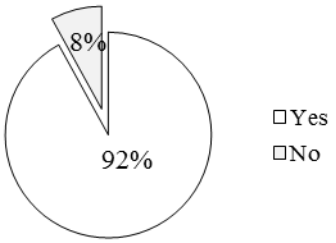


Fig. 10 Percentages of farmers want to change conventional to sustainable practice

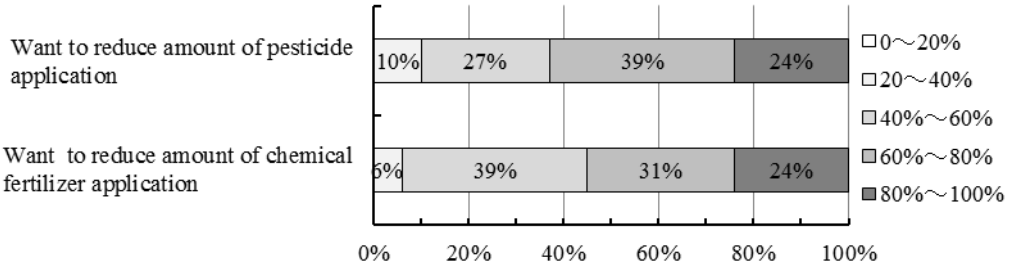


Fig. 11 Percentages of farmer want to reduce amount of agrochemical application

Figure 11 showed the expectation of farmers who wants to reduce chemical fertilizer and pesticide through alternative agriculture. 40% of respondents want to reduce chemical fertilizer by 40% to 60%, 30% wants to reduce by 60% to 80% and 23% wants to reduce by 80% to 100%. In addition, 40% of respondents want to reduce pesticide by 60% to 80%, 23% wants to reduce by 80% to 100%.

CONCLUTION

The study found that rice and vegetable production is main sources of farmers in Samroung village. In addition, chemical fertilizer and pesticide are applying for increasing crop production. The amounts of chemical fertilizer and pesticides applied did not correlate with the level education of famers, also with the size of farmland as well. The amounts of pesticide applied did not correlate with the total annual household income. On the other hand, the amounts of chemical fertilizer applied showed slight correlation with the total annual household income from agriculture. In addition, increasing expense of agrochemicals application, especially expense of chemical fertilizer application, affects to the farmer's annual income. Moreover, it affects to their life that depends on low income from their agricultural products. Furthermore, the survey showed that 92% of farmer in the village want to change their practice to sustainable practice in the future. Therefore, agricultural education such as providing technical training, workshop is necessarily required for promoting sustainable use of agrochemicals as well as alternative ways based on organic farming practices and farming practice with low chemical input.

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Research article

Alternative Cropping Systems for North-West Cambodia

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Abstract A field research program commenced in north-west (NW) Cambodia in 2012 to test the feasibility of including a dry season crop for this upland area, increasing the cropping intensity from 2 to 3 crops per year. Dual purpose crop options that can be harvested for fresh forage or silage in the event of crop failure due to drought will also be evaluated. Forest clearing after 1998 has been followed by the expansion of upland cropping in NW Cambodia. Major threats to sustainable agricultural production in the region are: (a) rapid soil degradation, soil fertility decline, loss of crop diversity; and (b) poverty and lack of income diversity for small-holder farmers. Access to improved agricultural technologies could provide solutions to these problems. Current farmer practice involves growing two crops per year, with an early wet season crop (March-June) and followed by a main wet season crop (July-October). Land is ploughed after the main wet season crop or left fallow from November to February. Due to high rainfall in NW Cambodia in September and October, there is significant residual water remaining in the soil after the wet season that could be exploited by crops rather than weeds as it currently is. The risk of growing dry season crops would be reduced if tillage was eliminated and surface crop residues were retained to conserve soil water. Small-holder farmers in NW Cambodia struggle to cover household expenses with crop income. Annual gross margins from growing two crops of maize (USD 874/ha) are declining and farmers are turning to cassava (USD 1,066/ha) to increase income and reduce labour costs. Replacing early wet season maize with peanut is more profitable (USD 1,447/ha); moreover adding dry season sunflower into the peanut-maize rotation to grow three crops per year could return a gross margin of USD 1,888/ha.

Keywords upland cropping systems, land use efficiency, maize, sunflower, Cambodia

INTRODUCTION

North-West Cambodia has seen rapid expansion of rainfed upland cropping as a result of large-scale land clearing since the end of the Khmer Rouge civil war in 1998. Unfortunately this development has been associated with excessive cultivation and burning of crop residue which has led to rapid soil fertility decline and soil erosion. The Australian Centre for International Agricultural Research (ACIAR) has funded research since 2003 to address these problems and to develop more sustainable upland cropping systems for NW Cambodia.

CROPPING SYSTEMS TRENDS

The rapid expansion of maize and cassava area, which began in 2006, has led to a loss of crop diversity in the region (Fig. 1, Fig. 2). Maize yields are declining as soil fertility declines and this may be one of the reasons why farmers have begun to increase the area of cassava at the expense of

maize (Fig. 2). The expansion of cassava could also be due to the need for less labour and opportunity for household members to earn off-farm income.

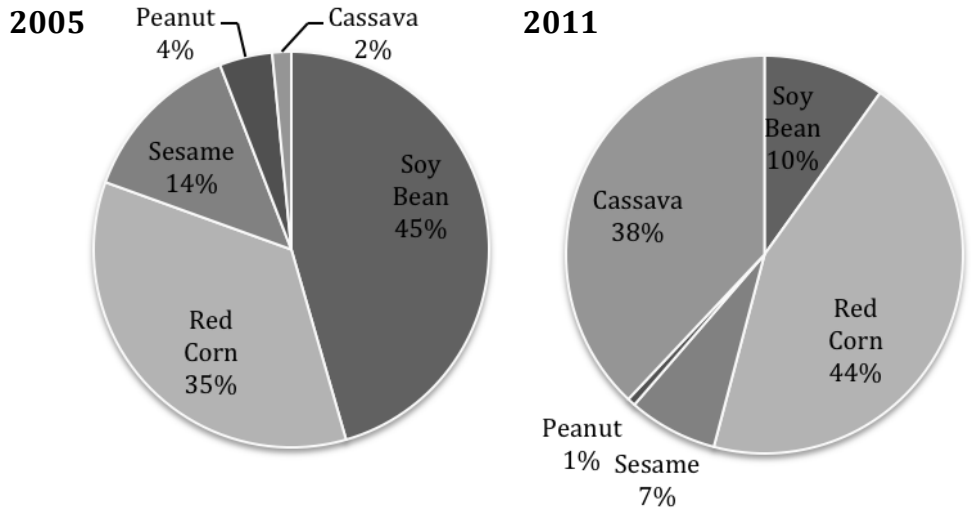

Fig. 1 Cropping trends in Battambang Province based on area of production
(Data source: pers comm. Battambang Provincial Department of Agriculture)

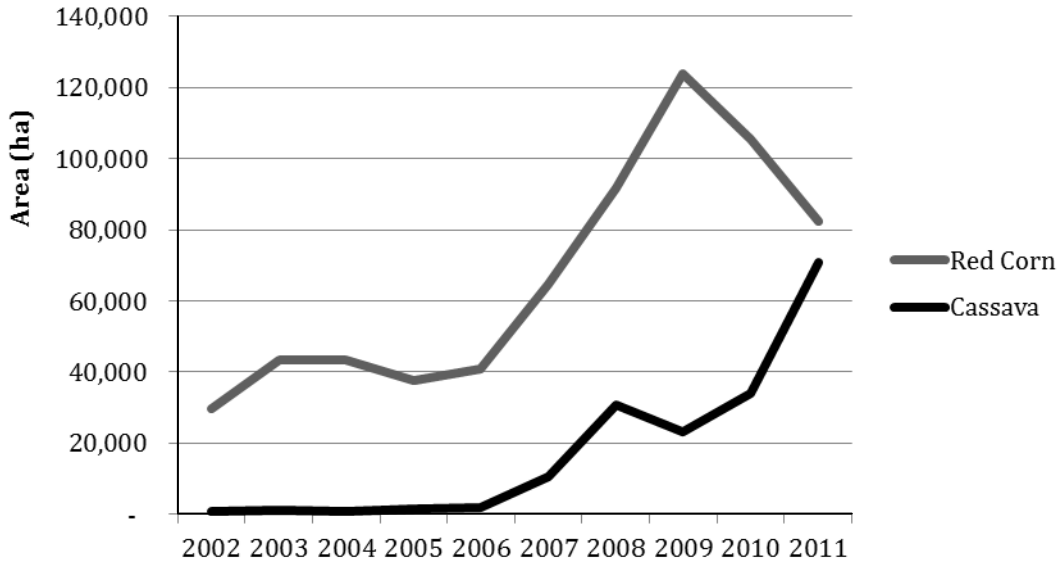

Fig. 2 Trends in the area of red corn and cassava in Battambang Province
Data source: Battambang Provincial Department of Agriculture

CLIMATE AND SOIL

NW Cambodia has a monsoonal climate with a rainy season between May and October and a distinct dry season between November and March (Fig. 3). The average annual rainfall at Battambang is 1,247 mm with 101mm, 391mm and 755 mm falling in the dry season (DS), early wet season (EWS) and main wet season (MWS) respectively.

