Research article

# Soil Types and Geographical Forms of the Degraded Uplands of Bohol, Philippines

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**Abstract** The main objective of this study was to identify the soil types and geographical forms in the degraded uplands of Bohol. This was accomplished by gathering secondary data from concerned institutions and from previous research results. Bohol is geographically located between 123°40' and 124°40' East longitude and extends from 9°30' to 10°15' North latitude, in the central portion of Visayas. It is generally flat and plain with only few mountainous areas at the northeastern portion suitable for massive cultivation of agricultural products. Some of these mountainous areas, particularly those preserved from degradation, can serve as habitat for interesting flora and fauna as well as natural land forms that travelers look for, such as the landform for which Bohol has been noted, the Chocolate Hills. The existing general land use data of Bohol has 13 categories. The top three categories in terms of area are the agricultural land, timberland and infra utilities. Agricultural land constitutes about 66.54% of the province total land area while timberland is only 24.6%. Approximately 167,160 hectares or 40.6% of the total provincial land area have slope gradients of 0-8%, largely covering the central of northern areas which comprise the prime agricultural zone utilized or irrigated and rainfed palay and corn production. The areas with 8-18% slopes accounted for 29% which is mostly planted with coconut, corn and subsistence crops and open/idle and eroded land areas. The rolling to mountain areas with slopes of 18% and above cover about 123,930 hectares or 30% of Bohol land area. Areas with slopes of 18% and above have been disturbed and exploited particularly for subsistence farming. Soil types of the degraded uplands of Bohol are of different soil classification. The most extensive soil type is Ubay clay which occurs from the central (Carmen and Sierra Bullones) to the north and northeastern (San Miguel to Alicia) and northwestern areas of Bohol. Faraon clay predominates at the southern municipalities of Lila, Dimiao, Valencia and Garcia Hernandez.

**Keywords** soil types, degraded uplands, rainfed palay, subsistence farming

## INTRODUCTION

Bohol is an island province in Central Philippines. With a land area of 4,821 square kilometers (1,861 sq mi) and a coastline 261 kilometres (162 mi) long, Bohol is the tenth largest island of the Philippines.

The terrain of Bohol is basically rolling and hilly, and about half the island is covered in limestone. Near the outer areas of the island are low mountain ranges. The interior is a large plateau with irregular landforms. Chocolate Hills are more than 1,200 uniformly cone-shaped limestone hills named for the grass growing on the hills that turns brown in the summer, making the landscape look like chocolate mounds.

Bohol is geographically located between 123°40' and 124°40' East longitude and extends from 9°30' to 10°15' North latitude, in the central portion of Visayas. It is generally flat and plain with only few mountainous areas at the northeastern portion suitable for massive cultivation of agricultural products. The slopes of these mountainous areas have good potential for commercial/urban and even

industrial site development because of their natural drainage capacity. Some of these mountainous areas, particularly those preserved from degradation, can serve as habitat for interesting flora and fauna as well as natural land forms that travelers look for, such as the landform for which Bohol has been noted, the Chocolate Hills, (Bohol Provincial Agriculture Profile, 2011). Cramb (2000) as cited by Newby and Cramb said that land degradation in densely-populated upland areas represents major environmental threats. (Newby and Cramb, 2007)

This study was done to identify the soil types and geographical forms in the degraded uplands of Bohol province through secondary data.

## METHODOLOGY

The island province of Bohol is the tenth largest island in the country. Geographically, it lies between 123 40' and 124 40' East longitude and extends from 9 30' to 10 15' North latitude This oval shaped province is located in the central portion of the Visayas lying between Cebu to the northwest and Leyte to the northeast. It has a land area of 4,821 square kilometres (1,861 sq mi) and a coastline 261 kilometres (162 mi) long (OIDCI, 2006).

Collection of data was mainly done through the access of secondary sources available in a particular government agency like the Office of the Provincial Agriculturist of Bohol, the Local Government Units and the Department of Agriculture of the national government of the Philippines. The researcher has also collaborated with the Agricultural Training Institute through the conduct of Focus Group Discussion with the upland farmers to validate the information on soil types and geographic forms in their respective areas.

The degraded agricultural upland sites being observed by the researcher include the farm communities of Carmen which is an interior municipality and central part of Bohol and the degraded upland farms of Mayana, Jagna and Taytay, Duero in the eastern part of the province.

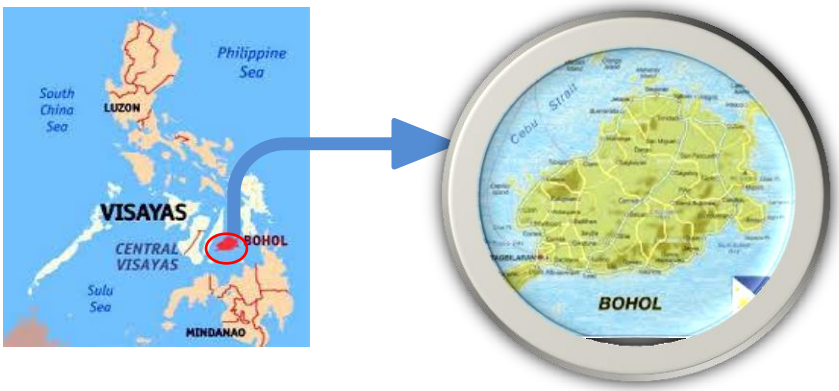


**Fig. 1 The study site: Bohol, Central Philippines**

## RESULTS AND DISCUSSION

### Geologic Features

As manifested in the project preview of an Australian Center for International Agricultural Research (ACIAR) funded project, within the agricultural province of Bohol, 45% of the island is designated as agricultural land and supports 80% of the island's population. However, nearly two thirds of the agricultural land has a slope of greater than 18% and receives more than two metres of rainfall per year. In a previous ACIAR project, it was concluded that activities that have the highest adverse impact on

agricultural sustainability (and therefore long term economic sustainability) in the upper Inabanga (the largest watershed on Bohol), included: up and down cultivation on sloping lands, continuous use of nutrient-depleting crops such as corn and cassava, and extensive cultivation of steep upland soils (ACIAR, Bohol).

Bohol may have been developed from the magnetic tectonic mechanism which resulted from the under thrusting of the southwest Philippine Plates east of Samar Island and Surigao in Northern Mindanao. The Mines and Geosciences Bureau of the Department of Environment and Natural Resources showed eleven (11) major geologic formations in the Bohol mainland and offshore islands. The most extensive are Carmen formation, Maribojoc and Wahig limestones, Ubay volcanic and Kabulao conglomerates (OIDCI, 2006).

**Fig. 2 The degraded uplands of the central part of Bohol**

**Physiography**

Bohol's mainland exhibits the following salient physiographic units. The east and west coast display northeast trending ranging up to 870 meters in elevation (Mt. Mayana) that drops steeply to the coast. These ranges reflect the major structural units of the island. The central (Carmen area) and northern part of the island (Trinidad) are vast expanses of relatively rolling plains and flat lands.

The development of beautifully-arranged, symmetrically formed "haycock hills" in Carmen-Batuan and Bilar - Balilihan area in the east central part of the island is suggestive of well-defined system of shears and joints. An elongated cluster of hills of moderate height lies in the northeastern part of the island (Ubay area).

An east-west ridge connects Alicia with Carmen

The Anda Peninsula and Loon Peninsula strongly suggest elevated plateaus, and

At least five different Plio-pleistocene terrace levels ranging in height from 10 to 300 meters have been etched both in Carmen sandstone and shales and Maribojoc limestones.

**Fig. 3 The severely degraded upland farms of Bohol**

## Soil Types

The Bureau of Soils and Water management –Land Resources Evaluation Project (BSW-LREP) identified 22 soil types within province. Of these soil typologies, the most extensive is Ubay clay occurring from the central (Carmen and Sierra Bullones) to the north and northeastern (San Miguel to Alicia) and northwestern areas. Faraon clay predominates at the southern municipalities of Lila, Dimiao, Valencia and Garcia Hernandez. The other soil types with relatively larger area coverage include the Batuan - Faraon complex, Ubay clay loam, Sevilla clay and Annam clay.

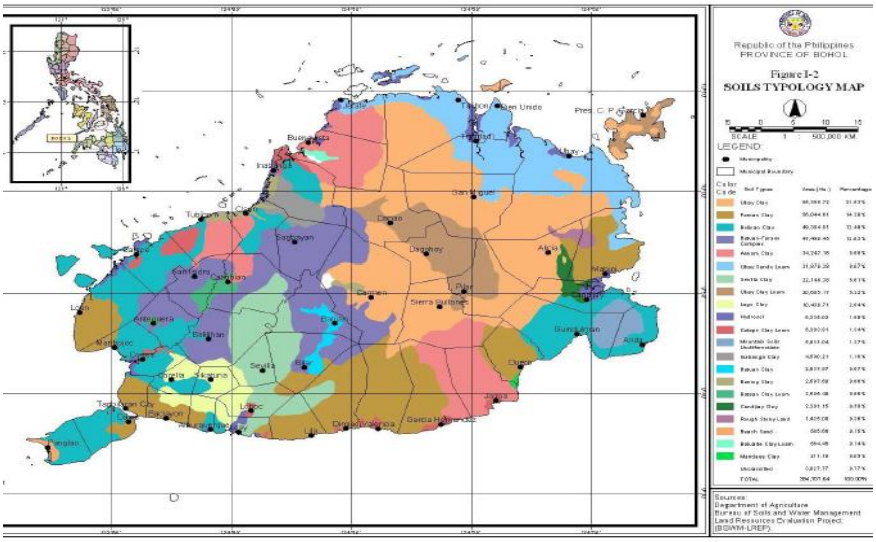


**Fig. 4 Map of soil types of Bohol**

**Fig. 5 Farmed steep slopes are common sites in the uplands of Bohol**

## CONCLUSION

Bohol is a limestone province with rolling and hilly terrain and has mountain ranges near the outer areas. The interior part is a large plateau with irregular landforms with the very distinct haycock formation called Chocolate Hills. The province has twenty two (22) soil types with Ubay clay occurring from the central to the northern part and Faraon clay predominates the southern part of the province.

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Research article

# Influence of Dissolved Organic Carbon on the Ecotoxicology of Copper on Aquatic Biota: Implication for the Revision of Water Quality Standardization in Cambodia

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**Abstract** The Mekong River is one of the world's greatest river systems and sustains human life and ecosystems. The livelihoods of 60 million people who live along the Lower Mekong Basin (LMB) rely on both the economic resource and the ecological health of the river. In this study, US EPA method was used for the acute toxicity with different water dissolved organic carbon (DOC) of Mekong River in Cambodia on *Chironomus javanus* and fish Nile tilapia (*O. niloticus*) to modify the effecting of DOC on copper toxicity. Both *C. javanus* and Nile tilapia were significantly less sensitive to copper in water high DOC (5.74 mg/L DOC), compared to water low DOC (1.12 mg/L DOC) exposures. The effect of DOC, as humic acid source on the acute toxicity of copper (Cu) to *C. javanus* and Nile tilapia also was investigated. The mortalities for both species increase with increasing copper concentration, but $LC_{50}$ value decreased as more toxic on Nile tilapia and *C. javanus*. This gave an order of toxicity of copper in water with low DOC > water with high DOC at the end point of $LC_{50}$. DOC might provide protection against Cu toxicity in the freshwater in term of completive between copper form and DOC. The result of the $LC_{50}$ with 95% confidence limit obtained at 48 hr in tap water on *Moina macrocopa*, *C. javanus*, Grass Carp (*Ctenopharyngodon idella*) and Nile tilapia were 12 µg/L, 16399 µg/L, 118 µg/L and 1383 µg/L, respectively. This gave an order of toxicity of copper in tap water with *M. macrocopa*> Grass Carp > Nile tilapia> *C. javanus*. Also, it could be noted that Moina was the most sensitive followed by Grass Carp, Nile tilapia, and *C. javanus* to copper. Present study indicated that water chemistry parameters can influence on copper toxicity to tropical freshwaters biota. Exposures in this series of laboratory experiment will provides a worst-case scenario and useful for determine the risk assessment of copper on Mekong tropical freshwater animals.

**Keywords** copper, water quality, aquatic biota

## INTRODUCTION

The livelihoods of 60 million people who live along the Lower Mekong Basin (LMB) rely on both the economic resource and the ecological health of the river MRC (2015). However, the development activities during the past decade and currently, including mining, industries, agriculture, deforestation and household wastes, have caused of extensive soil erosion and contributed increasingly to transfer of environmental levels of heavy metals especially copper (Cu) into the Mekong River (Ti and Facon, 2004; Coates et al., 2006).

Copper (Cu) is known as the important that all living organisms require its small amounts (5-20 µg/g) to survive Solomon (2009). However, too much Cu concentration more than (20 µg/g) will become toxic Wright and Welbourn (2002) and Bradl (2005)**.** Cu has been documented as one of the most toxic metals to aquatic organism and ecosystem (Bradl, 2005; Carreau and Pyle, 2005; Scudder et al., 1988). Impacts of Cu on an aquatic atmosphere are complex and depend on the physicochemical characteristics of water as mentioned by Kamunde and MacPhail (2011) and Nadella et al. (2009). Therefore, the acute toxicity of Cu to fish, invertebrates and other aquatic organisms are influenced by water quality parameters such as hardness, alkalinity, pH and dissolved organic carbon (DOC) (Linbo et al. 2009; Santore et al., 2001; U.S.EPA, 2002). And the most effective parameter for reducing of Cu toxicity to fish is DOC (Linbo et al., 2009). According to Liu and Sheu (2003) and U.S.EPA (2002) DOC is a vital water quality parameter and it is also a primary food source in the aquatic food web which supports growth of microorganisms and Complex to the metal form.

Many research papers were designed and conducted on ecotoxicology of Cu worldwide, but most of them focused on temperate aquatic species. The information on the impact of toxicity effects of soluble copper on the tropical aquatic biota is limited. So the ecotoxicology of Cu on aquatic biota with Mekong River Cambodia compared with dosed distilled and tap water will be a good representative for tropical aquatic species. In the present study, the ecotoxicology of copper on aquatic biota under different water DOC were investigated in order to help and protect the Mekong River in the future and for implication for the revision of water quality standardization in Cambodia.

## OBJECTIVE

The objective of the study is focus on ecotoxicology of copper on aquatic biota under different water dissolved organic carbon.

## METHODOLOGY

**Water sampling:** In this study, water samples were collected at two sites in Cambodia's Mekong River, which focus on different water dissolved organic carbon. The site 1 is located in Stung Treng at 13°30'52.50"N/105°55'54.00"E, next to the Lao PDR border. The site 2 is located in the Kampong Cham at 11°59'18.77"N/105°28'10.26"E, next to the Vietnam border.

**Test organisms:** The native organisms used in the present study were Moina (*Moina macrocopa*), *Chironomus javanus*, Grass Carp (*Ctenopharyngodon idella*) and Nile tilapia (*Oreochromis niloticus*). These species were provided by the Department of Fisheries, Khon Kaen, Thailand and have been cultured in at ecotoxicology laboratory of Khon Kaen University, Thailand.

**Chemical and test procedure:** The standard stock solution (100 mg/L) for studied metals was freshly prepared by dissolving of copper sulfate $CuSO_4$ $5H_2O$. The test organisms were subjected to different concentrations of the stock copper solution in each container. The control was kept in experimental water without adding copper.

**Preparation of the standard DOC:** The concentration DOC was augmented using a commercially available humic acid (Aldrich Humic acid (AHA), Sigma-Aldrich, st, Louis, MO, USA). DOC test water were then diluted to the final concentrations (1 and 5 mg/L DOC) to which the animal were exposed**.**

**DOC analysis:** The dissolved organic carbon concentration in each sample of the filtered (0.45 µm) exposure water was determined by using a Shimadzu total organic carbon analyzer (model 5050A; Mandel Scientific, Guelph, ON, Canada). The total organic carbon in each sample was calculated automatically by subtracting inorganic carbon from total carbon.

**Toxicity test:** Acute copper toxicity experiments were performed for a 4-d period (96h) using small fishes at 5 days old, the second instar larva of *Chironomus javanus* and for a 2-day period for Moina

(*Moina macrocopa*) at < 1 day old. The number of dead organisms were counted every 24 hours and removed from aquarium as soon as possible. During the toxicity test, organisms were not fed. The experimental were performed at room temperature of 25±1C°, with a Photoperiod of 16h light: 18h darkness. All control result in lower mortality, less than 10% which revealed the acceptability of the test (U.S.EPA, 2002).

**Statistical analysis**: Toxicological dose-response data involving quintal response (mortality) following toxicity of copper on the test species were determined by used of Probit Analysis LC50 Determination Method (SPSS, version 19 software). The rate response determined at the end of the 96-h for Grass Carp (*Ctenopharyngodon idella*) and Nile tilapia (*Oreochromis niloticus*), and 48-h for Moina (*Moina macrocopa*) and Chironomids (*Chironomidus javanus*). Significance in 95% confidence interval (95% CI) of detect 48 and 96 hour LC50 value were determined using the Chi-Square technique (Ezeonyejiaku et al., 2011).

## RESULTS AND DISCUSSION

**Water quality:** The water quality parameters measured during the test at site 1 and site 2 were pH 7.77 ± 0.02 and 7.83±0.00, Conductivity 191± 1.53 and 192.33±1.03 µS/cm, TDS 45±005 and 50±0.89 mg/L, dissolve oxygen 10.46±0.05 and 8.23±0.04 mg/L, and total hardness ($mg^{2+}$ and $Ca^{2+}$) 88±4 and 112±4 mg/L as CaCO3, respectively. The mean value of other water quality parameters such as DOC, BOD and alkalinity were 5.74±0.08 and 1.12±0.26 mg/L, 541.86±7.39 and 542.86±7.39 mg/L, 1.33±0.20 and 0.4±0.17 mg/L and 118.66±4.61and 113.33±2.30 mg/L, respectively. And a summary of measured heavy metal data for all experiments (e.g., Cu, Zn, Mn, Fe, Pb, Cd, Cr, Mg and Ca) were shown in (Table 1).

**Table 1 Physical- chemical composition of Mekong River in Cambodia**

| Physical-chemical variable (units) | Site1 | Site2 |
|---|---|---|
| pH | 7.83±0.00 | 7.77±0.01 |
| Temperature (C°) | 27.4±0.26 | 27.38±0.25 |
| DO (mg/L) | 8.23±0.04 | 10.46±0.05 |
| EC (µS/cm) | 192.33±1.03 | 191.66±1.12 |
| TDS (mg/L) | 50±0.89 | 45.66±0.81 |
| Alkalinity (mg/L as $CaCO_3$ ) | 113.33±2.30 | 118.66±4.61 |
| Hardness (mg/L as $CaCO_3$) | 112±4 | 98.66±8.32 |
| BOD (mg/L) | 0.4±0.17 | 1.33±0.20 |
| DOC (mg/L) | 1.12±0.26 | 5.74±0.08 |
| Cu (µg/L) | 0.005±4.98 | 0.005±3.38 |
| Zn (µg/L) | 0.003±4.72 | 0.002±0.14 |
| Mn (µg/L) | 0.004±0.13 | 0.007±0.28 |
| Fe (µg/L) | 0.033±0.14 | 0.022±0.38 |
| Pb (µg/L) | 0.005±5.60 | 0.002±2.85 |
| Cd (µg/L) | 0.0002±2.24 | 0.0009±0.11 |
| Cr (µg/L) | 0.019±1.40 | 0.017±0.74 |
| Mg (µg/L) | >5* | >5* |
| Ca (µg/L) | >5* | >5* |

**: The limitation of analytic is not determined we need to make more dilution, Mean (±SE), n=3*

### The Effluence of DOC of Mekong River on Copper Sensitivity

A strong relationship between DOC concentration and copper toxicity showed in (Table 2). Both Nile tilapia and Chironomid were significantly less sensitive to copper at water high (5.74 mg/L DOC), compared to water low (1.12 mg/L DOC) water exposures. The protective effect of increasing water dissolved organic carbon against metal toxicity of copper has been reported in a wide range of aquatic

life and thus many water quality regulation are adjusted for water DOC USEPA (1996, 2002). DOC were found to provide significant protection from acute copper exposure as the $LC_{50}$ at water (5.74 mg/L DOC) was more than two-fold higher than (1.12 mg/L DOC) of fish Nile tilapia; and more than one-fold at water (5.74 mg/L DOC) was higher than (1.12 mg/L DOC) of Chironomid. Although there has been limited study into the effect of exposure water DOC on copper toxicity in Nile tilapia and Chironomid, Gillis et al. (2008) studied the acute toxicity test of copper to glochidia (larvae) of freshwater mussel under different water hardness and dissolved organic carbon reported that the addition of DOC (as Aldrich Humic Acid) 1.6 mg/L with the soft water was the result of decrease in Cu sensitive as ten- fold increase in $EC_{50}$ of E. triquetra. In addition, it is interesting to note that the copper toxicity was affected by the DOC. The outcomes of the present study come in agreement with the out finding of Mclntyre et al. (2008) who reported that DOC levels of 1-6 mg/L were found to partially restore olfactory capacity in salmon that were exposed to copper.

**Table 2 $LC_{50}$ with 95 percent confidence interval of copper on Chironomid (*Chironomus javanus*) and Nile tilapia (*Oreochromis niloticus*) of two different DOC of Mekong River**

| Species | DOC (mg/L) | $LC_{50}$ with 95% Cl (µg/L) | | | |
|---|---|---|---|---|---|
| | | 24h | 48h | 72h | 96h |
| Nile tilapia | 5.74 | 1228 (1138-1340) | 1052 (890-1296) | 939 (771-1185) | 742 (562-981) |
| | 1.12 | 1236 (1128-1371) | 806 (494-1334) | 561 (129-1177) | 397 (123-761) |
| Chironomid | 5.74 | 8237 (5471-32105) | 5033 (3035-88359) | 2206 (-) | 853 (-) |
| | 1.12 | 2864 (-) | 2443 (-) | 983 (-) | 707 (-) |

*CL= Confidence limit, $LC_{50=}$ Median lethal concentrations, (-) = 95% Confidence limit (lower-upper value) exposure at 96 hours*

## The Effluence of DOC from Humic Acid Source on Copper Sensitivity

DOC provided by the addition of Humic Acid alone to test waters significantly decrease copper toxicity to Both Chironomid and Nile tilapia. The mortalities for both species increased with increasing copper concentration, and the $LC_{50}$ values decreased indicating more toxicity on Nile tilapia and Chironomid. This gave an order of toxicity of copper in water with low DOC > water with high DOC at the 96hr $LC_{50}$. DOC appears to provide protection against Cu toxicity in the freshwater by completing between free copper and DOC.

## Acute Toxicity with Tap Water

The $LC_{50}$ 48 hrs values for copper were 12 µg/L in Moina, 16399 µg/L in Chironomid, 294 µg/L in Grass Carp and 1869 µg/L in Nile tilapia, respectively (table 3). This gave an order of toxicity of copper in tap water with Moina > Grass Carp > Nile tilapia > Chironomid. The outcomes of the present study came in agreement with those of Mastin and Rodgers Jr (2000) who reported that *D. magna* was the most sensitive of nontarget animals tested for all the tree copper herbicides. In similar toxicity experiments that exposed a heterogeneous assemblage of test organisms to copper, cladocerans (e.g., Ceriodaphnia and Daphnia) were the most sensitive species Schubauer-Berigan et al. (1993) and Dobbs et al. (1994). According to Pokethitiyook et al. (1987) reported that the mean value 24, and 48 hr $LC_{50}$ for copper in *Moina macrocopa* with water pH 29 were 19 µg/L and 17 µg/L, respectively. However, these reports were higher than the present study, suggesting the different in methodologies. The mean value 24, and 48 hr $LC_{50}$ for $CuSO_4$ $5H_2O$ in *C. javanus* were 24127 and 16399 µg/L, respectively. Hence, the acute test of 48 and 24 hr showed an opposite relationship between $LC_{50}$ and exposure time,

increase in the concentration reduces the time to kill 50% of *C. javanus*. Previous studies, the 48 hr $LC_{50}$ for $CuSO_4$ was 1073 µg/L in *C. ramousus* third instar larvae Majumdar and Gupta (2012). Other outcomes Mastin and Rodgers Jr (2000) reported that 48 hr $LC_{50}$ of midge larvae *C. tentans* exposed to Clearigate and Cutrine-Plus were 373.5 and 460.9 µg/L, These values were considerably lower than responding value in *C. javanus*, indicating higher vulnerability to Cu.

**Table 3 $LC_{50}$ with 95 % confidence interval of copper to Moina (*Moina macrocopa*) ,Chironomid (*Chironomus javanus*), Grass Carp (*Ctenopharyngodon idella*) and Nile tilapia (*Oreochromis niloticus*) of tap water**

| Species | Test time | $LC_{50}$ with 95% Cl (µg/L) |
|---|---|---|
| Moina *(Moina macrocopa)* | 24hr | 46 (33-68) |
| | 48hr | 12 ( - ) |
| Chironomid *(Chironomus javanus)* | 24hr | 24127 (13264-36397) |
| | 48hr | 16399 ( - ) |
| Grass Carp *(Ctenopharyngodon ldella)* | 24hr | 330 (293-373) |
| | 48hr | 294 (238-353) |
| | 72hr | 232 (180-293) |
| | 96hr | 188 (126-275) |
| Nile tilapia (*Orecochromis nileticus*) | 24hr | 2388 (2261-2592) |
| | 48hr | 1869 (1157-5235) |
| | 72hr | 1740 ( - ) |
| | 96hr | 1383 (859-2718) |

*CL= Confidence limit, $LC_{50=}$ Median lethal concentrations, (-) = 95% Confidence limit (lower-upper value) at exposure time*

## CONCLUSION

DOC appears to provide protection against Cu toxicity in the freshwater by complexing between free Cu and DOC. The present study indicated that water chemistry parameters can influence Cu toxicity to tropical freshwater biota. Exposure of the test species to this series of laboratory experiments has provided useful data for determine the risk of Cu in Mekong river water compared with dosed distilled and tap water, and for implication for the revision of water quality standardization in Cambodia.

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Research article

# Influence of Water Hardness on Ecotoxicology of Copper on Aquatic Biota: Implication for the Revision of Water Quality Standardization in Lao PDR.

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**Abstract** The ecotoxicology of copper on freshwater organisms were studied using field-collected water from two local sites along Lower Mekong Basin in Lao PDR, which focused on different water hardness 20±2.83 and 108±0.00 mg $L^{-1}$ as $CaCO_3$ (water in rainy season), 105±3.35 and 140±4.00 mg $L^{-1}$ as $CaCO_3$ (water in dry season) and distilled water was reconstituted by adding reagent-grade chemicals which reconstituted water hardness 18±3.58 and 86±4.56 mg $L^{-1}$ as $CaCO_3$. In this study, the US EPA method was used for the acute toxicity test to juvenile *Cyprinidae (Labeo rohita)* and *Moina macrocopa* at different water hardness. Mortalities were at 24, 48, 72 and 96 hr for *L. rohita* and 48 hr for *M. macrocopa*. At water hardness of 20±2.83 mg $L^{-1}$ as $CaCO_3$, the percentage mortality of *L. rohita* was 100% at 96 hr by Cu 0.13 mg $L^{-1}$. The mortality was 100% at 96 hr of water hardness 108±0.00 mg/L as $CaCO_3$ at Cu 0.37 mg $L^{-1}$. There was a 3-fold increase in water hardness (from 20±2.83 and 108±0.00 mg $L^{-1}$ as $CaCO_3$) and Cu was highly significantly toxic to *L. rohita*. The percentage mortality of *L. rohita* was 100% at 96 hr by Cu 0.37 mg $L^{-1}$, on 105±3.35 and 140±4.00 mg $L^{-1}$ as $CaCO_3$, and both were highly significant difference ($P < 0.001$). A 8-fold increase in water hardness (from 105±3.35 and 140±4.00 mg/L as $CaCO_3$) and Cu was significantlytoxic to *L. rohita*. At 20±2.83 mg $L^{-1}$ as $CaCO_3$ hardness, the percentage mortality of *M. macrocopa* of 100% was very highly significant at 48 hr by Cu 0.07 mg $L^{-1}$, while percentage mortality was 100% at 48 hr of water hardness 108±0.00 mg $L^{-1}$ as $CaCO_3$ at Cu 0.13 mg $L^{-1}$, the difference was highly significant as well. A 3-fold increase in water hardness (from 20±2.83 to 108±0.00 mg $L^{-1}$ as $CaCO_3$) had significant toxic effect of Cu to *M. macrocopa* with overlapping 95% confidence intervals of $LC_{50}$ values. The percentage mortality of *M. macrocopa* of 100% at 48 hr by Cu 0.13 mg $L^{-1}$, on water hardness of 105±3.35 and 140±4.00 m $L^{-1}$ as $CaCO_3$, were both highly significant. A 2-fold increase in water hardness (from 105±3.35 and 140±4.00 mg $L^{-1}$ as $CaCO_3$) did not significantly ($P > 0.05$) have toxic effect of Cu to *M. macrocopa.* The effects of Cu on organisms depend on water hardness, i.e., increasing water hardness reduce the toxic effect of Cu on aquatic organism.

**Keywords** Water hardness, aquatic biota, copper

## INTRODUCTION

The Mekong Basin supports about 60 million people, most of whom depend directly on the natural resource for their livelihood (MRC, 2010; Snidvongs & Teng, 2006). Moreover, activities that discharge heavy metals directly or indirectly into natural water systems with little or no treatment may cause serious environmental effects. Heavy metals are widely used in industries and are common water pollutants; thus knowledge of their toxicity to aquatic organisms are significance (Rathore & Khangarot, 2003).

Cu is a significance trace element to organisms, its often found in industrial wastewaters which become extremely toxic for aquatic animals as their concentration in water increase. The hardness of water is a major factor which influences the toxic effects of Cu to aquatic organisms because increase in water hardness can decrease Cu toxicity due to competition between metal ions and $Ca^{2+}$ and $Mg^{2+}$ ions for uptake sites of organisms (Gary, 1996; Yim, Kim, & Kim, 2006).

The levels of Cu and its distribution in natural water bodies in Lower Mekong Basin are not well known. Recent investigations suggest that background levels may be higher than expected. However, data on heavy metal toxicity in Laos is limited. Therefore, research on the ecotoxicology of Cu on freshwater biota of Mekong River in Laos is important.

## METHODOLOGY

The study sites were 2 locations at 2 different seasons (rainy and dry seasons) along Lower Mekong Basin in Lao PDR with focus on different water hardness; Vientiane (17°58´1.18´´N/ 102°35´1.66´´E), a city of around 692,900 inhabitants with a density of 176 people $km^{-1}$ (Phonvisai, Coowanitwong, Shapkota, Pradhan, & Hossain, 2006). Vientiane discharges its municipal sewage into ThatLuang wetland that discharges into the Mekong River downstream of the city. The other site is Pakxan District (18°22´23.29´´N /103°39´43.85´´E. The sources of pollution in this site include domestic, industrial waste, agricultural runoff and mining activities. Those sites were chosen due to their proximity and are with activities that potentially contribute to pollution of the Mekong River (Table 1).

**Table 1 Sampling sites based on different water hardness along the Mekong River parts in Laos (n=3)**

| Location and Date | | Water hardness ($mg\ L^{-1}$ as $CaCO_3$) | Latitude (N) and Longitude (E) |
|---|---|---|---|
| Rainy season | Pakxan District (13 July,2014) | 20±2.83 | (17°58'1.18"N/ 102°35'1.66"E) |
| Rainy season | Vientiane Capital City (12 July,2014) | 108±0.00 | (18°22'23.29"N/ 103°39'43.85"E). |
| Dry season | Pakxan District (22 March,2015) | 105±3.35 | (17°58'1.18"N/ 102°35'1.66"E) |
| Dry season | Vientiane Capital City (21 March, 2015) | 140±4.00 | (18°22'23.29"N/ 103°39'43.85"E). |

**Table 2 Distilled water reconstituted by adding reagent-grade chemicals to make its characteristics similar to that of the Mekong River water (n=3)**

| Water quality parameters | Reconstituted water hardness | |
|---|---|---|
| | Soft water | Moderate hardness |
| pH | 7.06±0.1 | 7.73±0.1 |
| EC ($\mu s\ cm^{-1}$) | 36±0.0 | 347±0.0 |
| TDS ($mg\ L^{-1}$) | 18±0.0 | 173±0.0 |
| DO ($mg\ L^{-1}$) | 6.97±1.6 | 8.66±0.9 |
| Hardness ($mg\ L^{-1}$ as $CaCO_3$ ) | 18±3.58 | 86±4.56 |
| Alkalinity ($mg\ L^{-1}$ as $CaCO_3$) | 14±2.2 | 86±3.6 |

Distilled water was reconstituted to make it similar water hardness to Mekong River water by adding $NaHCO_3$, $CaSO_4 \cdot 2H_2O$, $MgSO_4$, KCI that following a USEPA procedure to give reconstituted water hardness as $CaCO_3$ for 18±3.58 $mg\ L^{-1}$ and 86±4.56 $mg\ L^{-1}$ (Table 2).

## Statistical Analysis

Acute toxicity dose-response data, involving quintal response mortality following toxicity of copper on the test species; Cyprinidae *(Labeo rohita)* and *Moina macrocopa* were determined by using of PROBIT Analysis $LC_{50}$ Determination Method (SPSS Statistics Version 20 software). Mortality response of organisms were recorded when the animals sank to bottom of the containers and become motionless. The toxicity response determined at the end of the 96 hr for *L. rohita* and 48 hr for *M. macrocopa*. Significance in 95% confidence interval (95% CI) of detect 48 and 96 hr LC50 value were determined using Chi-Square technique.

## RESULTS AND DISCUSSION

### Acute Toxicity of Copper on Local Freshwater Organisms; Cypronidae - *Labeo rohita* and *Moina Macrocopa* under Different Water Hardness of Mekong River in Lao PDR during Rainy Season in 2014

Acute toxicity of Cu to juvenile fish Cyprinidae *(Labeo rohita)* during rainy season with water hardness 20±2.8 mg $L^{-1}$ as $CaCO_3$ was similar to that reported by (Perschbacher & Wurts, 1999) in his study on *Channel Catfish* where they reported 100% mortality in treatments containing magnesium-based 20 and 400 mg $L^{-1}$ as $CaCO_3$. These results demonstrate the sensitivity of the organism to Cu concentrations. However, the present study found that at water hardness of 20±2.8 mg $L^{-1}$ as $CaCO_3$, the mortality of *L. rohita* was 100% at 96 hr with Cu concentration of 0.13 mg $L^{-1}$ (CV < 20%), indicating very high significant difference. A similar result was obtained at 108±0.0 mg $L^{-1}$ as $CaCO_3$ at Cu concentration of 0.37 mg $L^{-1}$. . Comparative $LC_{50}$ at water hardness 20±2.8 and 108±0.0 mg $L^{-1}$ as $CaCO_3$ resulted to a significant 3-fold increase in the toxicity of Cu to *L. rohita* (Table 3).

**Table 3 Acute toxicity endpoints ($LC_{50}$) calculated for juvenile fish Cyprinidae (*Labeo rohita)* exposed to Cu (mg $L^{-1}$) into rainy season based on different water hardnesses (20±2.8 and 108±0.0 mg/L as $CaCO_3$)**

| Rainy season | | | | Rainy season | | | |
|---|---|---|---|---|---|---|---|
| $LC_{50}$ (mg/L) 95% Confidence Limits for conc. | | | | $LC_{50}$ (mg/L) 95% Confidence Limits for conc. | | | |
| Hour | 20±2.8 (mg/L as $CaCO_3$) | | | Hour | 108±0.0 (mg/L as $CaCO_3$) | | |
| | Estimate | Lower | Upper | | Estimate | Lower | Upper |
| 24 | 0.083 | 0.069 | 0.106 | 24 | 0.271 | – | – |
| 48 | 0.065 | 0.06 | 0.071 | 48 | 0.157 | – | – |
| 72 | 0.055 | 0.045 | 0.069 | 72 | 0.129 | – | – |
| 96 | 0.038* | 0.021 | 0.077 | 96 | 0.106* | – | – |

*Note: * = significant at 5% level*

Cu effects to different water hardness 20±2.8 mg $L^{-1}$ as $CaCO_3$, the percentage mortality of *Moina macrocopa* was 100% at 48 hr by Cu concentration 0.07 mg $L^{-1}$, indicating test acceptability highly significant difference, while percentage mortality was 100% at 48 hr of water hardness 108±0.0 mg $L^{-1}$ as $CaCO_3$ at Cu concentration 0.13 mg $L^{-1}$, that has highly significant difference as well, a 3-fold increase in water hardness (from 20±2.8 to 108±0.0 mg $L^{-1}$ as $CaCO_3$) was significantly different toxicity effect of Cu to *Moina macrocopa* that overlapping 95% confidence intervals of $LC_{50}$ values (Table 4).

**Table 4 Acute toxicity endpoints ($LC_{50}$) calculated for *Moina macrocopa* exposed to Cu (mg/L) into rainy season based on different water hardnesses (20±2.8 and 108±0.0 mg/L as $CaCO_3$)**

| Rainy season | | | | Rainy season | | | |
|---|---|---|---|---|---|---|---|
| $LC_{50}$ (mg/L) 95% Confidence Limits for conc. | | | | $LC_{50}$ (mg/L) 95% Confidence Limits for conc. | | | |
| Hour | 20±2.8 (mg/L as $CaCO_3$) | | | Hour | 108±0.0 (mg/L as $CaCO_3$) | | |
| | Estimate | Lower | Upper | | Estimate | Lower | Upper |
| 24 | 0.011 | - | - | 24 | 0.023 | 0.011 | 0.044 |
| 48 | 0.004* | 0.002 | 0.008 | 48 | 0.012* | 0.009 | 0.015 |

*Note: * = significant at 5% level*

**Acute Toxicity of Copper on Local Freshwater Organisms; Cyprinidae - *Labeo rohita* and *Moina macrocopa* under Different Water Hardness of Mekong River in Lao PDR during Dry Season in 2015**

Cu was toxic to Cyprinidae *(Labeo rohita)* during dry season with water hardnesses as $CaCO_3$ 105±3.34 mg $L^{-1}$ and 140±4.0 mg $L^{-1}$. Cu toxicity decreases with increasing hardness. Pourkhabbaz et al, (2011) found that *Gambusia holbrooki* is sensitive to Cu toxicity in soft, more than hard water. A 12-fold increase in water hardness (25 to 350 mg $L^{-1}$ as $CaCO_3$) substantially reduced the toxicity of Cu (up to 38-fold). In the present study, $LC_{50}$ for juvenile fish Cyprinidae *(Labeo rohita)* was 0.092 (0-0.048) mg $L^{-1}$ at water hardness of 105±3.4 mg $L^{-1}$ as $CaCO_3$, compared to $LC_{50}$ value 0.155 (0.113-0.188) mg $L^{-1}$ at water hardness of 140±4.0 mg $L^{-1}$ as $CaCO_3$. This is a 2-fold significant increase in toxicity on juvenile fish Cyprinidae *(L. rohita)* (Table 5).