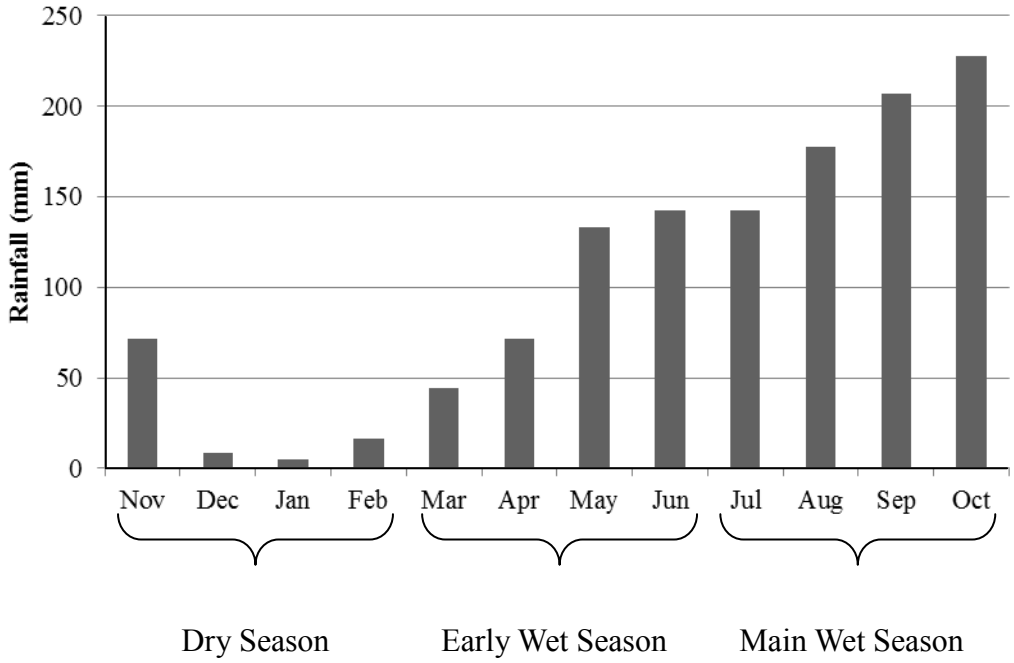

Fig. 3 Average seasonal rainfall distribution at Battambang Town
(Data source: Battambang Office, Ministry of Water Resources and Meteorology)

The average temperature at Battambang is 28.0 ^{o}C. April is the warmest month with an average maximum temperature of 36.1 ^{o}C and December the coolest with an average minimum temperature of 19.7 ^{o}C. Average relative humidity at Battambang is 80% rising to 86% in September-October and falling to 72% in March.

The main soils where upland crops are grown in NW Cambodia are known locally as Kampong Siem (Vertosol) and Labanseak (Ferrosol) (White et al., 1997). The Kampong Siem soils are black self-mulching clays and the Labanseak are red friable clay-loams. Martin et al. (2005) reported analyses for 25 ferrosols and 25 vertosols in crop fields in Ratanak Mondul District, Battambang Province. On average, the vertosols are higher in organic carbon and total nitrogen and have higher pH than the ferrosols (Table 1). These clay and clay-loam soils have the capacity to retain significant quantities of plant-available water in dry periods between rainfall events.

Table 1 Organic carbon, total nitrogen and pH (0-15cm) of ferrosols and vertosols in Ratanak Mondul District, Battambang

Soil	Organic carbon (%)	Total nitrogen (%)	pH (water)
Ferosol	2.07 (1.36-3.81)	0.176 (0.115-0.258)	5.5 (5.0-6.0)
Vertosol	2.46 (1.45-4.50)	0.181 (0.105-0.342)	6.5 (5.0-8.0)

Data source: Martin et al. 2005

ALTERNATIVE CROP OPTIONS

The main crops grown in the early wet season (March-June) include sesame, maize, mungbean and peanut, while the principal crops grown in the main wet season (July-October) are maize and soybean. Cassava is grown over a 12 month period.

There is potential for drought tolerant crops such as sunflower and sorghum to be grown during the dry season (November - February) on residual soil moisture after harvest of the main wet season maize crop, especially if the dry season crop could be sown at the end of October (Fig. 3). The success of the dry season crop is likely to be enhanced by no-till seeding into chopped maize residue to better retain residual soil water from the main wet season rains.

Inclusion of a dry season crop allows the potential for three crops to be grown during the year compared to the current practice of growing one (cassava) or two crops per year: early wet season (March - June) and main wet season (July - October) (Fig. 4). The three crop option is only possible if tillage is eliminated between crops to conserve soil moisture and enable timeliness of operations.

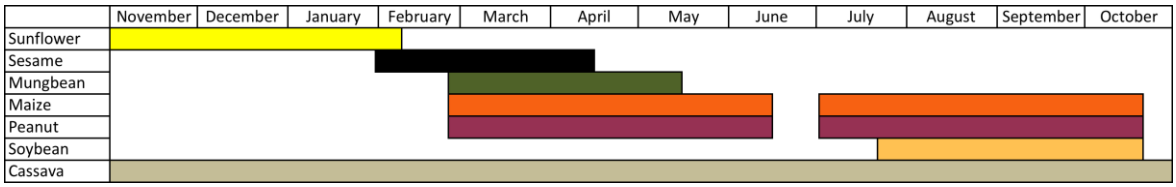

Fig. 4 Current upland crop calendar for NW Cambodia incorporating proposed dry season sunflower (*Data source: pers comm. B. Martin*)

Technically both mungbean and soybean can be grown in the early and main wet seasons. However, soybean is not drought tolerant and can fail in the early wet season. Mungbean crops often fail in the main wet season because of fungal infection of the pods in the humid conditions. Therefore it is recommended mungbean be planted only in the early wet season and soybean in the main wet season. Sesame is best grown in the early wet season to avoid attack from the sesame webworm (*Antigastra* spp.*)*

Apart from the problems of soil degradation and lack of crop diversity, maize and cassava fields in NW Cambodia are being invaded by tall grass weeds such as *Sorghum halepense* (Johnson grass), *Sorghum bicolor* (wild sorghum) and *Pennisetum polystachyon* (mission grass). If left uncontrolled after maize harvest, these grasses continue to grow throughout the dry season and consume the residual soil moisture from the main wet season rains. This gives a strong indication that there is sufficient residual soil moisture to grow a dry season crop. Farmers in this region have already experimented successfully with growing sunflower and sorghum in the dry season.

A challenge for introducing the dry season crop option is to successfully manage the maize crop residues and weeds at harvest without losing valuable soil water. A maize stalk chopper and a no-till planter have been imported from the USA to enable small plot replicated on farm trials of direct seeding of the dry season crop into the maize/weed residue. This will require chopping of the maize stalks and killing the weeds with a broad-spectrum herbicide (glyphosate) before direct seeding the dry season crop. As part of research for a PhD and the afore mentioned ACIAR project, trials with this system focusing on crop sequencing, cropping intensity and effects of maize residue as a mulch under a no till farming system will commence in 2013 in collaboration with farmers. Until the machinery is ready to use, trials will be hand planted following no till farming principles.

The important elements that a resilient crop sequence in NW Cambodia could include are:

1. A ‘grass’ crop such as maize which can provide sufficient residues to maintain ground cover mulch through the annual crop cycle;
2. A legume crop such as mungbean, peanut or soybean that can increase soil nitrogen fertility through fixation of atmospheric nitrogen; and
3. Other crop species such as sunflower or sesame to help to break disease, insect and weed cycles.