**Table 5 Acute toxicity endpoints ($LC_{50}$) for juvenile fish Cyprinidae *(Labeo rohita)* exposed to Cu (mg/L) during the dry season based on different water hardness (105±3.4 and 140±4.0 mg $L^{-1}$ as $CaCO_3$)**

| Dry season | | | | Dry season | | | |
|---|---|---|---|---|---|---|---|
| $LC_{50}$ (mg $L^{-1}$) 95% Confidence Limits for conc. | | | | $LC_{50}$ (mg $L^{-1}$) 95% Confidence Limits for conc. | | | |
| Hour | 105±3.4 (mg $L^{-1}$ as $CaCO_3$) | | | Hour | 140±4.0 (mg $L^{-1}$ as $CaCO_3$) | | |
| | Estimate | Lower | Upper | | Estimate | Lower | Upper |
| 24 | 0.145 | 0.072 | 0.449 | 24 | 0.248 | 0.226 | 0.273 |
| 48 | 0.123 | 0 | 0.063 | 48 | 0.176 | 0.145 | 0.204 |
| 72 | 0.107 | 0 | 0.049 | 72 | 0.161 | 0.126 | 0.19 |
| 96 | 0.092* | 0 | 0.048 | 96 | 0.155* | 0.113 | 0.188 |

*Note: * = significant at 5% level*

**Table 6 Acute toxicity endpoints ($LC_{50}$) calculated for *Moina macrocopa* exposed to Cu (mg $L^{-1}$) into dry season based at different water hardness (105±3.4 and 140±4.0 mg $L^{-1}$ as $CaCO_3$)**

| Dry season | | | | Dry season | | | |
|---|---|---|---|---|---|---|---|
| $LC_{50}$ (mg $L^{-1}$) 95% Confidence Limits for conc. | | | | $LC_{50}$ (mg $L^{-1}$) 95% Confidence Limits for conc. | | | |
| Hour | 105±3.4 (mg $L^{-1}$ as $CaCO_3$) | | | Hour | 140±4.0 (mg $L^{-1}$ as $CaCO_3$) | | |
| | Estimate | Lower | Upper | | Estimate | Lower | Upper |
| 24 | 0.055 | 0.031 | 0.121 | 24 | 0.143 | 0.063 | 5.711 |
| 48 | 0.01* | 0.005 | 0.016 | 48 | 0.023* | 0.003 | 0.062 |

*Note: * = significant at 5% level*

The percentage mortality of *Moina macrocopa* was 100% at 48 hr at Cu concentration 0.13 mg $L^{-1}$, on 105±3.4 and 140±4.0 mg $L^{-1}$ as $CaCO_3$ hardness. A 2-fold increase in water hardnesses as $CaCO_3$ (from 105±3.4 and 140±4.0 mg/L) did not significantly *(P > 0.05*) affect Cu toxicity to *Moina macrocopa* (Table 6).

**Acute Toxicity of Copper on Local Freshwater Organisms; Cyprinidae *(Labeo rohita)* and *Moina macrocopa* on Distilled water with Different Water Hardness**

The effects of water hardness as $CaCO_3$ at 18±3.6 mg $L^{-1}$ and 86±4.6 mg $L^{-1}$ on acute toxicity of Cu to on juvenile fish Cyprinidae *(Labeo rohita)* at water hardness 18±3.6 mg $L^{-1}$ as $CaCO_3$ was similar to that reported by Olaifa et al, (2004) who worked on juvenile *C. Gariepinus* exposed to various Cu concentrations, e.g., 0.6, 0.71 and 0,70 mg $L^{-1}$ at 10.42 mg $L^{-1}$ as $CaCO_3$. Baldwin et al (2003) studied the influence of water hardness on the inhibitory effects of copper on juvenile coho salmon *(Oncorhynchus kisutch).* However, in the present study found at 18±3.6 mg $L^{-1}$ as $CaCO_3$ hardness, the percentage mortality of *L. rohita* was 100%, it was found that at 96 hr with Cu concentration of 0.02 mg $L^{-1}$, the percentage mortality was 100% at 96 hr of water hardness of 86±4.6 mg $L^{-1}$ as $CaCO_3$ at Cu concentration 0.16 mg $L^{-1}$. A 7-fold increase in water hardnesses as $CaCO_3$ 18±3.58 and 86±4.56 mg $L^{-1}$ did not significantly affect Cu toxicity on *L. rohita)* (Table 7).

**Table 7 Acute toxicity endpoints ($LC_{50}$) of juvenile fish Cyprinidae *(Labeo rohita)* exposed to Cu (mg $L^{-1}$) into distilled water hardness (18±3.6 and 86±4.6 mg $L^{-1}$ as $CaCO_3$)**

| Soft hardness | | | | Moderately water hardness | | | |
|---|---|---|---|---|---|---|---|
| $LC_{50}$ (mg $L^{-1}$) 95% Confidence Limits for conc. | | | | $LC_{50}$ (mg $L^{-1}$) 95% Confidence Limits for conc. | | | |
| Hour | 18±3.6 (mg $L^{-1}$ as $CaCO_3$) | | | Hour | 86±4.6 (mg $L^{-1}$ as $CaCO_3$) | | |
| | Estimate | Lower | Upper | | Estimate | Lower | Upper |
| 24 | 0.013 | 0.008 | 0.087 | 24 | 0.105 | 0.042 | 0.835 |
| 48 | 0.008 | 0.006 | 0.013 | 48 | 0.067 | 0.033 | 0.121 |
| 72 | 0.006 | 0.004 | 0.008 | 72 | 0.052 | 0.028 | 0.087 |
| 96 | 0.006* | 0.004 | 0.007 | 96 | 0.042* | 0.017 | 0.083 |

*Note: * = non-significant at 5% level*

**Table 8 Acute toxicity endpoints ($LC_{50}$) for *Moina macrocopa* exposed to Cu (mg $L^{-1}$) at different water hardness (18±3.6 and 86±4.6 mg $L^{-1}$ as $CaCO_3$)**

| Soft hardness | | | | Moderately water hardness | | | |
|---|---|---|---|---|---|---|---|
| $LC_{50}$ (mg $L^{-1}$) 95% Confidence Limits for conc. | | | | $LC_{50}$ (mg $L^{-1}$) 95% Confidence Limits for conc. | | | |
| Hour | 18±3.6 (mg $L^{-1}$ as $CaCO_3$) | | | Hour | 86±4.6 (mg $L^{-1}$ as $CaCO_3$) | | |
| | Estimate | Lower | Upper | | Estimate | Lower | Upper |
| 24 | 0.000797 | 0.000521 | 0.00083 | 24 | 0.024895 | 0.004465 | 0.06329 |
| 48 | 0.000493* | 0.000087 | 0.000965 | 48 | 0.013725* | 0.004918 | 0.024119 |

*Note: * = non-significant at 5% level*

The percentage mortality of *Moina macrocopa* at was 100% at 48 hr by Cu concentration 0.04 mg $L^{-1}$ had highly significant difference *( P< 0.001)*, while percentage mortality was 100% at 48 hr of 86±4.6 mg $L^{-1}$ as $CaCO_3$ at Cu concentration 0.13 mg/L, that has highly significant difference *(P < 0.001)*, a 28-fold increase in water hardness (18±3.6 and 86±4.6 mg $L^{-1}$ as $CaCO_3$) did not significantly *(P > 0.05)* toxicity effects of Cu to *(Moina macrocopa)* that overlapping 95% confidence intervals of $LC_{50}$ values (Table 8).

## CONCLUSION

High water hardness could reduce toxic effect of copper on (indicate species tested. As a result of $LC_{50}$ with 95% confidence interval in water hardnesses as $CaCO_3$ (20±2.8 mg $L^{-1}$, 108±0.0 mg $L^{-1}$, 105±3.35 mg $L^{-1}$, and 140±4.00 mg $L^{-1}$ were 0.038 (0.021-0.077) mg $L^{-1}$, 0.106 mg $L^{-1}$, 0.092 (0-0.048) mg $L^{-1}$ and 0.155 (0.113-0.188) mg $L^{-1}$ for *L. rohita*. Moreover, *M. macrocopa* were 0.004 (0.002-0.008) mg $L^{-1}$, 0.012 (0.009-0.015) mg $L^{-1}$, 0.01 (0.005-0.016) mg $L^{-1}$ and 0.023 (0.003-0.062) mg $L^{-1}$, respectively.

Distilled water with soft hardness and moderately water hardness were reconstituted water similar as true water of Mekong River (18±3.6 and 86±4.6 mg $L^{-1}$ as $CaCO_3$), the $LC_{50}$ with 95% confidence interval of *L. rohita* were 0.006 (0.004-0.007) mg $L^{-1}$ and 0.042 (0.017-0.083) mg/L. and *M. macrocopa* were 0.000493 (0.000087-0.000965) mg $L^{-1}$ and 0.013 (0.0049-0.0241) mg $L^{-1}$.

The results of this toxicity tests for copper will contribute to ecotoxicology data to manage the aquatic environment for revise environmental quality standard in Lao PDR.

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Research article

# Comparison of the Water Footprint of Cassava and Sugarcane in Northeast, Thailand

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Received 20 December 2015 Accepted 11 July 2016 (*Corresponding Author)

**Abstract** The water footprint (WF) is an indicator of water use consists of the direct and indirect water use throughout the life cycle of crop produce and it varies on different climate and agricultural production system. This study aims to assess the water use of cassava and sugarcane cultivation in northeastern, Thailand using WF concept which is a tool for sustainable water analysis and management. The results of this study show the average the WF of cassava (345 $m^3$/ton) is more than that sugarcane (157 $m^3$/ton). At the provincial level, the WF of cassava is the most highest in Amnat Charoen (378 $m^3$/ton; green WF 44 $m^3$/ton, blue WF 233 $m^3$/ton and grey WF 101 $m^3$/ton), while Buri Ram has the lowest WF (313 $m^3$/ton; green WF 38 $m^3$/ton, blue WF 181 $m^3$/ton and grey WF 94 $m^3$/ton). For sugarcane, Amnat Charoen show the highest of WF of 167 $m^3$/ton, which consists of green WF 20 $m^3$/ton, blue WF 84 $m^3$/ton and grey WF 63 $m^3$/ton. Meanwhile, the lowest WF was 133 $m^3$/ton in Bueng Kan (green WF 16 $m^3$/ton, blue WF 64 $m^3$/ton and grey WF 54 $m^3$/ton). As a result, the different location, crop, agricultural production systems and yields have an effect on WF. Therefore, not only developing the efficiency water system to water resources sustainable but also increased crop productivity and soil fertility are certainly important for decrease the amount of water used in this region.

**Keywords** Water footprint, cassava, sugarcane, water resource, northeast Thailand

## INTRODUCTION

Cassava and sugarcane is an annual crop in tropical region and can be cultivated in almost soil type and low organic matter such as in Northeastern region, Thailand generally is sandy soil, an average rainfall 30 years is 1,447.70 mm (Meteorological Department, 2009). Cassava and sugarcane is the main cash crop in northeast region which is a total cassava and sugarcane cultivation area of 4,578,385 and 3,260,700 ha and an average yield is 14,493,229 and 36,978,370 ton, respectively (office of agricultural economics, 2012). However, high production of cassava and sugarcane depends on not only their varieties, soil texture, fertility but also water supply still needs for increasing of the production in Thailand.

Meanwhile, northeast region has a low average rainfall and long dry season. Lack of water may effect to growth and yield in this region. Sometimes rainfall is insufficient for cultivation must be supplemental irrigation, surface water and groundwater for produce high crop yield. Therefore, a

limited of water resource in Northeast region is should be seriously and carefully to water use and management.

A tool that has been used to estimate water requirement on crop production is the water footprint (WF). The concepts of the WF have been introduced by Hoekstra in 2002 which was an indicator of water used for produces the goods and service, by measured through over the full supply chain considering water use both direct and indirect including by source and polluted volumes in water. The WF consists of three component which are the green WF refer to the rainwater consumed, the blue WF refers to the volume of surface and groundwater consumed (evaporated) as a result of the production of a product and the grey WF refers to the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards (Hoektra et al., 2011). The WF concept is considered as an alternative toot to improve the water used plan and manage under the existence of a limited resource on the climate change (Hoekstra et al., 2009).

Therefore, the objective of this study was to assess WF of cassava and sugarcane cultivation in Northeast, Thailand with the findings can be used as a guideline for future water resource management for cassava cultivation in Northeast, Thailand.

## METHODOLOGY

**Table 1 Harvest Area, production and yield average on period 2003-2012 of cassava and sugarcane in Northeast, Thailand**

| Province | Cassava | | | Sugarcane | | |
|---|---|---|---|---|---|---|
| | Average harvested area (ha) | Average production (ton/year) | Average yield (ton/ha) | Average harvested area (ha) | Average production (ton/year) | Average yield (ton/ha) |
| Loei | 26,518.7 | 531,095.5 | 20.0 | 13,249.2 | 803,122.7 | 60.6 |
| Nong Bua Lum Phu | 6,866.9 | 137,659.5 | 20.0 | 7,663.4 | 479,683.7 | 62.6 |
| Udon Thani | 26,855.2 | 551,312.0 | 20.5 | 64,239.0 | 3,900,521.0 | 60.7 |
| Nong Khai | 6,753.8 | 128,970.1 | 19.1 | 1,625.3 | 99,780.8 | 61.4 |
| Bung Kan | 4,113.4 | 84,256.0 | 20.5 | 241.6 | 18,000.0 | 74.5 |
| Sakon Nakhon | 11,731.9 | 217,621.2 | 18.5 | 4,015.1 | 240,684.7 | 59.9 |
| Nakhon Phanom | 3,017.7 | 56,545.6 | 18.7 | 1,200.8 | 73,203.3 | 61.0 |
| Mukdahan | 15,920.4 | 299,082.5 | 18.8 | 14,171.1 | 908,303.3 | 64.1 |
| Yasothon | 7,639.8 | 156,861.6 | 20.5 | 1,415.8 | 90,985.6 | 64.3 |
| Amnat Charoen | 5,265.0 | 99,356.4 | 18.9 | 1,042.3 | 66,145.6 | 63.5 |
| Ubon Ratchathani | 19,490.5 | 380,353.9 | 19.5 | 1,819.2 | 132,560.0 | 72.9 |
| Sri Sa Ket | 11,192.7 | 222,623.2 | 19.9 | 834.4 | 55,434.3 | 66.4 |
| Surin | 7,039.1 | 128,947.5 | 18.3 | 14,679.9 | 969,175.3 | 66.0 |
| Burirum | 31,498.8 | 636,715.3 | 20.2 | 18,148.9 | 1,150,709.0 | 63.4 |
| Mahasarakham | 17,461.9 | 333,141.4 | 19.1 | 7,777.4 | 495,478.0 | 63.7 |
| Roi Et | 14,925.4 | 285,697.3 | 19.1 | 4,215.6 | 281,601.1 | 66.8 |
| Kalasin | 43,352.4 | 918,329.2 | 21.2 | 41,621.9 | 2,714,353.7 | 65.2 |
| Khon Kaen | 35,243.1 | 690,881.6 | 19.6 | 75,477.1 | 5,076,625.0 | 67.3 |
| Chaiyaphum | 59,413.8 | 1,183,106.8 | 19.9 | 56,839.9 | 3,599,376.3 | 63.3 |
| Nakhon Ratchasima | 266,674.8 | 5,437,998.3 | 20.4 | 84,747.7 | 5,232,631.7 | 61.7 |
| **Total** | **620,975.4** | **12,480,554.9** | **392.9** | **415,025.6** | **26,388,375.1** | **1,289.3** |

*Source: Office of Agricultural Economics (2012)*

**Study area and planting design:** Data collections were the data of cassava and sugarcane cultivation areas in Northeast, Thailand during 2003-2012 cover 20 provinces collected from the Office of

Agricultural Economics (Table 1). The planting time of cassava is between April through May and harvesting time is between October through November (8 months), while planting time of sugarcane is October and harvesting time is December (14 months). Climate data of past 30 years from Thai Meteorological Department and soil type from Office of Soil Survey and Land Use Planning.

**Calculation of water footprint of cassava and sugarcane:** Water footprint calculated of cassava and sugarcane cultivation use the water footprint concept following the WF assessment manual of Hoekstra et al. (2011) as showed in equation (1)

$$WF = WFgreen + WFblue + WFgrey \quad (1)$$

Green and blue water footprint can be calculated by using crop water use (CWU, $m^3$/ha) divided by cassava and sugarcane yield (Y, ton/ha) as equation (2) and (3)

$$WFgreen = \frac{CWU}{Y} \quad (2)$$

$$WFblue = \frac{CWU}{Y} \quad (3)$$

Equation (2) and (3) CWU can be calculated by accumulation of daily evapotranspiration (ET, mm/day) using the CROPWAT model as equation (4)

$$CWU = 10 \times \sum_{d=1}^{lgp} ETgreen, blue \quad (4)$$

Where the factor 10 is applied to convert the unit from mm into $m^3$/ha and lgp denotes the length of growing period in days which is .244 days for cassava and 426 days for sugarcane.

In this study, evapotranspiration (ET) can be calculated by CROPWAT 8.0 model (FAO, 2009) as following equation (5) (Hoekstra et al., 2011) which required the spatial data (latitude, longitude of Meteorological stations and elevation), climate data of each province (maximum temperature (°C), minimum temperature (°C), humidity (%), wind speed (km/day), sunshine (hours) and rainfall amount of past 30 years (2003-2009)), crop parameters (crop name, planting date, harvest, crop coefficient (Kc), crop development state, the length of growth stage, rooting depth, critical depletion and crop height) and soil characteristic (soil series, soil texture, total available soil moisture and initial soil moisture depletion).

$$ET_{green,\ blue} = Ks \times Kc \times ET_0 \quad (5)$$

Where Kc is the crop coefficient, Ks a water stress coefficient, and $ET_0$ the reference evapotranspiration (mm/day).

The grey water footprint was calculated by multiplying the chemical application rate per hectare (Appl, kg/ha) with the leaching-run-off fraction (α) divided by the maximum acceptable concentration (Cmax, kg/$m^3$) minus the natural concentration for the pollutant considered (Cnat, kg/$m^3$) and then divided by the crop yield (ton/ha) (Charoensuk et. al., 2012) as equation (5)

$$WFgrey = \frac{(\alpha \times Appl)/(Cmax - Cnat)}{Y} \quad (5)$$

The leaching-runoff fraction (α) assumed 10% of the chemical application rate (Allen et al., 1998). In this study considered only the effect of nitrogen fertilizer used. The maximum acceptable concentration for nitrate (Cmax) reference from surface water and groundwater standard value is 5 mg/litter (Pollution Control Department Thailand, 2011) and the natural concentration for the pollutant considered (Cnat) is 0 mg/litter (Mokonnen and Hoektra, 2011).

## RESULTS AND DISCUSSION

### Water Footprint of Cassava

The calculation of water footprint (WF) of cassava cultivation for 20 provinces in Northeastern Thailand showed that the average total WF was 345 $m^3$/ton consist of green, blue and grey WF were 40 $m^3$/ton, 208 $m^3$/ton and 97 $m^3$/ton, respectively (Table 2). At the provincial level, Amnat Charorn (378 $m^3$/ton) has higher WF than Mukdahan (375 $m^3$/ton), Ubon Ratchathani (375 $m^3$/ton), Roi Et (370 $m^3$/ton), SriSa Ket (369 $m^3$/ton), Mahasarakham (361 $m^3$/ton), Surin (356 $m^3$/ton), Nong Khai (350 $m^3$/ton), Yasothon (347 $m^3$/ton), Khon Kaen (346 $m^3$/ton), Sakon Nakhon (346 $m^3$/ton), Chaiyaphum (336 $m^3$/ton), Nong Bue Lum Phu (334 $m^3$/ton), Nakhon Phanom (334 $m^3$/ton), Loei (327 $m^3$/ton), Udon Thani (326 $m^3$/ton), Bung Kan (322 $m^3$/ton), Nakhon Ratchasima (320 $m^3$/ton), Kalasin (318 $m^3$/ton) and Burirum (313 $m^3$/ton) which is the lowest one.

As the result show blue WF higher than grey WF and green WF in all provinces. The highest blue WF was found in Ubon Ratchathani (235 $m^3$/ton), while the lowest one was 181 $m^3$/ton in Burirum. Grey WF, Surin is the province where the grey WF is the highest (104 $m^3$/ton), while Kalasin has the lowest grey WF (90 $m^3$/ton). Meanwhile, green WF which is the lowest WF of cassava cultivation was found Amnat Charoen has the highest green WF (44 $m^3$/ton) and lowest green WF was 37 $m^3$/ton in Kalasin. These results are consistent with Kongboon and Sampattagul (2012) which reported that the blue WF of cassava in Northern Thailand is higher than green are 232 and 129 $m^3$/ton, respectively.

**Water Footprint of Sugarcane**

As show in Table 2, sugarcane consists of green, blue and grey WF. The average total WF was 157 $m^3$/ton consist of green, blue and grey WF were 19 $m^3$/ton, 76 $m^3$/ton and 62 $m^3$/ton, respectively. At the provincial level, the WF increases in the following order: Amnat Charorn and Sakon Nakhon (167 $m^3$/ton), Yasothon and Udon Thani (165 $m^3$/ton), Mukdahan (164 $m^3$/ton), Nong Khai (163 $m^3$/ton), Nong Bue Lum Phu (161 $m^3$/ton), Loei, SriSa Ket and Mahasarakham (160 $m^3$/ton), Nakhon Phanom (159 $m^3$/ton), Roi Et (158 $m^3$/ton), Kalasin and Chaiyaphum (156 $m^3$/ton), Nakhon Ratchasima (155 $m^3$/ton), Burirum and Khon Kaen (149 $m^3$/ton), Surin (146 $m^3$/ton), Ubon Ratchathani (145 $m^3$/ton) and Bung Kan (133 $m^3$/ton).

Besides, the result show that blue WF of sugarcane cultivation was higher than gray WF and green WF in all provinces. The highest blue WF, grey WF and green WF were found in Amnat Charorn (84 $m^3$/ton), Loei and Udon Thani (66 $m^3$/ton) and Amnat Charorn, Yasothon, Loei and Sakon Nakhon (20 $m^3$/ton), respectively. Whiles, the lowest blue WF, grey WF and green WF was found in Bung kan with 64, 54 and 20 $m^3$/ton, respectively. During 2003-2012, northeast region was low the harvested yield and also the low rainfall amount makes the rainwater is not enough for water consumption. So, the irrigated water was the main water used for sugarcane cultivation and blue WF was higher than green WF and grey WF. But this study was not similarly with Kongboon and Sampattagul (2012) who study WF of sugarcane in northern, Thailand which reported that green WF of sugarcane was higher than blue WF and grey WF.

The WF of crops varies across of difference crop species, crop yields and region. The WF of cassava is larger than sugarcane by 2.2 times. So, in this region sugarcane is better than cassava which is can save more water use for sugarcane production. When compared the WF of cassava and sugarcane in northeast was lower than Thailand and global (Table 3). The green WF, which is the rainwater that evaporated during crop growth for Thailand is substantially lesser than the global average. However, in northeast region not only rainwater but also irrigated water is the main water used. This is mainly due to the differences in crop yield. The difference of topography, soil characteristic, yield, crop coefficient, cultivation period and area, evapotranspiration, and water balance are influential to the total WF (Sukumalchart et al., 2011).

**Table 2 The water footprint of cassava and sugarcane in Northeast, Thailand**

| Province | WF of cassava ($m^3$/ton/year) | | | | WF of sugarcane ($m^3$/ton/year) | | | |
|---|---|---|---|---|---|---|---|---|
| | green | blue | grey | total | green | blue | grey | total |
| Loei | 39 | 192 | 95 | 327 | 20 | 74 | 66 | 160 |
| Nong Bua Lum Phu | 39 | 201 | 95 | 334 | 19 | 78 | 64 | 161 |
| Udon Thani | 38 | 195 | 93 | 326 | 19 | 80 | 66 | 165 |
| Nong Khai | 41 | 209 | 99 | 350 | 19 | 78 | 65 | 163 |
| Bung Kan | 38 | 191 | 93 | 322 | 16 | 64 | 54 | 133 |
| Sakon Nakhon | 42 | 201 | 102 | 346 | 20 | 80 | 67 | 167 |
| Nakhon Phanom | 40 | 192 | 101 | 334 | 19 | 75 | 66 | 159 |
| Mukdahan | 43 | 231 | 101 | 375 | 19 | 83 | 62 | 164 |
| Yasothon | 41 | 214 | 93 | 347 | 20 | 83 | 62 | 165 |
| Amnat Charoen | 44 | 233 | 101 | 378 | 20 | 84 | 63 | 167 |
| Ubon Ratchathani | 43 | 235 | 97 | 375 | 17 | 73 | 55 | 145 |
| Sri Sa Ket | 42 | 231 | 96 | 369 | 19 | 80 | 60 | 160 |
| Surin | 43 | 209 | 104 | 356 | 18 | 68 | 61 | 146 |
| Burirum | 38 | 181 | 94 | 313 | 18 | 68 | 63 | 149 |
| Mahasarakham | 42 | 219 | 100 | 361 | 19 | 79 | 63 | 160 |
| Roi Et | 43 | 227 | 99 | 370 | 19 | 79 | 60 | 158 |
| Kalasin | 37 | 192 | 90 | 318 | 18 | 76 | 61 | 156 |
| Khon Kaen | 40 | 209 | 97 | 346 | 17 | 72 | 59 | 149 |
| Chaiyaphum | 39 | 201 | 95 | 336 | 18 | 74 | 63 | 156 |
| Nakhon Ratchasima | 37 | 189 | 93 | 320 | 18 | 72 | 65 | 155 |
| Average | 40 | 208 | 97 | 345 | 19 | 76 | 62 | 157 |

**Table 3 A comparisons WF of cassava and sugarcane between Northeast, Thailand and Global scale**

| Scale | Cassava WF ($m^3$/ton) | | | | Sugarcane WF ($m^3$/ton) | | | |
|---|---|---|---|---|---|---|---|---|
| | Green | Blue | Grey | Total | Green | Blue | Grey | Total |
| Global* | 550 | 0 | 13 | 564 | 139 | 57 | 13 | 210 |
| Thailand* | 192 | 232 | 85 | 509 | 90 | 87 | 25 | 202 |
| Northeast | 40 | 208 | 97 | 345 | 19 | 76 | 62 | 157 |

** Source: Mekonnen and Hoekstra, 2011*

## CONCLUSION

The water footprint of cassava and sugarcane in Northeast, Thailand for 20 provinces during 2003-2012 based on the crop yield over the full life span were 345 $m^3$/ton and 157 $m^3$/ton, respectively consists of three components: for cassava cultivation; green WF 40 $m^3$/ton, blue WF 208 $m^3$/ton and grey WF 97 $m^3$/ton. While, sugarcane cultivation; green WF 19 $m^3$/ton, blue WF 76 $m^3$/ton and grey WF 62 $m^3$/ton. In this region, blue WF higher than grey and green in both crops due to northeast region

is relatively arid and low rainfall amount which affected to low crop yield. The usage of water in both from irrigation and surface water is necessary. The results from this study can be applied to water resource management guidelines for cassava and sugarcane cultivation which related to increase the crop yield in Northeast region.

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Research article

# Variation in Storage Temperatures for Foot and Mouth Vaccine in Cambodia

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**Abstract** Vaccine efficacy may be influenced by pre-use storage condition. This study assesses vaccine cold storage management and vaccine handling practices at 30 veterinary drug stores spread across the provinces of Pursat (n=10), Kampong Cham (n=9) and Phnom Penh (n=11) in Cambodia. Electronic data loggers were used to record the temperature in each cold storage facility every thirty minutes for a period of thirty days. The findings indicated that vaccines were exposed to freeze temperature for 24-100 hrs (3%-14%) and more than 100 hrs (15%-87%) of time recordings in 8 and 9 facilities respectively. Vaccines were exposed to heat for 254-327 hrs (35%-45%) of time recordings in 3 facilities and between 468-7200 hrs (65%-100%) in 4 facilities. Most of the refrigerators also contained food and/or drinks, leading to the frequent door opening. Vaccines were often stored in the bottom drawers and door shelves, which were the warmest locations within refrigerators in the study. The vast majority of the study refrigerators (93.3%) were not equipped with a maximum-minimum thermometer. Daily refrigerator temperature recording was not practiced in any of veterinary drugstores. This study also highlighted the considerable temperature fluctuations to which vaccines were exposed to a number of refrigerators. The frequent power failures which occur in Cambodia contribute to these temperature fluctuations. This study consequently also investigated the speed and duration of temperature rise in a cold storage facility during a typical power failure in Phnom Penh. The results suggested that corrective training for vaccine wholesalers/retailers and relevant government staff may be a useful first step in attempting to improve vaccine storage conditions, hence, improved potency. Maintenance of vaccine potency is likely to improve the success of vaccination programs in Cambodia. This critical but neglected issue requires improved practices and ongoing monitoring. The results also highlight the need for improvement and solutions to avoid ongoing future exposure of vaccines to freezing, too cold and too hot temperatures, particularly in hot tropical countries like Cambodia.

**Keywords** data logger, veterinary drug store, vaccine, vaccine cold storage, Cambodia

## INTRODUCTION

Vaccination is a key control method for foot and mouth disease (FMD) in countries where the disease is endemic as is the situation in Cambodia. Immunization is a highly effective way of protecting

individuals and communities from infectious disease. However, successful vaccination campaigns require proper storage, transportation and handling of vaccines, including inactivated FMD vaccines (El-Sayed, El-Din, Rizk, & El-Aty, 2012). The FMD vaccines currently used in Cambodia are inactivated, oil adjuvant purified antigen preparations. Vaccine shelf life is always indicated by the manufacturer and is usually six to twelve months under the specified conditions of storage. Typically these include storage between 2-8 ˚C protected from light and freezing. Typically freezing the vaccine or heating the vaccine will promote emulsion breakdown and destroy vaccine integrity/efficacy over time (S. Seneque, Merial (Asia), personal communication, September 5, 2014). A study by Bell et al., (2001) revealed that failure to keep the thermometer in the vaccine storage facilities was associated with vaccine storage temperatures outside recommended range (2-8 $^{o}$C). Cortese and Smith (2004) reported freezing of vaccine will disrupt the integrity of the antigens and degrade the adjuvant and overheating can have the same effect. Incorrect handling or storage of vaccine may result in an ineffective vaccine being administered and failure of protection (Rashid, Rasheed, & Akhtar, 2009). To remain potent, FMD vaccines should be stored under refrigeration usually at 4±2 $^{o}$C for the optimal retention of antigenic potency (Garland, 1999) and should not be used if they have frozen or exposed to high temperatures or are outside the use by date (Cortese & Smith, 2004). Weir and Hatch (2004) suggested that never store vaccines on refrigerator-door shelves, where they are often exposed to warm air every time the door opens. The vaccine is thought to lose immunogenic potency progressively as the storage temperature increases above these levels. Thawing frozen vaccines or re-cooling over-heated vaccines does not restore vaccine integrity (Cortese & Smith, 2004) and damages their immunogenicity (Garland, 1999).

When an inactivated oil adjuvant FMD vaccine was stored at 4 $^{o}$C for 15 months, no appreciable vaccine potency loss could be detected by the direct challenge testing of vaccinated cattle and specific antibody assay (Doel, 2003; Garland, 1999). Recent research has confirmed that FMD vaccine may keep their potency for two years at 4 $^{o}$C, three weeks at 25$^{o}$C and one week at 37 $^{o}$C with full protection against challenge with FMDV O1/Aga/EGY/93 (El-Sayed et al., 2012). Protection was decreased to 80% when vaccines were stored at 25 $^{o}$C for 4 weeks and at 37 $^{o}$C for 2 weeks. The efficiency of the cold chain is, therefore, a critical factor for optimal vaccine storage (Garland, 1999). Farmer interviews during the 2010 FMD outbreak in Cambodia suggested very poor protection of cattle in responses to vaccination administered by government authorities in Kampong Cham province. The major reasons for this failure were thought to be poor planning, timing and implementation of the vaccination program, as well as improper vaccination technique (under-dosing) and weaknesses in the vaccine cold chain (Sieng & Kerr, 2013). The donated FMD vaccine used was reported not to have been stored at the proper temperatures recommended by the manufacturer (District veterinarians and village animal health workers, personal communication, October 30, 2010). These allegations require proper testing as temperature in vaccine cold storage facilities in Cambodia have not previously been investigated and reported. Consequently, this study represents is first attempt to measure the performance of government and commercial vaccine cold storage facilities in three regions of Cambodia.

## OBJECTIVE

In this study we aimed to investigate vaccine storage temperatures in veterinary drug stores in two Cambodian provinces and in the capital city of Phnom Penh.

## METHODOLOGY

The main study (Study 1) design involved continuous monitoring of temperatures for 30 days at 30 veterinary drugstores (VDs) spread across the provinces of Pursat (PS, n = 10), Kampong Cham (KC, n

= 9), and the capital Phnom Penh (PP, n = 11). All known eligible VDs in the 3 areas was invited to participate based on selection criteria including significant vaccine sales and willingness to participate. The study sites included predominantly vaccine retailers but also government vaccine stores of the study sites. In KC almost all vaccine stores in Prey Chhor district (3) and Kampong Cham provincial town (6) participated in the study. In PS province, six (6) VDS participated in Sampov Meas district, as well as four (4) from Bakan district. Eleven (11) stores in PP participated in the research study. A total of thirty refrigerators in 30 VDs located in 3 areas in Cambodia were thus selected for the study. Of these thirty VDs, 3 were government cold storage facilities, and 27 were vaccine retailers. Of the 27 VDs, 26 used a domestic type refrigerator and one used a cold-box. Two out of 3 government cold storage facilities used domestic type refrigerator and one (PP) involved a large refrigerated vaccine storage facility. Temperature recording was via electronic data loggers[1] (Thermochron®), programmed to record temperatures at 30 minute intervals for 30 days, a total of 1,440 readings for each refrigerator. The recording accuracy was ±1 $^{o}$C. The performance of the data loggers was tested in a refrigerator with a known temperature as demonstrated by a thermometer. The precise date of placement of the data loggers was unknown to participants until immediately before placement. A single data logger was placed centrally in the refrigerator or cold box next to vaccines but not placed immediately beside or on an ice pack or ice. The VDs were visited every week by research assistants to ensure that the data logger was still in the same position. Each half-hourly temperature recording was classified as 'freezing' (≤ 0 ˚C), 'too cold' (> 0 but < 2 ˚C), 'recommended range' (2-8 ˚C) or 'too hot' (> 8 ˚C) and the proportion of samples in each category determined for each data logger.

These data were analyzed within temperature categories by one way analysis of variance (AOV) to test the effect of province (and the reliability of its power supply) on the proportion of samples in each category. A separate dataset was created in which the duration of each period spent within each temperature category over the 30 days experimental period was recorded. This enabled analysis of the mean time spent in each temperature category. This was repeated measures analysis so a mixed restricted maximum likelihood (REML) model was fitted with data logger as a random effect and province, temperature category and their interaction fitted as fixed effects. Analyses were performed using JMP 12[2] with a statistical significance level of $P < 0.05$. Because power failures are a frequent and sometimes prolonged event in Cambodia, an additional small study was carried out to test the effect of a power failure on temperatures within a vaccine storage facility (Study 2). The study used the data loggers and ran for a period of 18 days. The government vaccine cold storage facility in Phnom Penh was chosen for this study because the presence of a 24 hour guard at that facility allowed accurate recording of the time that the electricity blackout began and ended, so that these times could be matched with the temperatures recorded by the data loggers inside the vaccine cold storage facility during the same period. The effect of location within a refrigerator on temperature variability was also investigated in a VD in Phnom Penh (Study 3). The study was carried out for a period of 30 days by using the same data loggers.

## RESULTS AND DISCUSSION

At the completion of study period for Study 1, we received 30 completed data loggers, giving an overall successful recording rate of 100. Table 1 summarizes the performance of each refrigerator during the 30 day study period, including mean, median, maximum and minimum temperatures recorded and time spent in each of the four temperature categories: 'freezing' (≤ 0 $^{o}$C), 'too cold' (> 0 but < 2 $^{o}$C), 'recommended range' (2-8 $^{o}$C) and 'too hot' (> 8 $^{o}$C). The final column in

[1] *Thermochron® DS1921, Dallas Identification/ALFA-TEK Australia, 7/42-50 Stud Road, PO Box 882, Bayswater, VIC. 3153, Australia*
[2] *JMP version 12 (SAS Institute Inc., NC, USA, 2015)*

**Table 1** titled 'No. of changes' refers to the number of times that refrigerator moved between temperature categories during the recording period.

In Phnom Penh, eleven refrigerators were monitored for a median 743 (range 716-750) hours. Although two of the eleven PP refrigerators were equipped with a maximum and minimum thermometer, in neither of them was the internal temperature of the refrigerator regularly monitored. In fact, one of the two refrigerators that was equipped with a maximum and minimum thermometer nevertheless had 100% of its data-logger temperature recordings at > 8 $^{o}$C (too hot). Three other refrigerators in PP also registered a significant proportion of recordings (21.4%, 35.3% and 39.8%) in the 'too hot' temperature range (> 8 $^{o}$C), while other 3 refrigerators vaccines were exposed to too cold (> 0 but < 2 $^{o}$C) and freezing temperature (≤ 0 $^{o}$C) in 25.6%, 75.2% and 98.1% of recordings. Of the 11 PP refrigerators, 9 were also used to store food and/or drinks. In all refrigerators, vaccines were stored on door shelves.

In Kampong Cham, nine refrigerators were monitored for a median 743 (range 769-793) hours. None of the refrigerators were equipped with a maximum and minimum thermometer. Vaccines in one refrigerator were exposed to both heat temperatures (> 8 $^{o}$C) for 13.0% of recording and too cold and freezing temperatures for 43.6% of recordings (

**Table 1**). In four refrigerators, vaccines were exposed to too cold (> 0 but < 2 $^{o}$C) and freezing temperature (≤ 0 $^{o}$C) for 33.2%, 57.4%, 38% and 83.5% of the temperature recordings. The results for the POAHP's refrigerator are especially significant because large quantities of donated and government FMD and other types of vaccines are stored there periodically. The temperatures in that facility were freezing (≤ 0 $^{o}$C) for approximately three quarters of time (78.6%) and too hot (> 8 $^{o}$C) in 14.5% of recordings. Of the nine refrigerators, 8 refrigerators were also used to store food and/or drinks. In 8 of the 9 KC refrigerators, vaccines were stored in the door shelves.

In Pursat, nine refrigerators and an ice box were monitored for a median 725 (range 668-743) hours. None of the vaccine storage facilities were equipped with a maximum and minimum thermometer. In two refrigerators vaccines were exposed to heat (> 8 $^{o}$C) for 65.0%, and 76.3% of the temperature recordings. Vaccines were exposed to too cold (> 0 but < 2$^{o}$C) and freezing temperatures (≤ 0 $^{o}$C) in 2 refrigerators for 48.9% and 49.2% of the temperature recordings. The most pronounced example of temperature variability in Pursat was recorded in refrigerator PS8, which recorded 44.9% of reading in the 'too hot' range (> 8 $^{o}$C) and 19.0% of readings in the 'freezing' category (≤ 0 $^{o}$C). The results from the single set of cold box recordings (PS4, Table 1) showed that vaccines were exposed to heat > 8 $^{o}$C for 45.4% of the temperature recordings. As in Kampong Cham province, the temperatures in that government facility (PS1) were freezing (≤ 0 $^{o}$C) for 37.8% of recordings and too cold (> 0 but < 2 $^{o}$C) for 21.2% of recordings. All 10 monitored refrigerators in Pursat were used to store food and/or drinks. In all nine refrigerators, vaccines were found to be stored on door shelves.