ECONOMIC ANALYSIS

In Battambang Province in 2011, maize and cassava were the dominant crops grown. Gross margins have been calculated for cassava, maize, peanut and soybean based on interviews with farmers in Samlout/Pailin in 2010/11 as part of the ACIAR project ASEM/2010/049 (Table 2). In this case, crop gross margins are calculated (on a per hectare basis) as the gross income from the crop less the variable costs incurred in achieving it, such as seed, fertilizer, in-crop weed control and harvesting costs. The potential gross margin for sunflower was calculated based on yield estimates and prices from Thailand and the prices being aligned with those for soybean.

Table 2 Gross margin sensitivity for cassava, maize, peanut, soybean and sunflower

Cassava fresh tuber.

Yield (kg/ha)	Price (USD/t)		
	USD32	USD64	USD95
20,000	USD77	USD711	USD1,345
30,000	USD115	USD1,066	USD2,017
40,000	USD154	USD1,422	USD2,690

Maize on cob

Yield (kg/ha)	Price (USD/t)		
	USD127	USD159	USD191
3,000	USD76	USD171	USD265
4,500	USD280	USD437	USD595
7,000	USD483	USD704	USD925

Peanut in shell

Yield (kg/ha)	Price (USD/t)		
	USD604	USD762	USD921
1,000	USD123	USD273	USD423
2,000	USD710	USD1,010	USD1,310
3,000	USD1,297	USD1,747	USD2,197

Soybean kernel

Yield (kg/ha)	Price (USD/t)		
	USD400	USD450	USD500
1,000	USD128	USD178	USD228
2,000	USD468	USD568	USD668
3,000	USD807	USD957	USD1,107

Dry season sunflower (low input, estimated)

Yield (kg/ha)	Price (USD/t)		
	USD400	USD450	USD 500
750	USD89	USD126	USD164
1,500	USD378	USD453	USD528
2,250	USD668	USD780	USD893

Data source: Anon. (2012)

Table 3 Gross margin comparison for cassava, maize, peanut, soybean and sunflower

Crop sequence	Average Annual Gross Margin (USD/ha)
Maize-Maize	USD874
Cassava	USD1,066
Peanut-Maize	USD1,447
Sunflower-Maize-Soybean	USD1,458
Sunflower-Peanut-Maize	USD1,888

Data source: pers comm. K. Kynal 2010, University of Battambang students 2011

Table 3 shows the comparison of potential average annual gross margins (using the average yields and prices) between the crop sequences under evaluation. At a first glance, farmers seem to be justified in switching from maize-maize to cassava as the gross margin for cassava is higher based on average yields and prices (Table 3). However, ACIAR research in Samlout/Pailin between 2008 and 2012 has shown that peanut can be a very profitable crop. A peanut-maize sequence could give a much higher gross margin than maize-maize or cassava. The peanut-maize sequence is also a better option to maintain soil fertility.

The addition of dry season sunflower to the peanut-maize cropping sequence would give an estimated annual gross margin of USD1,888, which is more than double that for maize-maize and almost double that for cassava. Another rotation option is sunflower-maize-soybean which is a good rotation option agronomically but might be less profitable than sunflower-peanut-maize (Table 3). However, this assumes relative crop prices remain the same. A disadvantage of the sunflower-maize-soybean option is that there is very little crop residue remaining after the soybean crop and there would be less ground cover for the dry season crop.

An important marketing consideration for sunflower, as with other crop species, is that the maturity of the NW Cambodian crop does not coincide with the harvest timing of the same crop species in Thailand. Lopburi Province is the main sunflower production area in Thailand. The peak monthly rainfall is September for Lopburi and October for Battambang so it is expected that the Cambodian crop would be planted one month later than the bulk of the Thai crop. Battambang also receives marginally more dry season rain (101 mm) than Lopburi (70 mm) meaning that dry season sunflower production might be safer in NW Cambodia compared to Thailand.

The average yield of sunflower under rainfed conditions in Australia is around 1,700 kg/ha with a realistic range from 700 to 2,400 kg/ha (Serafin et al., 2011). It is expected that dry season sunflower in Battambang Province could average up to 1,500 kg/ha. If the area of sunflower in Battambang Province expanded to 50,000 ha then the potential production would be at least 50,000 tonnes of sunflower seed per annum assuming a more conservative average yield of 1,000 kg/ha.

CONCLUSION

The current upland cropping system in north west Cambodia is facing many challenges including a loss in crop diversity, declining soil fertility, extensive soil erosion and continued deforestation. Soil characterisation in this region is not well determined but soils are generally inherently fertile, friable, well-structured soils, which if managed in a sustainable manner could greatly assist in alleviating rural poverty. Research is ongoing into sustainable cropping systems for this region. This research will provide the basic information required to improve soil management and water-use efficiency in upland areas of NW Cambodia. It will also develop 'response cropping' planting guidelines to reduce the risk of crop failure due to drought and demonstrate to farmers alternative cropping options on their land. The research will also identify the most suitable dual purpose crops that can be harvested for fresh forage or silage in the event of crop failure due to drought.

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Research article

Economics of Weed Management in Maize in Pailin Province Cambodia

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Abstract In Pailin Province, Cambodia, small-holder farm households derive most of their income from upland cash crops such as cassava, maize, soybean, mungbean and sesame. Since the end of the Khmer Rouge civil war in 1998, large areas of rainforest have been cleared opening the way for rapid expansion of cropping, especially maize. The crop expansion has occurred on ferrosols and vertosols which had high initial fertility after clearing. Continuous cropping with maize has resulted in a decline in soil fertility and an increase in losses due to biotic factors, especially weeds which have contributed to a decline in maize yields. Due to the increased cost of agricultural labour, farmers have rapidly taken up the use of herbicides for weed control in maize. A survey of 88 households in 6 villages was carried out to determine the effectiveness and economics of weed control methods for maize, being used by farmers. The results indicate that farmers are moving away from the traditional two cultivations for land preparation and two in-crop hand weedings. This has been due to replacement of the second ploughing with pre-sowing glyphosate, and the replacement of hand-weeding with selective in-crop herbicides in response to the cost and scarcity of labour. Although the current herbicide-based system for maize is working well, it is not likely to be sustainable without crop rotations and use of a wider range of herbicides. Maize crops in Pailin are being invaded by *Sorghum* weed species, and these species are not controlled by the commonly used atrazine. Rotation of crops and herbicides will be necessary to prevent a build up of naturally resistant weeds and development of genetic herbicide resistance in weed populations.

Keywords weed, management, maize, survey, rotation, economics

INTRODUCTION

Pailin town (12°50’47” N, 102°36’48” N) is located in North-Western Cambodia on the border with Thailand. The majority of farm households in Pailin Province depend on production of cash crops such as cassava, maize, soybean, mungbean and sesame. However, the most common crop is maize and production has expanded significantly since the end of the Khmer Rouge civil war in 1998.

Farmers usually grow two crops of maize in the rainy season. Early Wet Season (EWS) maize is planted in March-April and in the Main Wet Season (MWS), the crop is usually planted in July-August (Chan et al., 2009).

Much of the land under production of maize has been cleared of rainforest or forest regrowth over the last 20 years. Most of the soils used for cropping are derived from basalt or limestone parent material and have high natural fertility. The grain yield potential for maize in the region is 8 - 10 t/ha (Belfield and Brown, 2009). However, the average maize grain yield was estimated at 3.2 t/ha in 2011, less than half of the potential (Brown and Johnstone, 2012).

There are a number of factors such as abiotic (light, water, temperature and nutrient) and biotic (weeds, insects and pathogens) that contribute to decreased crop yields (Oerke, 2006). Weeds are one of the major causes of poor yields on small-holder farms in Pailin. Due to the increased cost of agricultural labour (USD 1/day in 2002 to USD 3/day in 2010) and shortage of labour, farmers have rapidly taken up the use of herbicides for weed control in maize.

OBJECTIVE

The aim of this study was to document weed management practices and to identify the social, economic and environmental constraints to the adoption of better weed management practices in Pailin Province, Cambodia.

METHODOLOGY

Data were collected from maize growers in six villages in Boryakha Commune in Pailin. A total of 88 households were selected randomly for the study. Sample size was determined using the Yamane formula (Yamane 1967) to give a 10% margin of error. Households were selected from the Villages of Borhuy (22), Boryakha (15), Rong Chak (11), Bortainsou (16), O Chra Lech (14), and O Sngout (10).

Qualitative data were obtained from the respondents using a pre-tested, structured interview conducted by enumerators who were familiar with the existing social settings. The interview schedule included both open-ended and closed-ended questions.

Descriptive statistical tools were used to analyze the quantitative data. The important statistical measures that were used to summarize and categorize the data were means, percentages, frequencies and standard deviations using Excel and the IRRISTAT statistical package was used for regression analysis (Anon., 2011).