The number of episodes between temperature ranges that each site encountered in all study areas was described in Table 1. The results from the analysis of the variables showed that there was no significant effect of Province, Government/Private status or interaction between these two for mean or median temperature, or the percentage of time spent in different temperature categories ($p > 0.05$). However, for the standard deviation of temperature, and the number of temperature episodes in

different categories while there was no overall effect of the province (Table 1) there was significant interaction between the effects of Province and Government/Private status ($p < 0.05$, Fig 1).

**Table 1 Details of each of the vaccines storage refrigerators including the cumulative percentage of temperature recordings in each of four temperature categories, and number of changes between these categories over a 30 day period**

| | Site | vaccines in door shelf | Food/drinks also stored | Mean temp (°C) | Median temp (°C) | Freezing (%) | Too cold (%) | Correct (%) | Too hot (%) | Temp. range max-min (°C) | No. of changes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phnom Penh (PP)** | [a]PP1 | no | no | 6.40 | 6.5 | 0.0 | 0.0 | 98.9 | 1.1 | 4.5 - 16.0 | 6 |
| | PP2 | yes | no | 13.60 | 14.0 | 0.0 | 0.0 | 0.0 | *100.0* | 8.5 - 26.5 | 1 |
| | PP3 | yes | yes | 4.04 | 4.0 | 0.0 | 3.0 | 96.5 | 0.5 | 1.0 - 10.5 | 23 |
| | PP4 | yes | yes | 5.89 | 5.0 | 0.6 | 6.5 | 71.5 | *21.4* | 0.0 - 25.0 | 127 |
| | PP5 | yes | yes | 0.92 | 0.5 | *40.1* | 35.1 | 24.4 | 0.5 | -2.5 - 11.5 | 212 |
| | PP6 | yes | yes | -1.30 | -1.5 | *86.9* | 11.2 | 1.7 | 0.1 | -4.0 - 13.0 | 32 |
| | PP7 | yes | yes | 2.33 | 2.5 | 4.3 | 23.4 | 71.9 | 0.4 | -1.0 - 15.0 | 318 |
| | PP8 | yes | yes | 4.18 | 4.0 | 1.4 | 8.3 | 84.7 | 5.6 | -1.0 - 24.5 | 171 |
| | PP9 | yes | yes | 6.94 | 6.5 | 3.2 | 10.3 | 51.2 | *35.3* | 0.0 - 15.0 | 224 |
| | PP10 | yes | yes | 8.14 | 8.0 | 0.1 | 0.1 | 60.1 | *39.8* | 0.0 - 15.0 | 230 |
| | PP11 | yes | yes | 3.54 | 4.5 | *15.1* | 10.5 | 67.9 | 6.5 | -9.5 - 14.5 | 61 |
| **Kampong Cham (KC)** | KC1 | yes | yes | -1.30 | -2.0 | *76.4* | 7.1 | 11.4 | 5.1 | -8.5 - 20.0 | 121 |
| | KC2 | yes | yes | 3.28 | 3.0 | 7.7 | 25.5 | 63.7 | 3.2 | -1.5 - 14.5 | 160 |
| | KC3 | yes | yes | 3.17 | 2.5 | *26.9* | 16.7 | 43.4 | *13.0* | -8.0 - 22.5 | 190 |
| | KC4 | yes | yes | 2.28 | 2.0 | 7.2 | 30.8 | 61.4 | 0.7 | -1.5 - 12.5 | 676 |
| | KC5 | yes | no | 1.70 | 1.5 | *12.3* | 45.1 | 42.4 | 0.3 | -2.0 - 13.5 | 213 |
| | [b]KC6 | no | yes | 1.51 | -1.0 | *73.6* | 5.1 | 6.8 | *14.5* | -4.0 - 24.5 | 45 |
| | KC7 | yes | yes | 4.56 | 3.5 | 6.5 | 17.1 | 59.2 | *17.2* | -3.5 - 20.5 | 242 |
| | KC8 | yes | yes | 5.17 | 5.0 | 8.0 | 6.7 | 65.9 | *19.4* | -3.0 - 19.5 | 344 |
| | KC9 | yes | yes | 5.63 | 5.5 | 4.2 | 7.2 | 66.4 | *22.2* | -2.0 - 17.5 | 187 |
| **Pursat (PS)** | [b]PS1 | yes | yes | 1.10 | 1.0 | *37.8* | 21.2 | 40.9 | 0.1 | -3.5 - 10.5 | 1165 |
| | PS2 | yes | yes | 6.34 | 6.5 | 0.0 | 0.0 | 94.0 | 6.0 | 4.0 - 12.0 | 26 |
| | PS3 | no | yes | 9.24 | 9.5 | 0.0 | 0.0 | 35.0 | *65.0* | 2.0 - 19.5 | 59 |
| | [c]PS4 | yes | yes | 8.56 | 7.5 | 0.0 | 0.7 | 53.9 | *45.4* | 1.0 - 24.5 | 80 |
| | PS5 | yes | yes | 1.77 | 2.0 | *26.5* | 22.7 | 50.7 | 0.1 | -3.5 - 9.0 | 141 |
| | PS6 | yes | yes | 3.56 | 3.5 | 0.0 | 9.4 | 90.1 | 0.5 | 0.5 - 11.5 | 185 |
| | PS7 | yes | yes | 4.20 | 3.0 | 0.1 | 17.5 | 71.7 | 10.7 | 0.0 - 22.0 | 236 |

| Site | vaccines in door shelf | Food/drinks also stored | Mean temp (°C) | Median temp (°C) | Freezing (%) | Too cold (%) | Correct (%) | Too hot (%) | Temp. range max-min (°C) | No. of changes |
|---|---|---|---|---|---|---|---|---|---|---|
| PS8 | yes | yes | 5.94 | 6.5 | *19.0* | 0.3 | 35.8 | *44.9* | -9.0 - 13.0 | 58 |
| PS9 | yes | yes | 9.85 | 9.5 | 0.0 | 0.0 | 23.7 | *76.3* | 6.5 - 14.5 | 164 |
| PS10 | yes | yes | 1.96 | 2.0 | 3.7 | 45.2 | 50.8 | 0.3 | 0.0 - 10.0 | 926 |

*[a]Department of Animal Health and Production vaccine cold storage, [b]Provincial Office of Animal Health and Production vaccine cold storage, [c]Cold box rather than refrigerator*

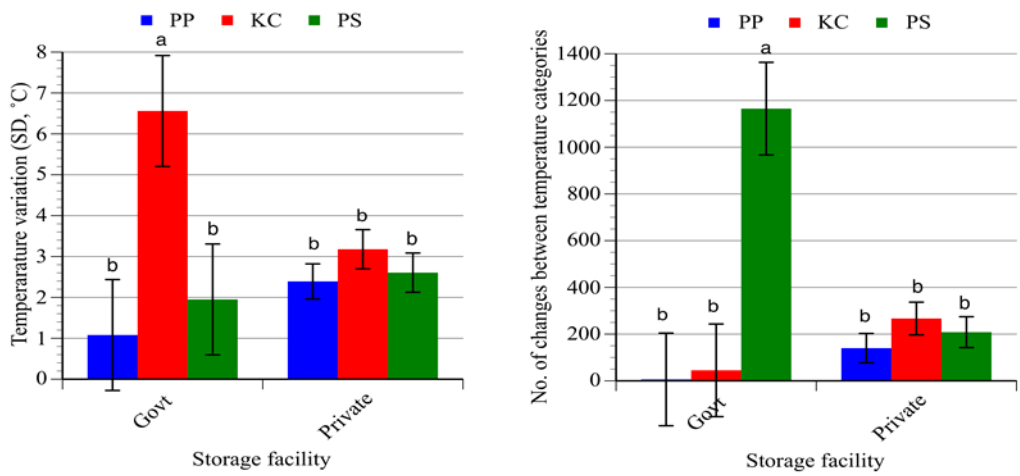


**Fig. 1 Significant interaction between the effects of study area and ownership on temperature variation (SD, Left) and number of changes between temperature categories (Right)**

Given the very small number of Government facilities, this should be interpreted with caution. This demonstrates that most of the variation in these was due to large variation between the Government sites included in the study. In particular, the vaccine storage facility in POAHP of KC recorded very high variability in temperature, and the POAHP of PS a high number of transitions between temperature categories. On the other hand, the POAHP in PP showed very consistent maintenance of temperature. Indeed, although the study was small, it provides clear evidence of serious problems with vaccine storage that could jeopardize the success of a vaccination program. Vaccine damage depends on the ambient temperature and the duration of exposure to adverse temperatures (Wawryk, Mavromatis, & Gold, 1997) and should not be used if they have been frozen or exposed to high temperatures (Cortese & Smith, 2004). The vaccine cold storage is critical point for the successful or failure of the vaccination program (Thakker & Woods, 1992). Those vaccine refrigerators can no longer maintain temperatures in recommended range (2-8 °C) have to be brought for the services or replaced (Grasso, Ripabelli, Sammarco, Manfredi Selvaggi, & Quaranta, 1999). Weir and Hatch (2004) suggest that never store vaccines on the refrigerator-door shelves. Failure to keep the thermometer in the vaccine refrigerators was associated with vaccine storage temperatures outside recommended range (2-8 °C) (Bell et al., 2001). None of the cold storage facilities were routinely monitored by the

owners/managers. Storing vaccines contrary to the manufacturers' recommendation is likely to adversely affect their potency and consequent efficacy in the field, reducing the effectiveness of disease prevention programs which rely heavily on vaccination. Even though the study was small, it highlighted serious problems with 53.3% (n = 16) of the study vaccine cold storage facilities where 56.3% (n = 9) set to freeze and too cold temperatures from 43.6%-98.1% and 43.7% (n = 7) set to too hot temperatures from 35.3%-100% of the recordings. Moreover, the study results suggest that the majority of wholesalers/retailers and government officials in charge of cold storage facilities would benefit from a brief and specific training session on vaccine and cold storage management in order to ensure all vaccines are stored at the correct temperature range or avoid the damage of vaccines while storing inside their refrigerators. The Study 2 investigating the consequences of power failure on temperatures within the DAHP's Phnom Penh vaccine storage facility revealed that the temperature spike on the day 8 coincided with a 6-hours electricity blackout recorded by the DAHP guard. Ninety minutes after the blackout began the storage facility temperature had risen above acceptable refrigeration range (8 $^{o}$C), and after 6 hours without electricity, the temperature had risen to 16 $^{o}$C. After the electricity supply was restored, it took two hours for the temperature within the cold storage facility to return to the refrigeration range 2-8 $^{o}$C. The effect on temperature of location within a refrigerator (Study 3) was investigated using the best performing commercial study refrigerator owned by a private VD in PP (PP3). The refrigerator registered 96.5% of temperature recording the correct refrigeration range (2-8 $^{o}$C) during the 30 days study period. Marked variation was recorded depending on the location within the refrigerator. The mean temperatures of 0.7 (-2.5 - 4.5), 1.5 (-0.8 - 5.0), 0.0 (-2.3 - 5.5), 6.8 (4.0 - 8.8) and 5.3 (1.3 - 8.8) were recorded at the top shelf, 2$^{nd}$ shelf, 3$^{rd}$ shelf, bottom drawer and door shelf within the refrigerator respectively. The temperatures at the bottom drawer and door shelf were much warmer than other parts of the fridge.

## CONCLUSION

Most of the vaccine cold storage facilities in all 3 study areas failed to maintain the recommended temperature range (2-8 ˚C) where vaccines in 8 facilities were exposed to freeze temperature, ranging between 24-100 hrs (3%-14%) and 9 facilities (including two from the POAHP) spent more than 100 hrs (15%-87%) of the temperature recordings. In three and four facilities, vaccines were exposed to above the recommended max temperature for 254-327 hrs (35%-45%) and 468-7200 hrs (65%-100%) of recordings. The practical implications of this on vaccine efficacy cannot be determined with certainty and are the subject of a separate study. However, they are unlikely to be positive and some simple measures could be attempted in order to improve vaccine storage conditions in both governmental and commercial facilities. SEACFMD reliance on vaccine to control FMD (FAO control of Avian Influenza) needs to consider these results and their importance on success of vaccination programs. The results from this study suggest that training program for government vaccine responsible staff (DAHP and POAHP) must be developed and recommend that each POAHP holds training for vaccine retailers. Education of vaccine distributors is a logical step, as lack of understanding about the effects of heating, freezing and temperature fluctuations on vaccine potency is doubtless part of the problem. The Cambodian government is aware that farmer uptake of vaccination will be discouraged if vaccines damaged by cold chain failures fail to provide expected protection. Licensing of vaccine retailers is an option being considered by the Cambodian government so that government officers can audit commercial vaccine storage conditions. In the interim, vaccine distributors should be offered training to improve cold storage standards. At a bare minimum, these operators should be encouraged to use thermometers to check and record the operating temperatures twice daily in their refrigerators. The effects of repeated door opening should be presented to them, together with recommendations to store vaccines separately from food and/or drink, or at least to store them in the colder shelves. Likewise, the effect of power outages on refrigerator temperatures should

be demonstrated, together with the need for them to have an alternative source of power (generator) or ice in order to keep the vaccine refrigerated in such an event. While it is difficult to supervise conditions in commercial vaccine outlets, it is within the government's power to ensure that better temperature monitoring and management is applied at the government storage facilities responsible for managing the large quantities of donated and government funded vaccines which underpin disease control programs against FMD, HPAI and other animal diseases of national significance. All government vaccine cool rooms or refrigerators should be equipped with max-min thermometers in order that temperatures can be monitored and controlled. Protocols should be developed whereby remedial action is initiated by a temperature trigger point during power outages. It is also important that critical experimentation to better define the detrimental consequences of improper vaccine storage on vaccine efficacy be supported. This will assist with the development of critical thresholds triggering discarding of vaccine if they are breached.

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Research article

# Soil Amendments for Maize Cultivation by Crop Rotations in Upland Cropping Systems of Southeast Cambodia

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**Abstract** A study was made of the importance of crop rotations on the growth and yield of maize in upland cropping systems of Cambodia. Maize (MZ) was grown continuously and in two-year rotations with cassava (CS), soybean (SB), mung bean (MB) and peanut (PN). Six different rotations T1, T2, T3, T4, T5 and T6 were designed and studied in the upland cropping systems in the provinces of Prey Veng and Svay Rieng in southeastern Cambodia. Mono-cropping with maize (T0) was used as the control treatment in the study. The study was undertaken in the period 2013 to 2015. The field experiments revealed an increase in crop yields in the order of T1 > T2 > T3 > T5 > T6. There was no significant difference in crop yield between T4 and the control (T0) treatment. The analysis of soils data revealed that there were no significant differences in soil nitrogen and phosphate levels pre-treatment and post–treatment in each of the rotations (paired samples t test, $p > 0.05$). However, post-treatment potassium levels were significantly lower than the pre-treatment levels in all cropping rotations ($p < 0.05$) except T0. The results of the study suggest that the maize-legume rotation is the most promising crop rotation for yield improvement in the upland cropping systems in southeast Cambodia.

**Keywords** maize, crop rotation, upland cropping system, Cambodia

## INTRODUCTION

It is Cambodian government policy to encourage crop diversification (i.e. to grow cash crops other than rice), especially in non-rice upland agro-ecological systems (Chan et al, 2009). Cambodian farmers, extension workers and researchers, are less familiar with crop rotations than with mono-cropping, as the focus of the research has been on cassava cultivation for many years on the same land. Cassava production is also perceived to degrade soil fertility. This is also a major contributing factor to the relatively low cassava yields in areas where cassava has been cropped over many years. Maintaining soil fertility is one of the main challenges in agricultural production systems in Cambodia. Intercropping is one of the options available for more sustainable agricultural production systems.

Other benefits of intercropping include, spreading of risk (relative to single cropping), improved weed management, and reduced incidence of insect pest and disease damage. The Government of the 3rd Constitution has adopted a development strategy which is partly based on crop intensification and diversification (MAFF, 2007). Most farmers in the provinces of Prey Veng and Svay Rieng have tried to intensify agricultural production through mono-cropping of cassava, reflecting the high demand for this crop in commercial markets. However, this cropping intensification has been done with little knowledge of procedures or technologies for maintaining soil fertility.

Soil fertility (and therefore crop yields) has shown a significant decline in areas with a long history of cassava cropping, as smallholder producers are unable to afford commercial fertilizers to replace the nutrients removed by successive cassava crops. To date, mono crops in Cambodia are generally low yielding, with little knowledge and financial information available on the best management practices for soil fertility maintenance in mono cropping systems, and often unsuitable are being grown. Attention to the agronomic aspects of rotation crops, especially soybean and mungbean is required. Growers need agronomic advice which will reduce the risk of degradation in soil fertility (Chan et al., 2009). To enhance food security and sustainable livelihoods, improvements are needed in agricultural techniques for enhancing production in upland rural areas of Prey Veng and Svay Rieng Provinces of Cambodia. A combination of poor soils and a dependence on non-irrigated agricultural production are the basis of low agricultural production and high levels of poverty in Prey Veng and Svay Rieng Provinces.

## OBJECTIVE

The goal of this project was to use an on-farm, farmer participatory approach to study a range of potential agricultural technologies for enhancing and sustaining agricultural production and incomes in Prey Veng and Svay Rieng Provinces. The main objectives of the study were to: (1) determine the promising crop rotation options for improving fertility and food crop production of the Prey Khmer soil group in upland cropping system of Prey Veng and Svay Rieng provinces; and (2) investigate the changes in soil chemical and physical properties after crop rotations.

## METHODOLOGY

The study was carried out in Prey Veng and Svay Rieng provinces which are located in the Southeastern part of Cambodia (Fig. 1). The continuous mono-cropping particularly with cassava in these upland areas has led to a progressive decline in soil fertility. There is an urgent need to identify alternative agricultural production options capable of economically improving both the soils and production, while the same time improving incomes of rural households which are almost 100% dependent on agriculture.

Six different treatments (combinations of maize (MZ), cassava (CS), mungbean (MB), soybean (SB) and peanut (PN)) T1 (SB-MZ-MB-MZ), T2 (PN-MZ-SB-MZ), T3 (MB-MZ-PN-MZ), T4 (CS-CS-CS-MZ), T5 (CS-MB-PN-MZ) and T6 (CS-SB-PN-MZ) were designed to investigate on the growth performance and crop yield of maize in eight basic production systems (7m × 10m) in the study areas of Prey Veng (n = 4) and Svay Rieng (n = 4) provinces. The mono-cropping of maize was used as a control in the present study. Field trials were conducted in the field of farmers and carried out at appropriate times throughout the growing seasons. The Proposed cropping treatments and timetable of cropping activities are summarized in Table 1. The plant height (cm), the number of ear per plant, ear length (cm), ear size (cm), weight (g) per ear and maize yield (dwt) per hectare (t/h) were measured before the next cycle of ration. Concurrently, soil samples were collected at depth of 10-30cm before and after each treatment to determine soil properties and measure the changes in their total C, organic C, N, $P_2O_5$, Ca, Mg, Na, K and exchangeable acidity ($pH_{KCl}$) and actual acidity ($pH_{H2O}$).

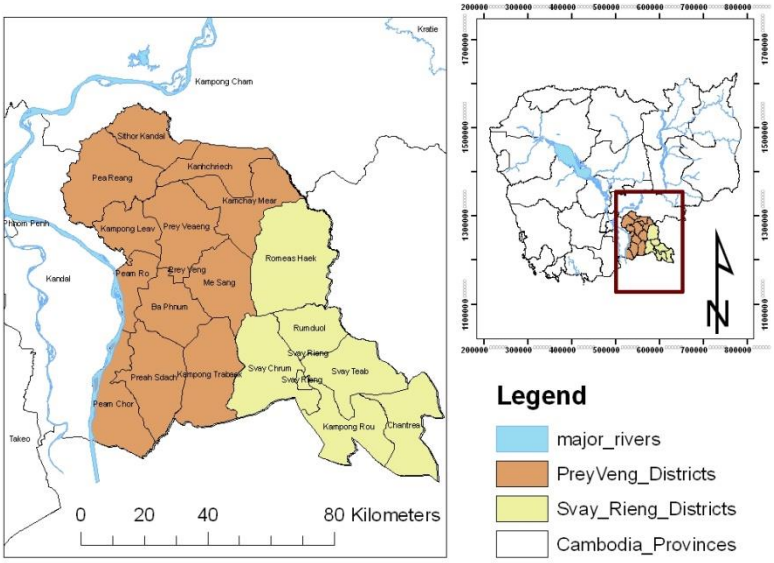


**Fig. 1 Map of the study areas**

**Table 1 Summary of crop rotations in the upland cropping system in Prey Veng and Svay Rieng provinces**

| Treatment | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|
| | EWS | LWS | EWS | LWS | EWS | LWS |
| T0 | - | MZ+F | MZ+F | MZ+F | MZ+F | - |
| T1 | - | SB+F | MZ+F | MB+F | MZ+F | - |
| T2 | - | PN+F | MZ+F | SB+F | MZ+F | - |
| T3 | - | MB+F | MZ+F | PN+F | MZ+F | - |
| T4 | - | CS+F | CS+F | CS+F | MZ+F | - |
| T5 | - | CS+F | MB+F | PN+F | MZ+F | - |
| T6 | - | CS+F | SB+F | PN+F | MZ+F | - |

*EWS, early wet season; LWS, late wet season; MZ, maize; SB, soybean; MB, mungbean; CS, cassava; PN, peanut; +F, fertilizer application*

All statistical analyses were performed using SPSS for Windows (Version 16.0). The t-test was applied to verify significant differences in the growth performance and crop yield between the six treatment methods with a control and differences in the growth performance and production yield between the two study areas. One way ANOVA was applied to verify the differences in the growth performance and crop yields among the six rotation designs. Paired samples *t* test was applied to verify the difference of soil physical and chemical properties before and after treatment. The significance was considered in a circumstance where $p < 0.05$.

## RESULTS AND DISCUSSION

Plant height (cm), number of ear per plant, and yield per hectare (t/h) of maize after crop rotation are presented in Table 2. A comparison revealed that there were no significant differences in plant height of control (T0) with each treatment (t-test, $p > 0.05$). However, there was a significant difference in number of ear per plant among all treatments (One-way ANOVA, $F(6, 49) = 12.11$, $p < 0.01$). Post-

hoc Tukey HSD tests showed that there were significant differences in number of ear per plant between T0 and T1, T2, T3 and T5 ($p < 0.05$), but T4 and T6 were not significant different in number of ear per plant with T0 ($p > 0.05$). A statistically significant difference was found among all treatments on ear length, $F (6, 49) = 11.45$, $p < 0.01$. The ear length of T0 was significantly shorter than that of T1, T2 and T3 ($p < 0.05$) using Games-Howell post-hoc test. Likewise, ear size were statistically different among all treatments (One-way ANOVA, $F (6, 49) = 11.42$, $p < 0.01$). Ear size of T1, T2 and T3 were statistically bigger than that of the control using Tukey HSD post doc test. A statistically significant difference was found among all treatments on weight of ear, $F (6, 49) = 8.50$, $p < 0.01$.

**Table 2 Summary of growth performance and crop yield of maize crop rotation in the upland cropping systems in Prey Veng and Svay Rieng provinces**

| Treatment | Statistics | Plant Height (cm) | Number of ear/ plant | Yield (t/h) |
|---|---|---|---|---|
| T0 (n = 8) | Mean | 111.9 | 1.1 | 4.9 |
| | S.D | 27 | 0.1 | 0.3 |
| T1 (n = 8) | Mean | 138.4 | 1.5 | 7.9 |
| | S.D | 26.4 | 0.1 | 1.1 |
| T2 (n = 8) | Mean | 125.8 | 1.4 | 6.9 |
| | S.D | 18.5 | 0.2 | 0.7 |
| T3 (n = 8) | Mean | 135.1 | 1.4 | 6.5 |
| | S.D | 22.2 | 0.2 | 0.9 |
| T4 (n = 8) | Mean | 112.6 | 1.1 | 4.9 |
| | S.D | 18 | 0.2 | 0.8 |
| T5 (n = 8) | Mean | 109.3 | 1.4 | 5.9 |
| | S.D | 16.7 | 0.1 | 0.7 |
| T6 (n = 8) | Mean | 122.9 | 1.2 | 5.8 |
| | S.D | 21.4 | 0.1 | 0.4 |

*S.D, standard deviation; Yield is on 100% dry weight*

Weight of ear of T1, T2 and T3 were significantly heavier than that of T0 using Games-Howell post-hoc test. Analytical results revealed that there were statistically significant differences in crop yield among all treatments (One-way ANOVA, $p < 0.05$). Further comparison indicated that crop yield of treatment 1 (T1) is statistically significant higher than that of the control (T0) (t-test, $p < 0.05$). Likewise, the crop yields of T2, T3, T5 and T6 are statistically significant higher than that of the control (t-test, $p < 0.05$). It seems like the plant height is associated with crop yield without consideration of rotation. Concurrently, it is more likely that crop yield is associated with number of ear per plant, ear length, ear size and weight of ear. The present study showed that maize growth was better in the crop rotation system than mono-cultured soil (control). This result is consistent with the results of an earlier study by Horst and Härdter (1994) which found that in pot experiments, maize growth was much better in the soil from the crop rotation than from the mono-cropping plots. Crop yield of the present study was increased through crop rotation which is consistent to a statement by Honeycutt et al., (1995).

The physical and chemical properties of soils before and after treatments are presented in Table 3. Soil before crop rotation composed of sand, silt and clay of 66%, 26% and 8%, respectively. When plotting the percentage of all particles in the triangle diagram, the texture of soil was found to be sandy loam. However, the soil texture was not altered after crop rotation. In general, the management practices do not alter the textural class of a soil on a field scale. Changing the texture of a certain soil would require mixing it with another soil material of a different textural class. For example, the

incorporation of large quantities of sand to change the physical properties of a clayey soil for use in greenhouse pots would be considered to change the soil texture (Brady and Weil, 2007).

**Table 3 Mean values of the chemical and physical properties of soils before (n = 8) and after (n = 8) treatment**

| Treatment | Org C | N | $P_2O_5$ | Ca | Mg | Na | K | pH |
|---|---|---|---|---|---|---|---|---|
| | | | Pre-treatment | | | | | |
| T0 | 2.4 | 1.18 | 188.69 | 2.59 | 1.68 | 0.18 | 0.25 | 4.6 |
| T1 | 2.4 | 1.18 | 188.69 | 2.59 | 1.68 | 0.18 | 0.25 | 4.6 |
| T2 | 2.4 | 1.18 | 188.69 | 2.59 | 1.68 | 0.18 | 0.25 | 4.6 |
| T3 | 2.4 | 1.18 | 188.69 | 2.59 | 1.68 | 0.18 | 0.25 | 4.6 |
| T4 | 2.4 | 1.18 | 188.69 | 2.59 | 1.68 | 0.18 | 0.25 | 4.6 |
| T5 | 2.4 | 1.18 | 188.69 | 2.59 | 1.68 | 0.18 | 0.25 | 4.6 |
| T6 | 2.4 | 1.18 | 188.69 | 2.59 | 1.68 | 0.18 | 0.25 | 4.6 |
| | | | Post-treatment | | | | | |
| T0 | 1.81 | 1.1 | 178 | 3.08 | 1.27 | 0.12 | 0.17 | 4.71 |
| T1 | 2.03 | 1.22 | 152.13 | 2.99 | 1.33 | 0.12 | 0.15 | 4.82 |
| T2 | 2.11 | 1.4 | 148.25 | 3.23 | 1.31 | 0.11 | 0.14 | 4.98 |
| T3 | 1.77 | 1.14 | 177.63 | 3.08 | 1.35 | 0.09 | 0.16 | 4.89 |
| T4 | 2.15 | 1.28 | 161.5 | 3.21 | 1.33 | 0.11 | 0.17 | 5.08 |
| T5 | 2.05 | 1.24 | 162.5 | 3.17 | 1.34 | 0.1 | 0.14 | 4.96 |
| T6 | 1.89 | 1.1 | 167.25 | 3.31 | 1.41 | 0.09 | 0.16 | 4.82 |

*Org C, N, $P_2O_5$, Ca, Mg, Na, K in mg $kg^{-1}$*

A comparison indicated that the total carbon of the post-treatment and pre-treatment in each rotation were not significantly different (Paired samples *t* test, $p > 0.05$), except T2 that total carbon of post-treatment was significantly higher than that of pre-treatment ($t = -2.59$, $p = 0.036$). Likewise, there were not significant differences in organic carbon between pre-treatment and post-treatment of most rotation (Paired samples *t* test, $p > 0.05$), except T0 and T4. Further analysis revealed that there were not significant differences in total nitrogen and phosphate between pre-treatment and post –treatment in each rotation (Paired samples *t* test, $p > 0.05$). A paired samples *t* test indicated that K of post-treatment were significant lower than that of pre-treatment in each rotation ($p < 0.05$), except T0. However, Ca of post-treatment was significant higher than that of pre-treatment in each treatment (Paired samples *t* test, $p < 0.05$), except T2 and T5. Analytical results revealed that Mg of the post-treatment were significantly lower than that of pre-treatment in all treatment (Paired samples t test, $p < 0.05$). However, Na of the post-treatments was not significantly lower than that of the pre-treatment, except T3 and T6 (Figure 18). The exchangeable pH of pre-treatment were significantly lower than that of post-treatment of T1, T2 and T4 (Paired samples t test, $p < 0.05$); however, there were not significant differences in the exchangeable pH of T0, T3, T5 and T6 (Paired samples t test, $p > 0.05$). Concurrently, a comparison showed that the actual pH of pre-treatment were not significantly different from that of post-treatment of T0, T1, T4, T5 and T6 (Paired samples t test, $p < 0.05$) while marginal difference was found in T2 and T3. A study of field crop productivity in relation soil properties in Basaltic soils of Eastern Cambodia found that drought, soil acidity, inadequate N fertilizer were the main factors accounting for the unreliable performance of maize (Seng et ., 2011).

## CONCLUSION

Crop rotation for maize production was successfully implemented in the upland cropping system in Prey Veng and Svay Rieng provinces in Cambodia. Experimental results revealed that crop yield increased in the order of T1 > T2 > T3 > T5 > T6. Although post-treatment K was significantly lower than that of pre-treatment, N and $P_2O_5$ were not significantly different before and after the treatment. This study suggested that the rotation of soybean-maize-mungbean-maize T1 (SB-MZ-MB-MZ) was the most promising crop rotation to increase maize yield in the upland cropping system of Cambodia.

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Research article

# Improving Upland Rice Production for Sustainability of Rice Self-Sufficiency in Ratanakiri Province, Cambodia

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**Abstract** Rice is the major source of carbohydrate, nutrient and income of poor farmers especially in rural areas in Cambodia, and Ratanakiri Province is one among them. Rice self-sufficiency was threatening while the population dramatically increasing and the rice production trend showed the declining. Given primary result showed that a few families were victims of rice self-insufficiency, notably, who possessed small farm, and large members' family. But none of those families experienced hunger as they superior to buy food aid from the market while the other mechanisms were also held. The linear multiple regression models showed that rice sufficiency of upland rice producer families were strongly depend on rice yield obtained. Traditional practices carried by many farmers resulting poor rice productivity. Thus, to meet and sustain rice self-sufficiency several management practices are needed to improve including increasing seeding rate, wisely select variety and planting method, fertilization while capacity building are more apparent for the rapidly adopt technological and economic environment and increasing income.

**Keywords** rice self-sufficiency, upland rice, upland community, Ratanakiri, Cambodia

## INTRODUCTION

Rice is the staple food, source of carbohydrate and nutrient for Cambodian, especially for rural and poor resource farmers (FAO, 2009; Ros et al., 2011; MAFF, 2012, Work Bank, 2013). By 2012, Cambodia has covered 2.97 million ha for rice production with an average yield of 3.1 t $ha^{-1}$ (MAFF, 2012). Cambodia, upland rice plays a key role in maintaining food security for rural areas, and account for around 20% of total rice production annually (MAFF, 2012). However, upland rice farming still follows traditional practices such as slash and burn for ethnic people while some have already adopted advanced technologies including land preparation, fertilization and pest control. Hence, the country's average upland rice production is only 1.2 t $ha^{-1}$ (MAFF, 2012). Ratanakiri Province, well-known for highland rice producing in Cambodia, has about 30,000 ha potential for upland rice production. In 2012, MAFF reported the decreasing trend of upland rice yield during the last decade and suggested to improve rice production nationwide, not only on lowland but as well as upland rice. There is a reported reduction in wet season rice productivity of rainfed upland rice in Ratanakiri Province, despite the constant of upland rice production while the population is dramatic increasing from about 70,000 ha in 2000 to 191,000 ha in 2012 (NCDD, 2010; RPDA, 2012). Notably, population increasing and low rice

yield would push toward food crisis in the province, particularly rice sufficiency. Thus, the study was aimed to determine the rice consumption status of upland rice farmers in Lum Choar commune, Ou Ya Dav District, Ratanakiri Province, Cambodia, and identified the improvement options.

## METHODOLOGY

The study was conducted in the dominantly upland rice production areas of Lum Choar commune, Ou Ya Dav district, Ratanakiri province where the most number of upland rice producers was reported (RPDA, 2012). Farmer respondents of the study were taken from the total families of rice producers in Lum Choar commune. The sampling of respondents was determined based on the Slovin's formula with ten percent (10%) margin of error. A total of 90 respondents out of 265 upland rice families were randomly selected. Direct interview (questionnaire survey) was administered describe the characteristics of farmer, upland rice production and household rice status. A combination of qualitative and quantitative, and Multiple Regression analysis using SPSS version 19.0 (SPSS Inc.) was employed.

## RESULTS AND DISCUSSION

### Level of Household Requirement

Table 1 show that the respondent have an average of 4 members and all of the respondent families are subsistence rice planting rather than commercial.Weekly plant height (cm) of the plants was taken in all treatments as shown in Table 1. It was found out that there was a difference of height in all treatments compared with the Control. However, based on the analysis of variance, it was found that the difference was insignificant in all treatments over the control plots.

For instant, based on self-sufficiency equation, we had estimation for the household rice requirement as in follow. The household survey showed that the requirement for food grains is fixed at 450 grams per person per day for rural areas. This translates into an annual requirement of:

$$\text{Household requirement} = 450 \text{ g/capita/day} \times 4 \text{ people} \times 365 \text{ days} = 657 \text{ kg} \quad (1)$$

Thus, to meet the rice self-sufficiency, each household has to produce at least 1,000 kg of paddy rice where the conversion ratio from paddy to polished rice was found about 64% (De Datta, 1981), and plus at least 30-40 kg of seed reserve for next planting (Table 1). Hence, rice self-sufficiency would be not the problem in the study area where the average yield of 1.46 ton per ha (0.93 ton polished) was recorded (Table 1).

However, Table 2 showed that about 8 percent of the respondent families were fell into rice insufficiency. Among those who faced rice insufficiency, majority was rice insufficiency for more than 50 days (85%). Difference in farmland size devoted for planting upland rice, yield and household member triggered this phenomenon (Table 1). About 10 percent of the respondent families own less than 1 ha devoted for rice production and about 8.9 percent got yield less than 1 ton per hectare. While production area is small and the rice yield is low, these families would fall into rice self-insufficiency.

In addition, none of the rice insufficiency families experienced hunger since they have coping mechanisms to feed rice to their family and children. All of seven respondents who suffered rice insufficiency resource to purchasing rice (100%), 85.7% asked from neighbours or their relatives, 28.6% said they sometimes milled some portion of their next cultivation seed in case of emergency. The result implied that most of farmers could afford to purchase supplementary food from market, even though majority of them obtained low income (Table 2).

**Table 1 Household member, education attainment, rice production area, yield, seeing rate, planting purpose and family income of upland rice producer families**

| Descriptions | Frequency | Percent | Mean+S.E |
|---|---|---|---|
| Household Member (person) | | | |
| • =< 3 | 50 | 55.60 | |
| • 4 | 21 | 23.30 | 4 ± 1 |
| • >= 5 | 19 | 21.10 | |
| Educational Attainment | | | |
| • No formal schooling | 50 | 55.60 | |
| • Primary school | 31 | 34.40 | |
| • Secondary school | 9 | 10.00 | |
| Upland Rice farm areas (ha) | | | |
| • <1 | 9 | 10.00 | |
| • 1-2.0 | 76 | 82.20 | 1.20 ± 0.50 |
| • 2.1-3.0 | 5 | 7.80 | |
| Yield (ton $ha^{-1}$) | | | |
| • >1.00 | 8 | 8.90 | |
| • 1.00-1.50 | 49 | 54.50 | 1.46 ± 0.37 |
| • 1.51-2.00 | 30 | 33.30 | |
| • >2 | 3 | 3.30 | |
| Seeding rate (kg $ha^{-1}$) | | | |
| • 20-30 | 66 | 73.40 | |
| • 31-40 | 20 | 22.20 | 30.10 ± 8. 90 |
| • >40 | 4 | 4.40 | |
| Purpose of planting rice* | | | |
| • Consumption | 90 | 100.00 | |
| • Income | 51 | 56.70 | |
| Family Income (US$/year) | | | |
| - <500 | 78 | 86.70 | |
| - 500-800 | 3 | 3.30 | 750 ± 420 |
| - 800-1,000 | 7 | 7.80 | |
| - >1,000 | 2 | 2.20 | |

**Table 2 Household rice sufficiency in Lum Choar Commune, Ou Ya Dav District, Ratanakiri Province, Cambodia**

| Descriptions | Frequency | Percent | Mean+S.E |
|---|---|---|---|
| Rice Status | | | |
| • Surplus | 27 | 30.0 | |
| • Sufficiency | 56 | 62.2 | |
| • Lacking | 7 | 7.8 | |
| Duration of Rice shortage | | | |
| • 50 days | 1 | 14.3 | 43 ± 9 |
| • > 50 | 6 | 85.7 | |
| Coping mechanisms to rice shortage* | | | |
| • Purchase from market | 7 | 100.0 | |
| • Ask from neighbor/relative | 6 | 85.7 | |
| • Milled the seed for next cultivation | 2 | 28.6 | |

** multiple responses*

### Factor Affected Households' Rice Sufficiency and Improvement Options

A regression analysis was done on the following selected factors to determine which factor influenced household rice sufficiency: income, household member (social factors), areas of rice production, seed used rate, and rice yield (production factors). The result shows that there was a significant relationship between the availability of rice for household consumption and the selected variables. However, among the selected factors only rice yield had positively significantly affected on the availability of rice for household consumption (Table 3). The result indicates that the level of rice sufficiency for household consumption depend on upland rice yield.

**Table 3 Factors affecting household rice sufficiency**

| Model | Observation number | PR>F | Coefficient Value |
|---|---|---|---|
| Seed rate | 90 | 0.361 $^{ns}$ | -0.111 |
| Area of upland rice production | 90 | 0.327 $^{ns}$ | 0.103 |
| Rice yield | 90 | 0.018 * | 0.313 |
| Household member | 90 | 0.082 $^{ns}$ | -0.182 |
| Income | 90 | 0.906 $^{ns}$ | 0.013 |

** Significant at 0.05 level. $R^2$=0.117 (P=0.002)*

Suggesting that increasing rice yield is crucial to meet and sustain rice availability and sufficiency in upland communities, specifically in Lum Choar commune. On the other words, high rice yield would also increase family's income. This is understandable because Cambodia is well known as an agriculture country (MAFF, 2012; OECD, 2013; World Bank; 2013). Agriculture sector stands as third contributor to its GDP (MAFF, 2012). However, the scheme to increase upland rice yield per unit should be in parallel with sustainable development and environment harmony.