Farmers were asked about the yield obtained, the price received for the crop and the variable costs of land preparation, seed, planting, weed control, harvesting, threshing and transportation. These data were used to calculate the gross margin (income minus variable costs).

RESULTS AND DISCUSSION

The average household size in the study area is 5.25 people, of which 3.13 are working age adults and the average area of crop fields per household is 4.04 ha (Brown and Johnstone, 2012). This means that all of the activities such as planting, weeding and harvesting cannot be completed manually by family members. As a result Pailin farmers have begun to mechanize land preparation, and planting and have replaced in-crop hand weeding with selective herbicides.

The average yield was 4.07 t/ha and the average price was USD 172/t giving a total income of USD 700/ha. The average total cost of inputs for maize was USD 275 per hectare, and the highest and lowest costs were USD 491 and USD 143 respectively. The average gross margin was USD 425 per hectare, and some farmers had gross margins up to USD 1,152 while the others made losses of as much as USD 62. On average, farmers obtained a return of USD 1.54 per USD 1 spent which was considered a good return on investment. Break-even yield is the yield at which the gross margin equals zero and is calculated by dividing variable costs by the expected price (Table 1).

Table 1 Economic analysis of maize production in Pailin (per hectare)

Costs	Average	Maximum	Minimum	Median
Yield	4.07	8.27	1.05	3.97
Income	USD 700	USD 1,422	USD 180	USD 682
Variable costs	USD 275	USD 491	USD 143	USD 271
Gross margin	USD 425	USD 931	USD 37	USD 411
Gross margin/USD cost	USD 1.54	USD 2.35	USD (0.43)	USD 1.15
Break-even yield	1.60	2.86	0.83	1.58

The breakdown of variable costs is given in Table 2. The traditional practice for land preparation is for two ploughings and often a harrowing. Pailin maize farmers have reduced the amount of cultivation where only 59% are ploughing the field a second time. This reduction is consistent with the number of farmers using glyphosate which is 33%. It is assumed from these data that farmers are beginning to replace the final cultivation with a glyphosate application. This is a positive trend because reduced cultivation reduces the potential for soil degradation, increases the conservation of soil moisture for the crop and can improve the timeliness of sowing.

Table 2 also shows that there has been a strong trend away from hand planting with 44% of farmers hand planting compared to 52% machine planting. There is also a minority of farmers using hand-weeding for weed control: 34% for one hand-weeding and only 16% hand-weeding a second time.

The reduction in hand-weeding is associated with a high adoption of selective in-crop herbicides with 80% of maize farmers using atrazine and 78% using 2,4-D; with more than 97% of the two herbicides being mixed together and spayed at one time. The study also showed that a few farmers had used Atrazine alone to control weeds without the combination of 2,4 D. There are also 68% of farmers using paraquat as a late post-emergence directed in-crop spray.

Table 2 Breakdown of variable costs for maize production in Pailin

Input	Farms (%)	Average input cost
1st ploughing	98	USD 43.29
2nd ploughing	59	USD 20.86
Seed	100	USD 59.96
Hand planting	44	USD 15.39
Machine planting	52	USD 14.97
1st hand weeding	34	USD 6.58
2nd hand weeding	13	USD 1.62
Atrazine	80	USD 3.69
2,4-D	78	USD 2.46
Paraquat	68	USD 9.18
Glyphosate	33	USD 3.71
1st spraying	39	USD 2.37
2nd spraying	85	USD 7.23
3rd spraying	76	USD 6.58
Harvest	100	USD 58.49
Threshing	2	USD 0.59
Transport	80	USD 18.10
Total variable costs	100	USD 275.37

The overall average input costs do not give an accurate idea of input costs for the different cultivation and weeding strategies. Therefore the data were re-analyzed according to the following classifications:

Replacement of the second cultivation with glyphosate with treatments being:

1. No second cultivation and no glyphosate;
2. Second cultivation and no glyphosate;
3. Second cultivation plus glyphosate;
4. Glyphosate only.

Replacement of hand-weeding with in-crop herbicides with treatments being:

1. Hand-weeding only;
2. Hand-weeding plus in-crop herbicide;
3. In-crop herbicide only.

This analysis confirmed the trend for pre-sowing glyphosate being used to replace the second cultivation (Table 3). The input cost for glyphosate (USD 19.95/ha) was significantly lower than for cultivation (USD 34.69/ha). The cost of a second cultivation plus glyphosate (USD 47.22/ha) was significantly greater than cultivation or glyphosate alone. There were no significant effects on crop yield or gross margin for the substitution of the second cultivation with glyphosate. However,

reduction in cultivation is likely to reduce soil fertility decline and soil erosion and therefore deliver economic benefits in the future (Kelley, 1983).

Table 3 Effect of substitution of the second cultivation with pre-sowing glyphosate on yield, input costs and gross margin per hectare

2nd ploughing	Glyphosate	No. of farms	Yield (kg/ha)	Input cost	Gross margin
No	No	21	3,986	0.00	400.75
Yes	No	38	4,181	34.69	453.39
Yes	Yes	14	4,309	47.22	355.72
No	Yes	15	4,032	19.95	451.65
SE			317	1.31	59.80
5%LSD			892	3.69	168.17
Significance			NS	0.01	NS

A total of 9 households (10%) practiced hand weeding only (Table 4) and the average cost of weed control for hand weeding only was USD 35.19/ha. Twenty two households used both hand weeding and herbicide at a cost of USD 53.71/ha. The majority of households (57) used herbicide only for weed control at a cost of USD 36.53/ha. Although there was a higher yield (NS) for hand-weeding plus herbicide, the cost was significantly greater than for hand-weeding or herbicide alone. Although not significant, the gross margin for herbicide alone was the highest.

Table 4 Effect of replacing hand-weeding with in-crop herbicides on yield, input costs and gross margin per hectare

Hand-weeding	Herbicide	No. of farms	Yield (kg/ha)	Input cost	Gross margin
Yes	No	9	3,596	35.19	369.73
Yes	Yes	22	4,343	53.71	412.22
No	Yes	57	4,132	36.53	438.65
SE			273	5.10	52.09
5%LSD			767	14.33	146.46
Significance			NS	0.01	NS

Table 5 Regression of gross margin on the components of variable costs

Term	Coef.	SDEV	F-value	P
Constant	-729.36	61.7903	139.3280	0.0000
Yield (kg/ha)	0.1625	0.0060	723.3630	0.0000
1st ploughing	-1.1686	0.5693	4.2140	0.0420
2nd ploughing	-1.1747	0.4769	6.0680	0.0160
Seed	-0.5087	0.6000	0.7190	NS
Hand planting	-0.3599	0.4443	0.6560	NS
Machine planting	-0.9734	0.4219	5.3220	0.0230
1st hand-weeding	-1.2092	0.5910	4.1860	0.0420
2nd hand-weeding	-0.0681	1.9154	0.0010	NS
Atrazine	2.1125	5.6101	0.1420	NS
2,4-D	-8.6845	6.4735	1.8000	NS
Paraquat	-0.6807	0.7991	0.7260	NS
Glyphosate	-0.1541	1.6790	0.0080	NS
1st spraying	-4.4487	3.1909	1.9440	NS
2nd spraying	0.6463	2.4113	0.0720	NS
3rd spraying	-3.6185	1.4081	6.6030	0.0120
Harvest	-0.4189	0.3968	1.1140	NS
Threshing	-0.3736	2.2482	0.0280	NS
Transport	-0.5507	0.5227	1.1100	NS
Price per tone	4.0713	0.1633	621.7920	0.0000

Multiple regression analysis (Anon., 2011) was used to determine if individual variable cost and income components had an effect on the gross margin (Table 5). The cost of ploughing, machine planting, hand-weeding once and the third spraying all had a significant negative effect on

gross margin. Therefore the farmers should concentrate on reducing these costs to improve profitability.

Grain yields ranged from 900 to 8,333 kg/ha with an average of 4,130 kg/ha. The regression of gross margin on maize yield shows that, on average, for every extra tonne of yield the gross margin increased by USD 130. The price received for maize varied between USD 70 and USD 250 per tonne with an average of USD 172 per tonne.

93% of farmers used herbicides and 68% of these were satisfied with this method because their fields were mostly large and they had insufficient labour for hand-weeding. 87% of herbicide users reported good herbicide efficacy and quick action, 11% reported ineffective control, and 3% were concerned that herbicide application could have negative effects on soil and human health. There were three main reasons that led farmers to apply herbicide: less costly than hand-weeding; convenience and fast action; and labour shortage.