### Factors Lmiting Rice Production and Options for Yield Improvement

The Linear Regression model was used to represent the effects of selected social factors such as education level, income and management interventions (rice variety, sowing date, seed used history, planting methods, seeding rate, fertilization, and weed management) on rainfed upland rice yield.

**Table 4 Factors affecting upland rice yield (Regression Model)**

| Model | Observation number | PR>F | Coefficients |
|---|---|---|---|
| Sowing Date[a] | 90 | 0.361 $^{ns}$ | 0.065 |
| Planting Method[a] | 90 | 0.020 * | 0.241 |
| Variety Use[a] | 90 | 0.001** | 0.284 |
| Seed Use Duration[a] | 90 | 0.016 * | -0.213 |
| Seed Rate Use[a] | 90 | 0.000** | 0.715 |
| Fertilization[a] | 90 | 0.000** | 0.448 |
| Weed Management[a] | 76 | 0.696 $^{ns}$ | 0.077 |
| Education level[b] | 90 | 0.005** | 0.215 |
| Income[b] | 90 | 0.000** | 0.285 |

*[a] Management practices factors, [b] Social factors, * Significant at 0.05; **Significant at 0.01*
*$R^2$=0.70 (P=0.000)*

Significant affected were observed among selected factors (Table 3). Planting methods, rice variety, seed used history and fertilization were factors limiting productivity while sowing date and

weed management was significantly affected. The results indicated that traditional practices carried by farmers were the major yield' limiting factors which commendable implied from poor education and low income. Thus, to improve upland rice yield, farmers have to select variety and planting method wisely, or change their seed every 3-5 years. This is because after 4-5 years of continued recycling of the seeds, a decline in rice yield often takes place due to the accumulation of seed pathogens, impurity of genetic and mixed with the weed seed which later results to unhealthy crops and low yield (Seshu et al., 1988). Sehnoy et al (1988) reported that 20% of rice's yield decline was due to the use of poor seed quality. Commendably, increasing seeding rate would significantly increase yield.

Over the years, improved rice varieties has been proven to achieve 20% more yield than local varieties in many countries such as China, India, Vietnam, Philippines, Indonesia, Malaysia, Thailand, African nation, Australia, and Cambodia (Longping, 2004; Virmani and Kumar, 2004). In 2004, Longping pointed out that new improved and hybrid rice is a wise and great prospect for commercial production and would play a key role to ensure the world's food security. Self-sufficiency in rice is an important matter as it provides food, income and generates employment opportunities. Additional yield of rice means high economic profitability to farmers and food security. In the same manner, application of additional fertilizer would help to increase rice yield. Results of social profiles both education and income, played an important role in which way management practices were carried, significantly influence upland rice production. In rural areas where farming households invested so little in education contributed to poor production (FAO, 2009; Ros et al., 2011; MAFF, 2012; OCED, 2013 and World Bank, 2013). These authors emphasized that education may enhance productivity directly by improving the quality of management and labour. Education is an important asset to farm production in a rapidly changing technological or economic environment. With the rapid spread of technological innovations, the importance of formal schooling and/or training, workshop and farmer field school to farm production becomes more apparent. On the other hand, increasing upland rice productions with minimum inputs are directly influence the income of the upland rice producer families resulting to enhance rice sufficiency and food security for upland community.

## CONCLUSION

Traditional upland rice practices carried by poor and low educated farmers resulting low yield, where rice served as major carbohydrate and nutrient, and seriously threaten rice sufficiency in upland communities. Hence, improvement management practices including wisely select planting method, change seed use, adopt new rice varieties, increasing seeding rate and additional applied fertilizer will help to enhance rice production which notably improve rice sufficiency and directly increase the income. However, increasing family income and knowledge are apparently to improve upland rice production such as technological and climate change adaptation.

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Research article

# Current Agricultural Conditions and Constrains in Paktya Province of Afghanistan

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**Abstract** Agriculture is the backbone of economy of Paktya Province in Afghanistan with more than 80% people engages in agriculture for their livelihoods. In spite of such a large workforce involves in this activity, the outcomes are not very satisfied. A survey was conducted to discuss current conditions of agricultural sectors and constrains of agriculture in Paktya province. Survey was done in accordance with a questionnaire sheet on current agricultural condition and constrains. As per the survey it was found that majority of farmers use traditional farming methods and have very poor technical knowledge in agriculture. The low productivity and fertility of soils as well as the lack of irrigation water were identified as major factors causing low agricultural production at the research area. In addition, 32.4% of responded farmers answered soil erosion happens very severely and 50.0% answered soil erosion happens severely. It means that more than 80% of farmers require the proper conservation strategies for holding soil fertility. It was considered that soil degradation caused by erosion phenomena with high intensity rainfall causes low holding capacities of nutrients and water of soils. The development of proper conservation strategies as well as farmers education on proper soil management is indispensable to achieve sustainable agriculture in Paktya Province, Afghanistan.

**Keywords** Afghanistan, agriculture, constrains, condition, Paktya

## INTRODUCTION

Afghanistan is a landlocked country located in the central of Asia. It is bordered by Pakistan in the south and the east, Iran in the west, Turkmenistan, Uzbekistan and Tajikistan in the north and China in the far northeast (Favre and Kamal, 2004). The rugged terrain of Afghanistan shares the world's highest mountain ranges, Himalayas, Pamirs and Hindukush rising over 7,000 m and running from north east to south west. In Afghanistan, over 80% of the population relies directly on the natural resources to meet their daily needs. However, the United Nations Environmental Programme (UNEP) showed that two and a half decades of war and continuous drought have resulted in widespread environmental degradation throughout the country, which also raise a serious threat to the future of Afghan livelihoods (UNEP, 2003).

Afghanistan's climate is unique. The region is a center of origin for many fruits and nuts. Afghanistan is not blessed with many riches in resources, but perennial crops and the hard working Afghan farmers are a superior resource that can correspond to international market. Afghanistan's agriculture is the employment engine of the country. About 84% of the country's population is either directly involved in or related to farming activities.

Afghanistan has 34 provinces; one of these provinces is Paktya. It is located in the southern region of Kabul Province and has borders with Logar, Ghazni, Paktika and Khost Provinces, to the north it has borders with Pakistan as shown in Fig. 1. The total area is 6,259 $km^2$ and 65.1% of the province is mountainous/semi-mountainous terrain while a little more than one third (32.3%) of the area is made up of flat lands as shown in Table 1 (Harris, 2012). This province is divided to 14 districts; the capital is Gardez. According to the national statistical department, the total population of the province is less than one million households with an average of eight members in each household (CSO, 2010).

Paktya has an agricultural based economy. In Afghanistan, the agriculture sector contributes 26% of the country GDP (IRACSO, 2010), while the industry sector shares only 25%. Within the industry sector, mainly products come from very small scale agriculture based industries. It is estimated that approximately 94% of population living in the rural areas are engaging in agriculture related activities, also 80% work as agricultural labors/workforce in farmlands. Most of these agriculture related activities fall within small scale production systems with only a few farmers being self-sufficient.

According to land cover classification of Paktya by FAO (2014), huge areas are covered by rangeland and forests. Similarly, ArcGIS map showed large areas covered by forest and rangeland (Fig. 2). Wheat is a culturally most significant crop in a province and a staple food for all Afghans. Wheat is grown on an area of 21,105 ha with a production of 75,203 Mt (MAIL, 2014). Cereals like barley, maize or rice are the other important food grains. Approximately 90% of wheat is fall-planted and the rest is spring planted, also around 80% is produced from irrigated lands and only 20% from rain-fed areas. Although wheat straw has a relatively low nutrition for livestock, it is used for livestock feeding. Therefore, higher seed rates are recommended to meet the additional need of straw to be used as fodder. Wheat cultivation in almost all districts is rain dependent either directly or indirectly, because irrigation water is mostly drawn directly from natural rivers where are depending on rainfalls. The lack of irrigation infrastructure in almost all the provinces leads to almost complete failure of the crop cultivation during drought years. Due to the undulating topography of the province, local farmers have trouble with land preparation, sowing and irrigation.

## OBJECTIVE

The objective of this study is to discuss current conditions of agricultural sectors and constrains of agriculture in Paktya Province, which is locates in southern parts of Afghanistan.

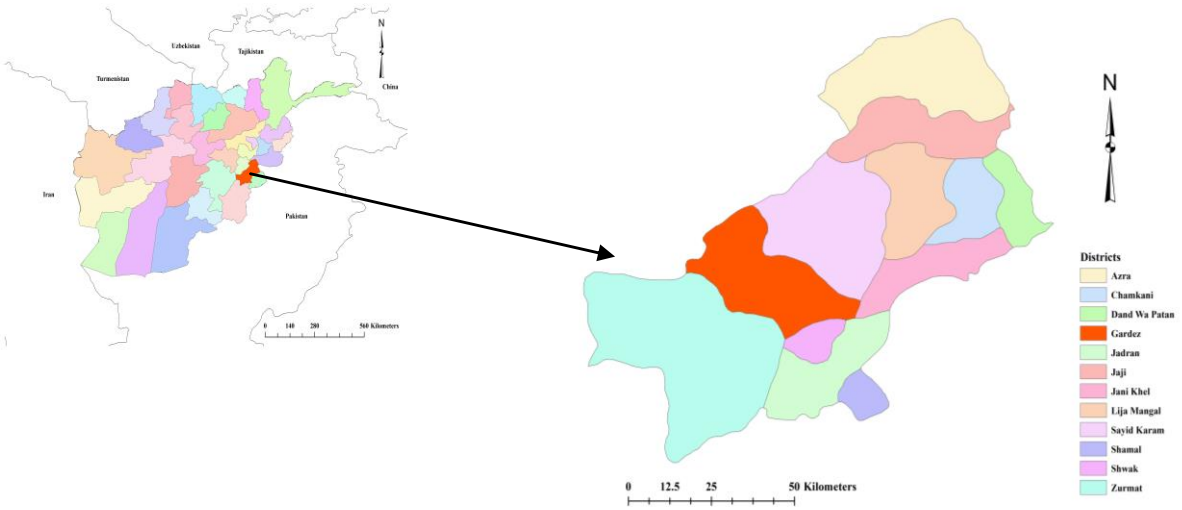


**Fig. 1 District map of Paktya Province**

**Table 1 General topography of Paktya Province**

| Flat | Semi flat | Mountainous | Semi mountainous | Not reported | Total |
|---|---|---|---|---|---|
| 32.3% | 1.9% | 52.0% | 13.1% | 0.7% | 100% |

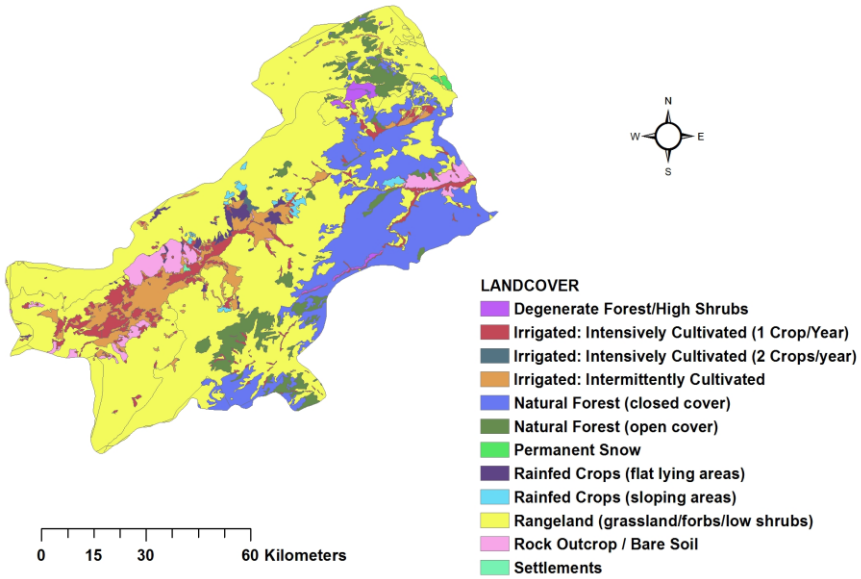


**Fig. 2 Land cover map of Paktya Province**

**Table 2 Questions in the questionnaire sheet**

| Category | Related question | Details |
|---|---|---|
| Basic information of household | - Farmer`s information | Name, Age, Gender, Number of family members, and Address |
| Farmland | -Cultivated area | Size (sq.meter,$m^2$) |
| Crop cultivated | -Kind of crops | Wheat, maize, barely, beans and vegetable |
| Water resource | -Source of irrigation water | Tube well, river and Karez |
| Topography | -Nature of terrain | Flat, semi flat, hilly and mountainous |
| Fertilization | -Type of fertilizers used | Urea, DAP (Diamonium Phosphate), farm yard manure, compost manure and ash |
| Agricultural chemicals | -Type of chemical used | Insecticide, herbicides, fungicides etc. |
| Soil degradation | -Soil erosion effect<br>-Effect soil erosion<br>-Soil conservation measure | Damage level, Nutrient loss and water pollution, Agronomic and physical measures |
| Agricultural extension service | -Extension service provision | Awareness of agricultural extension service |

## METHODOLOGY

In order to identify the current agricultural conditions and constrains, in Paktya Province of Afghanistan, a survey was done in Dawlatzai Village of Paktya Province, Afghanistan, the village is located in the center of Paktya Province and agriculture is the most important sector. Compared to other parts of the districts, it is safer and provides ample environment to conduct the research. A total of 34 farmers were randomly selected across the entire study area and interviewed in the survey. The questions in the questionnaire sheet were on basic information of household, farmland, crop cultivation, water resource, topography, fertilization, agricultural chemicals, soil degradation and agricultural extension services as shown in Table 2. Each farmer was requested to fulfil one form. All forms were fulfilled after all columns were understood by answerers. The data recorded for various parameters were subjected to statistical analysis. Critical Difference (CD) at 1% or 5% level of probability was computed to compare the statistical significance of different treatments.

## RESULTS AND DISCUSSION

### Soil Degradation

As shwon in Table 2, soil degradation was a key challenge for farmers of Paktya Province, environmetal stress by the province's people have drastically altered the landscape and caused widespread enviromental destruction. Since the people lack adequate financial capability to purchase fuel, they mostly cut trees, uproot shrubs and collect animal dung as sources of fuel. This results in extensive soil erosion by both water and wind. Currently, only 6% of the 15% of land in Afghanistan is usable. In case all the refugees come back to Afghanistan, there are predicted problems of land ownership and insufficient available land for agriculture. Natural forests have been severely degraded with deforestation. Although the soil regional map of the province classified by ArcGIS was indicated in Fig. 3, vast areas are subject to soil erosion due to the natural topography and the arid climate. Losses of vegetation and soil humus have created ever more arid conditions (Saba, 2001). Based on the questionnaire survey, 32.4% of responded farmers answered soil erosion happens very severely and 50.0% answered it happens severely as shown in Fig. 4. It means that more than 80% of farmers require the proper conservation strategies for holding soil moisture and fertility. According to the report of Afghanistan Environment (2008), more than 80% of the whole land of Afghanistan could be subject to soil degradation with soil erosion, declining soil fertility, salinization, falling groundwater table, and de-vegetation.

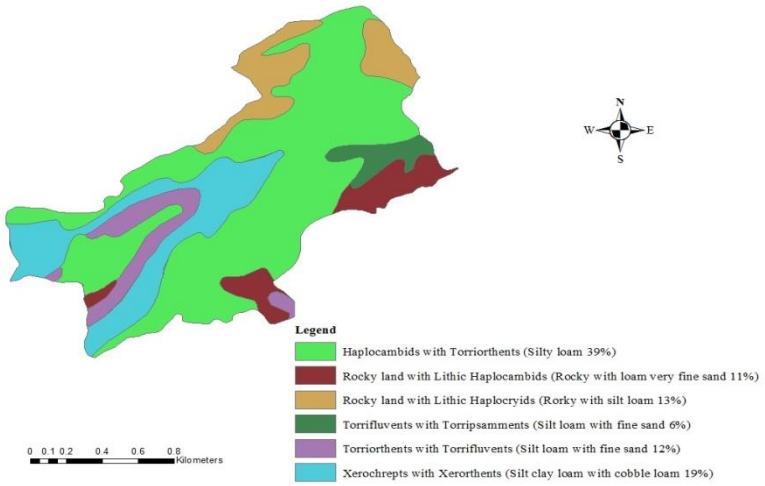


**Fig. 3 Soil region map of Paktya Province (USDA-SCS, 2001)**

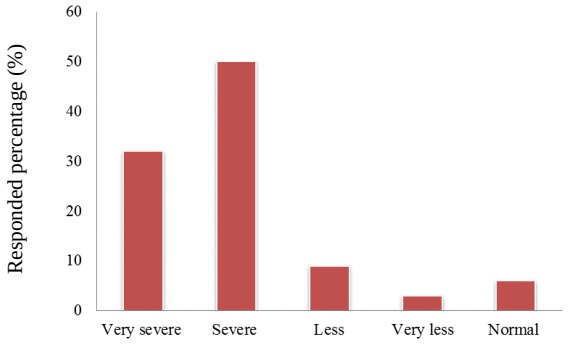


**Fig. 4 Damage level of soil erosion in Dawlatzai Village of Paktya Province**

According to the global assessment of soil degradation (GLASOD) about 16% of Afghanistan's land is severely affected due to anthropogenic activities, whereas the country's vulnerability to desertification is one of the highest in the world (3/4 of Afghanistan is vulnerable to desertification). The geological, topographical and meterological features of Afghanistan naturally increase the country's susceptibility to the processes of soil erosion, furthermore human activities significantly intensify them through farming on steep slopes, deforestation and de-vegetation of lands, as well as unsustainable use of scrub and grasslands.

**Fig. 5 Soil degradation observed in Dawlatzai Village of Paktya Province**

Some degradation is too severe to recovery without human intervention. One of the most threatening impacts arising from loss of soil and vegetation is desertification and increasing floods. Paktya Province is in a mountainous region located in the elevation at 1,500 to 2,300 m above mean sea level with the seasons of warm/dry summers and cold/chilling winter. The average annual rainfall is below 500 mm. The changes in monthly amounts of precipitation and average air temperature in Paktya is indicated (Fig. 5). The rainfall begins in January and reaches its peak in August and ends by October. It hardly rains during the months of May, June, July, August and September, especially in summer (from July to September), also the temperature in summer is high. As a result, water shortages frequently occur in the latter part of the cultivating season in August up-to harvest time in October, causing major difficulties in crop cultivation. Erosion causes a serious problem affecting the productivity of agricultural lands (De luis, et al., 2010). The lack of information on the factors influencing erosion in the dry regions hampers the formation of proper soil conservation plans. Rainfall

in this region is irregular and varies spatially and temporally. Short but intensive thunderstorms of highly erosive rainfall usually take place early in the rainy season in March and at the end of season in June. Although rainfall amounts are not considered high, the problems of soil erosion are severe due to high intensity rainfall on steep slopes with sparse or absent vegetation covered in the arid areas.

**Water Deficiency and Drought**

Paktya is one of the mountainous provinces; it is divided into different valleys and regions. The water of river resource is from Spin Ghar Mountains, which runs from high latitude to eastern part to Karma Agency region and the mountains are the main source of irrigation water for Paktya. The quantity of water is related to rainfall and snow accumulated in the mountains. Most of the rivers are impermanent with increased water levels in February and April, also usually dry in August and September as shown in Fig. 6. Zarmal, Patan and Arub are the main rivers flowing through the province. Springs, Karezs and tub wells also are used as water sources. Unfortunately, during the last three decades war, many Karezs and springs have been destroyed and majority of farmers are now digging the tub wells to get the water needed as shown in Fig. 7. Fuel is required to run these tube wells, but the higher price of fuel has caused another acute problem to the farmers of the province. Accordingly, majority of agricultural lands are rain-fed with no alternative methods of artificial irrigation.