CONCLUSION

This study documented trends in practices for weed management in Pailin Province Cambodia. The main drivers for change appear to have been the cost and availability of hand labour. This has led to mechanization of land preparation, and sowing and to the replacement of in-crop hand weeding with selective herbicides.

Although the current herbicide-based system for maize is working well, it is not likely to be sustainable without crop rotations and use of a wider range of herbicides. Maize crops in Pailin are being invaded by *Sorghum bicolor* (Shattercane) and *S. halepense* (Johnson grass) that are not controlled by atrazine. Rotation of crops and herbicides will be necessary to prevent a build up of naturally resistant weeds and development of genetic herbicide resistance.

ACKNOWLEDGEMENTS

We would like to acknowledge the Australian Centre for International Agricultural Research (ACIAR) for funding this research.

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Research article

Impacts of an Agricultural Water Use Restructuring Project on the Water Quality of Oxbow Lake

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Abstract Oxbow lakes in the Ishikari River Basin, Japan, are used as irrigation water sources, flood control ponds, and waterside parks, etc. In this study, we monitored water quality over the course of the restructuring project at Lake Chashinainuma. In this catchment area, irrigation water was pumped from the lake until 2010, but is now drawn from a distant river. As a result, the total nitrogen load balance changed from an outflow type to a storage type due to decreased removal of water from the lake. The lake water retention time also increased significantly. However, total nitrogen concentration decreased after the pumping station was abolished. We suggest that this reduction in total nitrogen concentration after 2011 reflected decreased particulate nitrogen due to biological purification effects that are expected with increased chlorophyll concentration. Hence, the change in load balance to an accumulation type may have been influenced by changes in agricultural water management and transformation of paddy fields into upland.

Keywords water quality paddy field, load balance, agricultural land improvement project

INTRODUCTION

Oxbow lakes are remnants of meandering floodplain rivers that have been cut off and physically isolated from their respective main river channels (Cullum et al., 2006). There are many oxbow lakes in the Ishikari River basin, and both naturally and artificially formed lakes are used as irrigation water sources, flood control ponds, and waterside parks. Hence, they are recognized as regional resources with multiple functions (Yamamoto et al., 2001). Many oxbow lakes are closed type waterways in which eutrophication occurs easily. Because oxbow lakes originate from rivers, much drainage water flows into them, and their water quality is strongly influenced by human activities, including agriculture in the catchment area. Yamamoto et al. (2002, 2004) studied the effects of nutrient inflow from an agricultural area in Hokkaido on the water quality of an oxbow lake.

Currently, land improvement projects, including land partition, enlargement, and rearrangement, creation of multipurpose paddy fields, and restructuring of irrigation and drainage facilities are ongoing in the Lake Chashinainuma watershed in Bibai, Hokkaido. These projects incur changes of land use and water management, and hence, influence water quality and the hydrological environment. However, few studies have examined the relationship between human activities, including land improvement projects, and water quality of oxbow lakes.

OBJECTIVE

This study object is to determine the impacts of the water use restructuring project on the physical and chemical water properties of the oxbow lake "Chashinainuma" in terms of; (1) Changes of nitrogen concentration in the lake and drainage water, (2) Impact of pumping station on water balance and water quality in the lake and (3) Evaluation of water balance and total nitrogen load

balance of the lake.

And this investigation contributes to the evaluation of changes in water quality following land improvement projects.

METHODOLOGY

This survey was performed at Lake Chashinainuma between 2007 and 2012. Lake Chashinainuma is located in the middle stream of the Ishikari river Basin. It has a water surface area of 13.1 ha and an average depth of 1.02 m. The size of the catchment area changed from 106 to 127 ha with the improvement project (Table 1, Fig.1), and the land is mainly used as farmland. In this watershed, irrigation water was pumped up from the lake until 2010, when the pumping station was abolished, and is now drawn from a distant river via open channels and pipelines. In addition, a new drain (D4) was constructed and the land use and crops were changed each year of the project. There are four direct drainage and inflow points from the farmland. In the restricting area, the drainage water from the fields cannot flow directly into the lake. The pressure-controlled tank for pipeline irrigation (T) and the surplus water from this tank drain into the lake via the D3 water management facility.

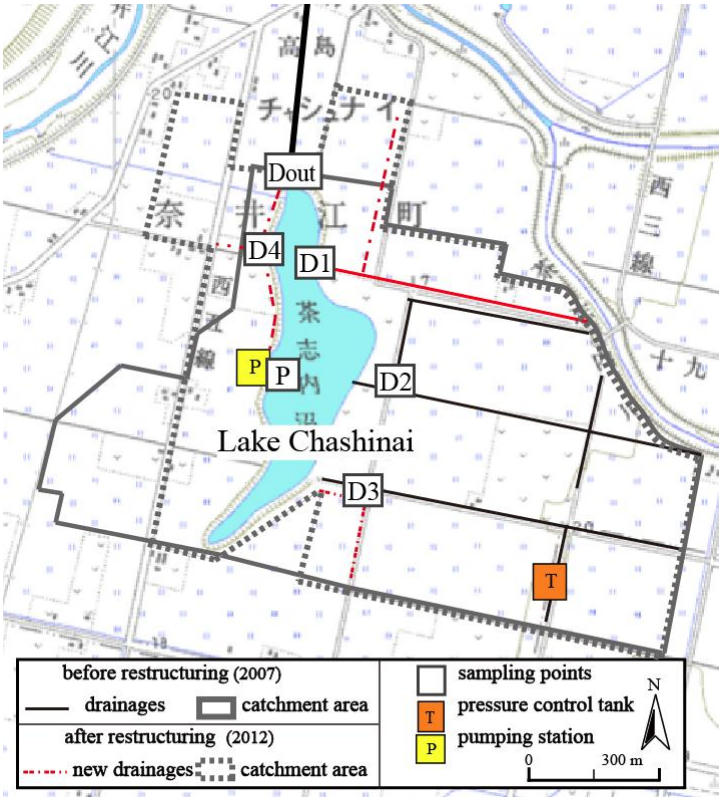

Fig. 1 Outline figure of catchment area and sampling points

To measure water quality, water was drawn from outflow drainage and inflow drainage sampling points in the lake. Water sampling was conducted about two times per month during irrigation periods, and once per month during non-irrigation periods from April 2007 to August 2012. Water sampling was performed two times a day during the paddling period (May) and once per day during normal irrigation periods (June–August) using an automatic water sampler (ISCO Inc.) from 2009 to 2012. Total nitrogen (TN), dissolved total nitrogen (DTN), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), and ammonium nitrogen (NH_4-N) contents were determined. These analyses conformed to Japanese Industrial Standards (JIS). Dissolved inorganic nitrogen (DIN) was calculated as the sum of NO_3-N, NO_2-N, and NH_4-N. Total organic nitrogen (TON) was

estimated by subtraction of DIN from TN. Particulate organic nitrogen (PON) was estimated by subtraction of DTN from TN. Dissolved organic nitrogen (DON) was calculated as the difference between DTN and DIN.

Table 1 Changes of land use and projects in the investigated area

Year		2007	2008	2009	2010	2011	2012
Catchment area (ha)		112	112	112	112	106	127
Crop type (ha)	Paddy	64	N.D.*	42	45	24	60
	Upland crop	42	N.D.*	59	60	71	67
Water body	2009; Water supply changes in a part of D1 catchment area						
Plantation	2011; Pumping station stopped and land arrangement in D4 catchment area						
Upland paddy	2012; Land arrangements in parts of D1 and D3 catchment area						

* *Crop type investigation was not carried out in 2008 because it was considered same in 2007.*

Precipitation data were used in the Automated Meteorological Data Acquisition System (AMeDAS) at Bibai and Iwamizawa cities. Evapotranspiration was calculated according to Penman's method.

RESULTS AND DISCUSSION

Changes of water quality in the lake

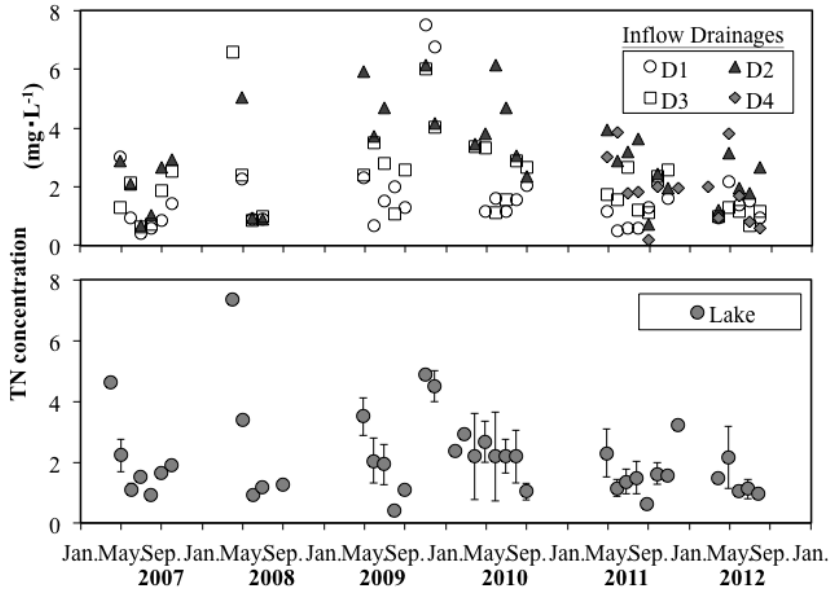

Fig. 2 Changes in TN concentration in the lake and its drains

Figure 2 shows monthly changes in TN concentration in the drains (D1–D4) and in the lake. When more than three samples were taken in a month, data are presented as the mean ± standard deviation. The concentration of TN in the lake changed periodically, with high values during April and May, low values during the normal irrigation period, and a concentration rise again in the winter. This trend was reflected in samples from the drains. Compared with D1 and D3, the concentration of TN in D2 was markedly increased. In the D2 catchment area, paddy fields are prevalent in the downstream and influence the water quality easily. Accordingly, the concentrations of TN in samples from D4 were high during the paddling period.

Figure 3 shows the changes in concentration of each nitrogen form in lake water. TN is comprised mainly of TON and NO_3-N. Concentrations of TN exceeded those allowed by the Japanese agricultural water use standard and environmental standard for environmental

conservation (≤1.00 mgL^{-1}) for most of the study period. Comparison of TN concentrations before and after the pumping station was abolished show that TN concentrations decreased. Figure 3 shows that this is reflected by decreased TON concentrations. Changes in NO_3-N concentration could not be confirmed.

During the years 2011 and 2012, approximately 70% of TON (40% of TN) was composed of PON, indicating a significant influence of PON on TN concentrations in this lake.

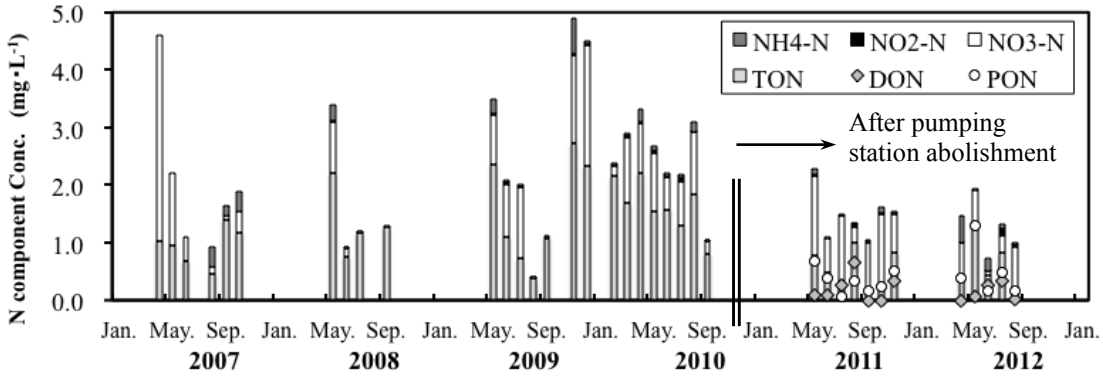

Fig. 3 Changes in nitrogen component of the lake water

Changes of water balance and total nitrogen balance during irrigation periods

Water balance during irrigation periods was calculated using the relation expression (Equation 1). The inflow discharge in 2011 decreased compared with levels seen in 2009 and 2010 (Fig. 4) due to advance of the pipeline and consequent decreases in paddy field area. Prior to 2010, approximately 40% of the lake water was left via the pumping station, thus abolishment of the pumping station caused significant changes in water balance during 2011. In addition, the transformation from paddy fields to cultivated area was accompanied by decreased inflow and outflow, and the retention time of the lake water increased from 3.37 day in 2009 to 5.98 day in 2011.

$$\Delta h = Q_{in} - Q_{out} + R - E \pm G + S - P \quad (1)$$

Δh, change in storage discharge; Q_{in}, discharge of inflow into the lake; Q_{out}, discharge from the lake outlet; R, precipitation; E, evapotranspiration; S, surplus water from pressure control tank; G, groundwater balance; P, discharge of intake water by pumpstation.

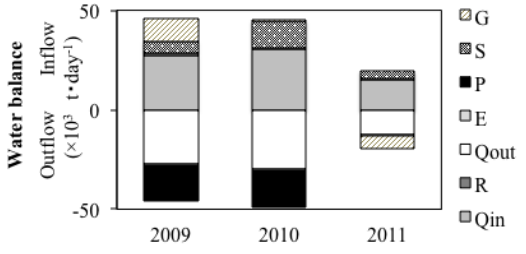

Fig. 4 Water balance of the lake

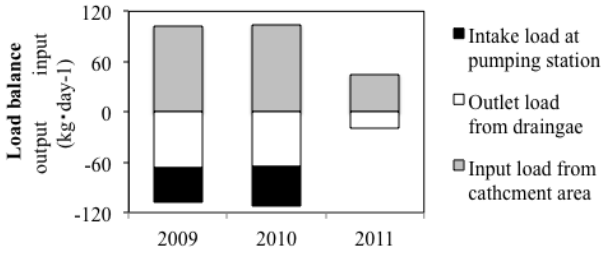

Fig. 5 Nitrogen Load balance in the lake

Total nitrogen balance during the irrigation periods of 2009–2011 was calculated from water balance and concentration. The concentration of TN in the lake water was used to calculate that of the intake water for the pumping station, and changes in nitrification and outflow through the ground were considered constant. The difference between input and output loads was approximately 110 kg day^{-1} and did not differ with that in 2009 and 2010. TN load balance during

irrigation periods changed from an outflow type to a storage type due to decreased removal by pumping (Fig. 5), suggesting that TN may accumulate in the future.

Changes in water quality factors under the agricultural water use restriction project

We predicted that decreased water removal after the pumping station was abolished would cause increased TN concentrations in the lake water. Though removal of water by pumping tends to take pollution from the lake, total nitrogen concentrations fell in 2010. Thus, changed inflow volume appears to be the main factor that influenced water quality in the lake. Although inflow water volume and load decreased after 2011, TN retention in the lake increased. Therefore, another process in the lake may also affect changes in water quality.

Consistent with the phenomena observed in Lake Chashinainuma, a study of Lake Kasumigaura confirmed that increasing retention time caused load removal from the lake (Nakamura and Amano, 2007). We suggest that extension of retention time may cause (1) sedimentation of particulate matter, (2) nitrogen fixation by phytoplankton or aquatic plants, and (3) organic matter decomposition due to microbes. Moreover, drawdown of the water level in the lake during the irrigation period was confirmed after 2011, and expansion of the habitation area for emerging plants was observed. On the other hand, increasing retention time may advance the organic decomposing effect, thereby increasing DIN by decomposing DON or organic matter in bottom sediments. However, exuberant reed growth was seen in 2011 and 2012 on the northern part of the lake and may have lowered concentrations of dissolved water items by absorbing DTN.

CONCLUSION

The results indicate that the water inflow volume from the catchment area decreased after the project, and the TN load balance of the lake changed to storage type despite decreased input load at Lake Chashinainuma. This decreasing of water inflow volume could be caused by changes of land use. The pumping station abolishment and the changing of water balance could affect the change of TN load balance. Interestingly, the concentration of TN in the lake water decreased after the project, largely due to fixation of TON. This decrease in TN concentration is attributed to physical biological phenomenon that stem from changes in the hydrological environment and crop types.

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Research article

Behavioural Factor of Boiling Drinking Water in Rural India

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Abstract In India, 0.4 million children die from diarrhoea which is a particularly alarming figure. There are several kinds of water sources in rural India, but most of them are contaminated. Boiling is an effective way to purify water and improve its safety for drinking. The objective of this study was to reveal the behavioural factor of boiling. A village near Sompeta city in Andhra Pradesh, India was selected as a survey site of this study. On-site surveys were conducted from 14th to 29th April and from 23rd September to 5th October in 2012. The surveys consisted of a water quality test of boiling and interviews with all 53 households that had a child of 3 or 4 years old. The contents of water quality test were coliforms, iron and total hardness, and the interview questions were about habits and thoughts relating to boiling. The effect of boiling, the reduction of infection risks, could be observed by the test. However, the evaluation of the taste of boiled-water was worse than non-boiled-water, even though iron could be removed. Thirty-two per cent households always use boiled-water and 15% use it only in rainy season. The main reason for boiling was to prevent infections. They knew boiling is an effective way to reduce the risk of infection and thus use boiled-water daily. On the other hand, 42% households use boiled-water only when they get sick and 11% of households do not use it. The reason for not boiling was not the cost and trouble but a lack of awareness of the necessity for it. In this area, doctors had given advice to boil water for the sake of children's health. Some households followed the advice and used boiled-water; however, there were a number of households that did not follow the advice and still used water without boiling.

Keywords drinking water, boiling, diarrhoea, child health, India

INTRODUCTION

About 1.5 million children aged five and below die from diarrhoea every year. This is the second cause of death in children (WHO, 2008). The most seriously affected country is India, in which about 0.39 million children die from diarrhoea (UNICEF and WHO, 2009). Pathogens which cause diarrhoea 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 relatively reduce the risk of diarrhoea (Fewtrell et al., 2005). In order to prevent children's death from diarrhoea, 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, and many kinds of activities were conducted all over the world.

Now 84% people have sustainable access to safe water in rural India (WHO and UNICEF, 2010) but it is not always safe and many people do not use it because of wrong recognition about the safety of the water source and bad taste (Sato and Yamaji, 2012). Furthermore, there is a high possibility that water is not safe at the point of use, even if the water source is safe (Wright et al., 2004). Household water treatment and safe storage (HWTS), including boiling, chlorinating, and

filtering water at home, can be effective to improve the quality of drinking water and prevent diarrhoea (Fewtrell et al., 2005). Boiling is the most common method of treating water at home and the effect is evident in India (Clasen et al., 2008), but a number of households do not boil water for drinking purposes. There are some studies concerning the promotion of boiling behaviour, for example, promotion through school (Freeman and Clasen, 2010) and women's self-help groups (Freeman et al., 2012), but the behavioural factor of boiling drinking water is not made explicit.

OBJECTIVE

The objective of this study was to reveal the behavioural factor of boiling drinking water, that is, the reason why a number of people don't boil it, in rural India. In order to discuss the most feasible method there, the effect of boiling at the site was presented first. Subsequently, the behavioural factor was examined.

METHODOLOGY

A village near Sompeta, in the city of Srikakulam district in Andhra Pradesh state, India was selected as the survey site of this study (Fig. 1). People in this village use three kinds of drinking water sources: (i) temple well that it is in the temple and has been used for a long time; (ii) bore well, of which there were 11 in this village and they were built by the state government about 10 years ago; and (iii) private well that was built in a house lot, of which the number are increasing. About 80% of households do not have a toilet thus surface water and ground water of unconfined aquifer are contaminated.

On-site surveys were conducted from 14th to 29th April 2012 and from 23rd September to 5th October in 2012. The survey consisted of a water quality test of boiling and an interview survey in households. All 53 households in this village that had a child of 3 or 4 years old were interviewed about their way of thinking regarding boiling. The boiling test was conducted on the temple well, a bore well in an elementary school, and a private well, by using a pot and gas stove in a household's kitchen. One litre of water was put into the pot and heated on the gas stove. Water was taken to measure water quality four times: before heating; 0 minutes after start of boiling; 5 minutes after start of boiling; and 10 minutes after start of boiling. The contents of the measurement were coliforms, Fe (iron) and TH (total hardness). The Sun Chemical Co. Ltd. detection paper was used for coliforms, and the Kyoritsu Chemical-Check Lab. Corp. test kit was used for Fe and TH.

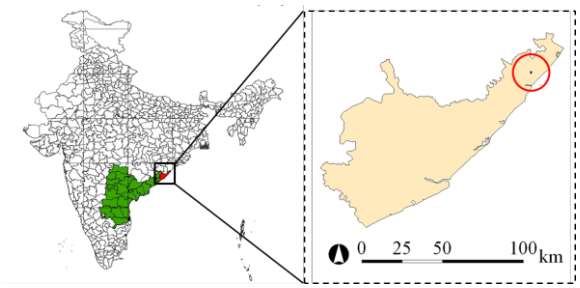

Fig. 1 Survey site

RESULTS AND DISCUSSION

Boiling habit for child is showed in Fig. 2. Thirty-two per cent of households always used boiled water for their child and 15% of households only used boiled water in rainy season. They use boiled water before the child becomes sick to prevent disease. On the other hand, 42% households used boiled water to relieve disease only when the child becomes sick. Furthermore, 11% of households never boiled water for their child.

The results of the boiling test for density of coliforms are shown in Fig. 3. According to the WHO's guidelines for drinking water quality, coliforms should not be detected in 1mL of sampled

water. Water from all sources had coliforms before boiling and this means all sources contained risks of diarrhoea. In particular, the temple well and private well had more coliforms as their depth is shallower than the bore well. However, water from all sources contained no coliforms after 10 minutes of boiling. Coliforms were killed by boiling therefore it can reduce risk of diarrhoea.

Table 1 shows the numbers and ratios for the frequencies of infection with cholera and typhoid that were added up by households' boiling habit. The households that did not have a habit of boiling water for their child before becoming sick tended to be infected with cholera and typhoid more often than the households that regularly boiled water. These results also suggest that boiling can reduce the risk of diarrhoea.

Figure 4 shows the results of the boiling test for the density of Fe, and Fig. 5 shows the same results for TH. A bore well with an iron pipe often makes the Fe density of its water high and makes its taste worse. According to the WHO's guidelines on drinking water quality, there is a reference value about Fe from a viewpoint of taste and colouring, though not from a viewpoint of safety. It specifies that the density of Fe should be under 0.3 mg/L. After boiling, Fe cannot be detected: the density was 0mg/mL. At that time, there was some white powder at the bottom of the pot which may have contained Fe. Boiling makes it possible to remove Fe from water. TH was often used as an indicator to check the taste of water, but it is not specified in the WHO's guidelines because the preference toward it depends on the person and region. TH tended to decrease by boiling, as Fig. 5 indicates.

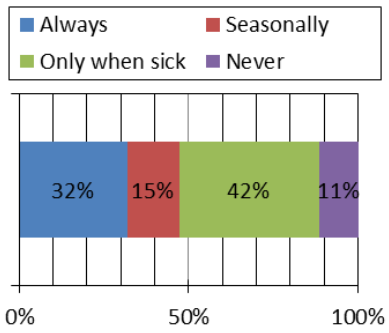

Fig. 2 Boiling habit for child

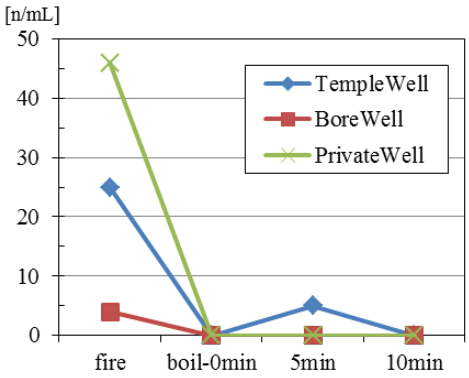

Fig. 3 Results of boiling test for coliforms

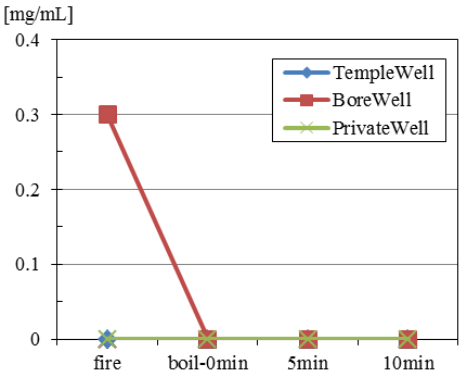

Fig. 4 Results of boiling test for Fe

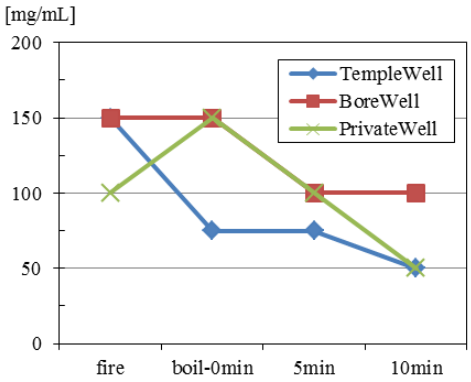

Fig. 5 Results of boiling test for TH

Table 1 Frequency of infection with Cholera and Typhoid by households' boiling habits

	Always / Seasonnally				Only when sick / Never				Total			
	Cholera		Typhoid		Cholera		Typhoid		Cholera		Typhoid	
Occasionally	1	4%	1	4%	3	13%	2	8%	4	9%	3	6%
Once	0	0%	4	16%	1	4%	8	33%	1	2%	12	24%
Never	23	96%	20	80%	19	83%	14	58%	42	89%	34	69%
I don't know	1	-	0	-	5	-	4	-	6	-	4	-
Total	25		25		28		28		53		53	100%

Each household evaluated which water was tastier: before boiling or after boiling. Table 2 presents the results that were added by households' boiling habits. Most of the households evaluated that water that was not boiled did not taste better than boiled water, regardless of the habit of boiling. Table 3 shows the results of the evaluation of the taste of boiled water. Households with a daily boiling habit tended to set a high value on the taste of boiled water compared to those without this habit. The taste of water may improve after boiling because Fe can be removed by boiling, but people's evaluations did not correspond with this. During the survey, some households said that boiled water was not tasty because it is warm. This suggested the possibility that boiling makes water taste worse by raising the water temperature. Indeed, most of households in this area do not have a refrigerator thus it is difficult for them to have cold water at home.

Table 4 shows the numbers and ratios of the reasons for not boiling that were added by households' boiling habits. Some households without a boiling habit answered "Bad Taste" as the reason. But according to this information alone, it is not clear why the mothers were not willing to give boiled water to their child, despite the fact that boiling water is safer. Two households answered "Cost" as the reason for not boiling. During the survey, they said that they want to boil but they do not have enough money for it. Figure 6 is a boxplot about household income that was added by boiling habits. The exchange rate was Rs 1 equals about USD 0.02 on 14th Dec 2012. The average income of all households was Rs 23,000. The households with high income tended to have a habit of boiling. However, the number of households with boiling habits that have a smaller income than the median income of households without boiling habits was not a few. It is possible for households with a small income to boil water daily. Boiling habit may also depend on whether they have a gas stove or not because it is related to income, costs, and labour. In this village, 62% of households had a gas stove for cooking and 38% did not have a gas stove. Figure 7 illustrates a comparison of boiling habits between households with gas stove and those without. There were small differences between them therefore the ownership of a gas stove does not have a significant effect. According to Table 4, all households that boil water in rainy season alone think boiling is not needed except in this season, and most of households that boil water only when their child is sick think that it is unnecessary to boil water before sickness occurs. The main cause of not boiling water for their child is a lack of awareness of its importance and necessity.

Table 2 Preference taste of water between before boiling and after boiling

	Always		Seasonally		Only when sick		Never		Total	
Before	14	82%	8	100%	19	90%	4	100%	45	90%
After	3	18%	0	0%	2	10%	0	0%	5	10%
No answer	0	-	0	-	1	-	2	-	3	-
Total	17		8		22		6		53	100%

Table 3 Evaluation about the taste of boiled water

	Always		Seasonally		Only when sick		Never		Total	
Very Good	0	0%	0	0%	2	9%	0	0%	2	4%
Good	8	47%	3	38%	4	18%	0	0%	15	29%
Not Bad	5	29%	1	13%	6	27%	1	20%	13	25%
Bad	4	24%	4	50%	10	45%	4	80%	22	42%
No answer	0	-	0	-	0	-	1	-	1	-
Total	17		8		22		6		53	100%

Table 4 Reason for not boiling water

	Seasonally		Only when sick		Never		Total	
Bad taste	0	0%	0	0%	3	75%	3	14%
Cost money	0	0%	2	13%	0	0%	2	9%
No need	8	100%	14	88%	1	25%	17	77%
No answer	0	-	6	-	2	-	14	-
Total	8	100%	22	100%	6	100%	36	100%

Table 5 shows the numbers and ratios of the reason for boiling that were added by households' boiling habits. Most of the households with a habit to boil water always or seasonally answered "Prevention from disease" as the reason. On the other hand, half of the households that boil water only when their child is sick answered "Relieve disease," while the remaining half answered "Doctor's advice" as the reason. They boil water only for the treatment of disease, not for the prevention.

Each household evaluated which water is safer, before boiling or after boiling. Table 6 shows the results that were added by households' boiling habits. The option of "No answer" was not shown as all households answered this question. All of the households with a boiling habit who stated that they boil water for the prevention from disease evaluated that boiled water is safer than non-boiled water. On the other hand, some of the households without daily boiling habits evaluated that non-boiled water is safer than boiled water. Furthermore, 23% of households that boil water only when the child is sick follow the doctor's advice and boil water for the treatment of disease in spite of the fact that they think non-boiled water is safer than boiled water.

Numbers and ratios of households that have been advised by a doctor to boil water were added by households' boiling habits, as shown in Table 7. Almost all households have been advised by a doctor; however there were still households without a boiling habit, regardless of the fact that they were advised by a doctor to do it. Doctors can influence people to enhance their awareness of child health, but not all people.

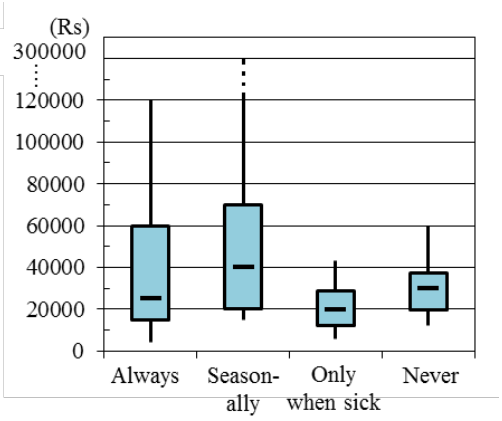

Fig. 6 Household income by boiling habit

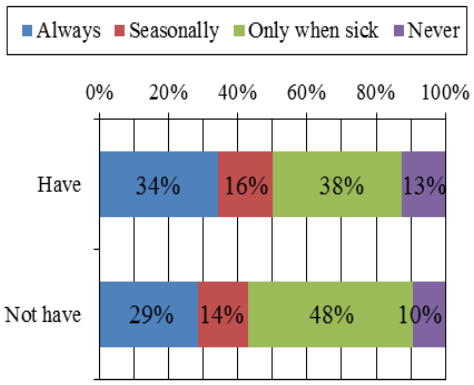

Fig. 7 Comparison of boiling habit between households with gas stove and without it

Table 5 Reason for boiling water

	Always		Seasonally		Only when sick		Total	
Prevention from disease	15	100%	6	86%	0	0%	21	55%
Relieve disease	0	0%	0	0%	8	50%	8	21%
Doctor's advise	0	0%	0	0%	8	50%	8	21%
Warm body	0	0%	1	14%	0	0%	1	3%
No answer	2	-	1	-	6	-	9	-
Total	17	100%	8	100%	22	100%	47	100%

Table 6 Comparative evaluation of the water safety between before boiling and after boiling

	Always		Seasonally		Only when sick		Never		Total	
Before	0	0%	0	0%	5	23%	2	33%	7	13%
After	17	100%	8	100%	17	77%	4	67%	46	87%

Table 7 Numbers and ratios of households that have been advised by a doctor to boil water

	Always		Seasonally		Only when sick		Never		Total	
Yes	17	100%	8	100%	21	95%	6	100%	52	98%
No	0	0%	0	0%	1	5%	0	0%	1	2%

CONCLUSION

The effect of boiling water was observed and people's behavioural factor of boiling was examined in rural India. The risk of diarrhoea could be reduced by boiling. Water from a bore well with an iron pipe has a high level of iron which worsened its taste; however boiling could remove it. Nevertheless, evaluation of its taste was not good because the water temperature may increase after boiling. The main reason for boiling was the prevention of infection. Households with boiling habits knew that boiling was an effective way to reduce the risk of infection and consequently boiled water for their child daily. On the other hand, the reason for not boiling was not the cost and trouble, but a lack of awareness of necessity for it. This lack of awareness made difference in people's boiling behaviour.

In this survey site, doctors had advised mothers not to use water without boiling. Some households followed it and started boiling water, but a number of households ignored it. Doctors have contacts with almost all households and thus have the opportunity to enlighten them about the correct knowledge and habit of children's health, but some households doesn't follow doctors' advice. The type of households that tend to follow doctors' advice and the ways in which doctors can enlighten all households on the necessity of boiling water should be examined after this study. Furthermore, there are other ways besides the doctor to enlighten households on the benefits of boiling water for children's health and these methods also require further investigation.

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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.

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