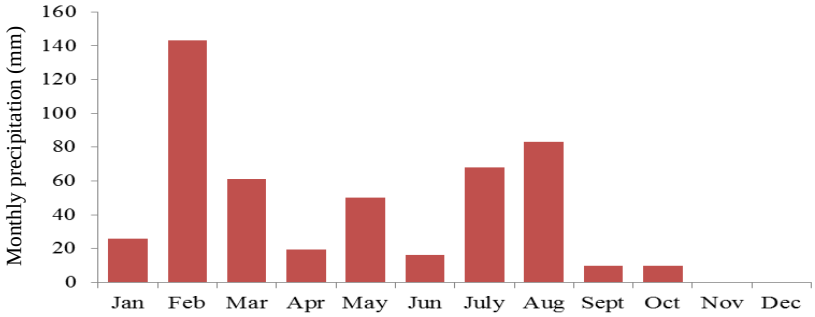


**Fig. 6 Monthly precipitation in Paktya Province**

**Fig. 7 Water problems in Dawlatzai Village of Paktya Province**

About 88% of farmers reported lack of irrigation is a main problem that they are facing (Fig. 8). More than 85% land needs artificial irrigation. This has proved as one of the noticeable factors that are reducing the agricultural productivity considerably. According to the UNEP Post-Conflict Environment Assessment Report on Afghanistan, the amounts of water used are less than one-third of total water potential at 75,000 million $m^3$. Due to three decades political unrest and civil war, Afghanistan faces many different problems; water scarcity, damaged water infrastructure systems (Habibullah Habib, 2014).

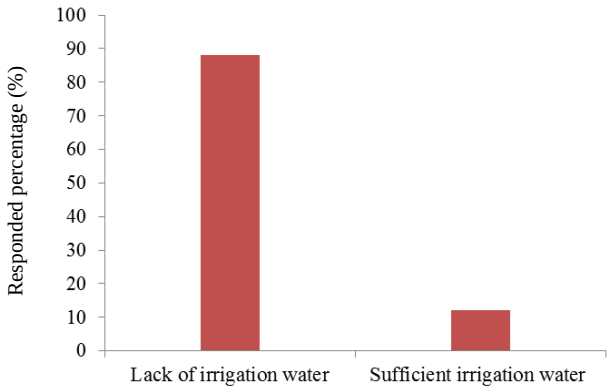


**Fig. 8 Shortage of irrigation water**

## Agricultural Extension Services

Agricultural extension is one of the powerful forces that are responsible for the growth of crops by transferring latest and improved technologies to the farmers and ultimately strengthens the national economy (Sadaf, et al., 2005). Paktya Province has fourteen districts. Unfortunately just one extension worker has been appointed for the six districts while the other 8 districts have none. It is impossible for a single person to reach the huge numbers of farmers and to solve their problems. According to the questionnaire survey, 64.2% of the farmers did not know about the active extension worker. As the result, the farmers lack the modern technical knowledge and still the age old traditional farming has been practiced, which is in turn hampering the agriculture production and ultimately the life style of people.

## Quality of Agricultural Materials

Quality seed is an important asset for quality of production. It effects germination as well as the overall vigor of the plants, especially for the case of wheat (Barnard and Calitz, 2011). The Department of Agriculture, Irrigation and Livestock is responsible for the seed distribution. But, due to the limited availability of certified seed and misguidance by many local seed distributors, farmers are forced to use the low quality uncertified seeds. More than 70% of the farmers were found not to have access to quality seeds. Utilization of poor quality seeds is one of the major problems in agriculture which is responsible for low crop productivity (DAIL, 2014).

Although Afghanistan Government has claimed that the pesticide contamination and requested to decrease its usage, but still there is continuous use of low quality insecticides. Poor quality insecticides affect natural environment and also induce some of the serious health issues due to their prolonged residual effects (Jabbar and Mallick, 1994). Some private agricultural companies and agro-clinics are importing the low quality insecticide and pesticide from Pakistan, Iran and China (DAIL, 2014). About 31.6% of the farmers are using the pesticides that are not even recommended for application. Thus, Afghan Government has been unable to completely ban or control such ill practices.

## CONCLUSION

Paktya Province is based on the agricultural economy, but the condition of the farmers is severe. According to the topographical and climate conditions, modern farming methods employing artificial irrigation are indispensable. If some alternative sources of irrigation or modern methods of irrigation are popularized among local farmers, the condition of agriculture would be largely improved. The main problems that Paktya Province is facing today are those of soil degradation, deforestation, lack of irrigation water and pollution, poor extension services and lack of agricultural inputs. All of these, in turn, contribute to the declining agricultural production. In addition, 32.4% of the farmers responded that soil erosion happens very severely and 50.0% answered soil erosion happen severely. It means that more than 80% of farmers require proper conservation strategies for holding soil fertility. In addition, 88% of farmers reported lack of irrigation water and that more than 85% of arable land needs artificial irrigation system.

## ACKNOWLEDGEMENTS

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Research article

# The Analyses of Efficiency and Factors Affecting Efficiency of Agricultural Cooperatives in Lower Northern Region of Thailand

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**Abstract** Agricultural cooperative has been a crucial community business for Thais in the rural area of Thailand over 100 years. It is important to analyses of efficiency and factors affecting efficiency. The research objectives were to (1) analyze the efficiency of agricultural cooperatives in the lower-northern area of Thailand utilized by the Data Environment Analysis Model (DEA Model) and (2) study the factors affecting the efficiency and operational development of agricultural cooperatives in the lower-northern area of Thailand. The research population comprised of agricultural cooperatives which identified as the general agricultural cooperatives. The study area covered nine provinces comprise of 196 cooperatives. The secondary data were collected from Financial Information Data Base of the Department of Cooperative Auditing, Ministry of Agriculture and Cooperatives. The data were analyzed by using Data Environment Analysis Model and Ordered Probit Model. The major findings were (1) the entire efficiency index of agricultural cooperatives in the lower-northern area of Thailand expressed at the medium score index of efficiency. The return to scale of agricultural cooperative operations in the lower-northern area of Thailand lighted on the Constant Return to Scale (CRS), Diminishing Return to Scale (DRS), as well as Increasing Return to Scale (IRS) of 15.31, 49.49, and 35.20, respectively. (2) Factors affecting the efficiency and operational development of agricultural cooperatives in the lower-northern area of Thailand expressed by value of total assets and value of credit business. According to the research results, it was suggested that the cooperative operations should be reached the maximum point of efficiency and it is necessary for cooperatives to make the operation cost management, the resources of co-operative operations which comprised of the entire co-operative assets. Moreover; the cooperatives should pay the crucial role on credit business management.

**Keywords** efficiency analysis, factors affecting efficiency, agricultural cooperatives Ltd.

## INTRODUCTION

A cooperative is an autonomous association of people who voluntarily cooperate for their mutual social, economic, and cultural benefit. Cooperatives include non-profit community organizations and businesses that are owned and managed by the people who use their services, a consumer cooperative, or by the people who work there or by the people who live there, hybrids such as worker cooperatives that are also consumer cooperatives or credit unions, multi-stakeholder cooperatives such as those that bring together civil society and local actors to deliver community needs, and second and third tier cooperatives whose members are other cooperatives. (The World Cooperative Monitor, 2015).

Cooperative in Thailand was defined by 2 major groups; 1) Agricultural Co-operative sector and 2) Non-Agricultural Co-operative. The agricultural cooperatives sector was comprised of agricultural cooperative, land settlement cooperative, and fisheries cooperatives while the non-agricultural sector was comprised of consumer cooperative, saving cooperative, service cooperatives and credit union cooperative. (The Federal of Savings and Credit Cooperative of Thailand Ltd, 2015)

In Thailand, Agricultural cooperatives were generally organized among the people engaging in agricultural earning with varying kinds and degrees of need, thus resulting with various agricultural cooperative types. Basically, the royal Thai government utilized agricultural cooperative as the tool for rural development especially in the agricultural and rural area since Thailand has been agricultural economy base so the agricultural sector still be the important part in Thai economy. In addition, agricultural cooperatives have been the biggest proportion among 7 types of Thai cooperatives which was accounted for 53 percent. (The Cooperative Promotion Department, Ministry of Agriculture and Cooperative, the Royal Thai Government, 2015)

It is importance to analyses the efficiency of agricultural cooperatives in Thailand especially in the Lower Northern region of Thailand which has been and still be the main agricultural area of the country. The research also examined factors affecting on their efficiency, and finally find out the guidance to help Agricultural Co-operatives to improve their operational efficiency.

## OBJECTIVE

The objectives of this study are as follows.

1. To analyze the agricultural cooperatives Ltd. efficiency in the lower northern region of Thailand.
2. To find out the factors affecting on agricultural cooperatives efficiency and develop agricultural cooperatives' operation in the lower northern region of Thailand.

## METHODOLOGY

The Study Population was comprised of agricultural cooperatives Ltd. which operated in 9 provinces in the lower northern region of Thailand which include Kampangpet, Tak, Nakhonsawan, Pichit, Pitsanulook, Petchabul, Sukhothai, Utaradit Provinces, and Uthaithani Province which accounted for 196 cooperatives.


**Fig. 1 Map of lower northern region of Thailand**

The data was collected by secondary data from the information data base of Department of Co-operatives Audit, Ministry of Agriculture and Cooperatives, The Royal Thai Government which comprised of the inputs data; cooperatives operational capitals, cooperatives' debt, expenditures, the numbers of officers, output data which comprised of total revenues, and number of cooperatives 'members. The data analysis was utilized Data Envelopment Analysis Model (DEA) to find out the index of efficiency. The DEA is a relatively new data oriented approach for evaluating the performance of a set of peer entities called Decision Making Units (DMUs) which convert multiple inputs into multiple outputs (W. Cooper, 1984). This concept could be expressed as the following diagram.

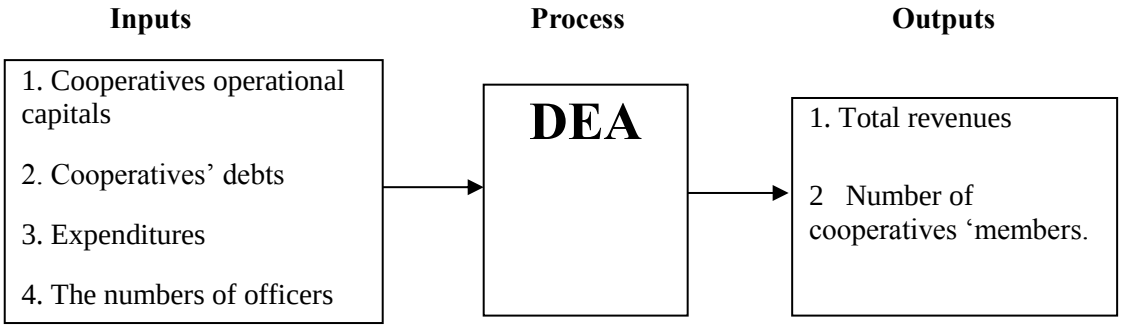


**Fig. 2 Concept of inputs to outputs through Data Envelopment Analysis Model**

The Analysis of factors affecting on Agricultural Co-operatives Ltd efficiency, was exploited by Ordered Probit which was expressed by the following equation:

$$Efficiency = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7) \quad (1)$$

Where: $X_1$, = *The Value of Agricultural Cooperatives Assets*
$X_2$, = *The Numbers of Agricultural Cooperatives Officers*
$X_3$, = *The Value of Agricultural Cooperatives Deposit*
$X_4$ = *The Value of Agricultural Cooperatives Credits*
$X_5$ = *The Value of Agricultural Cooperatives Selling Business*
$X_6$ = *The Value of Agricultural Cooperatives Collecting Business*
$X_7$ = *The Value of Agricultural Cooperatives Processing Business*

## RESULTS AND DISCUSSION

In order to answer the first research objective, the research results could be expressed as the efficiency of agricultural cooperatives Ltd. in the Lower Northern region of Thailand as showed in Table 1.

**Table 1 Agricultural Co-operatives Ltd. efficiency in the Lower Northern region of Thailand**

| The Level of Efficiency | | Agricultural Co-operatives Ltd. | | |
|---|---|---|---|---|
| Score | Meaning | Numbers | Percentage | The Average TE |
| 0.81 – 1.00 | The Highest Efficiency | 133 | 68.88 | 0.926 |
| 0.61 – 0.80 | The High Efficiency | 33 | 16.84 | 0.725 |
| 0.41 – 0.60 | The Medium Efficiency | 17 | 8.67 | 0.523 |
| 0.21 – 0.40 | The Small Efficiency | 9 | 4.59 | 0.311 |
| 0.00 – 0.20 | The Minimum Efficiency | 2 | 1.02 | 0.150 |
| Total | | 196 | 100 | 0.527 |

According to Table 1, the 133 out of 196 Agricultural Cooperatives Ltd. received the highest efficiency which accounted for 68.88 percent, with the 0.926 or 92.60 percent of Technical Efficiency (TE). This mean that majority of Agricultural Cooperatives Ltd in the Lower Northern region of Thailand performed their operation in the good shape. There were only 2 Agricultural Cooperatives accounted for 1.02 percent faced with the minimum efficiency which would be improved.

In order to answer the second research objective for factors affecting on efficiency, the results could be expressed as Tables 2 and 3.

**Table 2 Factors affecting on agricultural cooperatives Ltd. efficiency**

| Variables | Coefficients | Standard Error | Marginal Effects | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | t Stat | P (Y=0) | P (Y=1) | P (Y=2) | P (Y=3) | P (Y=4) |
| Intercept | 29152.10607 | 343926.6336 | 0.08476257 | 0.93254034 | -649299.13 | 707603.345 | -649299.13 | 707603.345 |
| X 1 | 0.029905614 | 0.0040159 | 7.44680323 | 3.3542E-12 | 0.0219836 | 0.03782763 | 0.0219836 | 0.03782763 |
| X 2 | -152661.379 | 52791.37576 | -2.8917863 | 0.00428213 | -256800.96 | -48521.802 | -256800.96 | -48521.802 |
| X 3 | -0.00717676 | 0.005729983 | -1.2524932 | 0.21194601 | -0.0184801 | 0.00412656 | -0.0184801 | 0.00412656 |
| X 4 | 0.029655875 | 0.007794125 | 3.80490123 | 0.00019177 | 0.0142807 | 0.04503105 | 0.0142807 | 0.04503105 |
| X 5 | -0.01626762 | 0.006648256 | -2.4469003 | 0.01532823 | -0.0293824 | -0.0031529 | -0.0293824 | -0.0031529 |
| X 6 | -0.01106485 | 0.013729747 | -0.8059036 | 0.42131665 | -0.038149 | 0.01601931 | -0.038149 | 0.01601931 |
| X 7 | -0.86824247 | 0.235262534 | -3.6905259 | 0.00029302 | -1.3323361 | -0.4041488 | -1.3323361 | -0.4041488 |

**Table 3 Results of Ordered Probit Model for analyzing factors affecting on agricultural cooperatives Ltd. efficiency**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | 29152.106 | 343926.634 | | 0.085 | 0.933 |
| | x1 | 0.03 | 0.004 | 0.841 | 7.447 | 0 |
| | x2 | -152661.379 | 52791.376 | -0.278 | -2.892 | 0.004 |
| | x3 | -0.007 | 0.006 | -0.127 | -1.252 | 0.212 |
| | x4 | 0.03 | 0.008 | 0.398 | 3.805 | 0 |
| | x5 | -0.016 | 0.007 | -0.147 | -2.447 | 0.015 |
| | x6 | -0.011 | 0.014 | -0.034 | -0.806 | 0.421 |
| | x7 | -0.868 | 0.235 | -0.156 | -3.691 | 0 |

According to factors affecting on agricultural cooperatives efficiency, there were 5 factors that had affected on efficiency which were 1) the numbers of agricultural cooperatives officers, 2) the value of agricultural cooperatives deposit, 3) the value of agricultural cooperatives credit, 4) the value of agricultural cooperatives selling business, and 5) the value of agricultural cooperatives processing business.

The research could be concluded that the majority of agricultural cooperatives Ltd. in the lower northern region of Thailand performed in the highest efficiency. This indicated that agricultural cooperatives Ltd. in the lower northern region of Thailand have been the main and crucial way to get into economic development since cooperatives would be the only one community business for people who live in the rural area that get along with the study of Chuamauengphan, (2003) and Kaewthip S.

(2014). The Royal Thai Government could have the program to promote the agricultural cooperatives business.

## CONCLUSION

Majority of agricultural cooperatives Ltd. in the lower northern region of Thailand performed in the highest efficiency. This means that in lower northern region of Thailand, agricultural cooperatives has been the crucial community business to help people for their better standard of living in Thailand. Moreover, the Royal Thai Government would take this research result to utilize the agricultural cooperatives Ltd. as the tool for community development.

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Research article

# Diversity of Aquatic Insects in the Organic and Conventional Rice Fields in Khon Kaen Thailand

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**Abstract** Water quality has significant effects toward the diversity and distribution of aquatic insect. The application of fertilizer and pesticides may degrade water quality and affect to diversity of aquatic insects. Aquatic insect in rice fields was surveyed to compare the diversity between organic and conventional rice fields in Khon Kaen province during June to October 2015. Three replication of sampling by aquatic sweep net were conducted at sampling sites. The result showed that aquatic insect was represented by 17 species belongs to 16 families of 6 orders. The order Hemiptera was the highest in abundance groups in the fields (5 families) followed by Odonata (3 families), Diptera (3 families), Coleoptera (2 families), Ephemeroptera was the lowest in abundance (2 families) and Collembola (unidentified family). The richness of aquatic insects in the organic rice field was found slightly higher than the conventional one. The species diversity index ($H'$) was 0.427 in organic site and conventional site was 0.401. This study is considered to have no significant in diversity or abundance of aquatic insects between organic and conventional rice field. Order Hemiptera was found abundant and dominant among other orders.

**Keywords a**quatic insect, organic rice field, conventional rice field

## INTRODUCTION

Rice production is one of the main agricultural activities in Thailand. Mostly, there are two types of rice cultivation include organic and conventional methods (Kenji et al. 2005). For the convention rice cultivation, synthetic chemicals such as fertilizer and pesticides are generally applied while these chemicals are not used in the organic rice cultivation. Aquatic insects play an important role in aquatic ecosystem functioning (Dunbar et al., 2010). They are an important component of invertebrate assemblages in aquatic ecosystem where they are a controlling group in food webs. At the larval stage, they constitute the principal nutritive fauna for fish. Diversity of aquatic insects in rice field can be divided into two groups: beneficial and insect pests (Bambaradeniya, 2000; DOA, 2010). The beneficial insects are usually known as natural enemies Natural enemies are also known as biological agents in biological control for minimizing the population of insect pests. In paddy field, some of the predators in rice fields are associated with water. Improper agronomic practices in rice field such as the extensive used of fertilizers and pesticides may degrade the disturbance of water quality. The diversity and distribution of aquatic insect communities, considering that some species of insects are very sensitive to pollution and prefer to live in good environment with good quality water (Mohd Rasdi et al. 2012). Thus, the objective of this study is to compared diversity of aquatic insects between organic and conventional rice cultivation in Khon Kaen province northeastern Thailand.

## METHODOLOGY

The study was carried out in irrigation rice fields at the Khon Kaen province, north-eastern Thailand during June to October 2015. Study site was divided into two plots; organic cultivation (no chemical pesticides and chemical fertilizers applied) and conventional cultivation (applied chemical pesticides and chemical fertilizers). The samples were taken two2 periods including early period (30 days after transplanting, DAT) and mid period (60 days after transplanting, DAT). Aquatic insects were collected in three replications at each sampling areas. The insects were randomly collected using sweeping net dragged about one meter. The samples were preserved in 70% ethyl alcohol and were identified at least up to taxonomic order using the identification guides of Dudgeon (1999), McCafferty (1983), Yule and Sen (2004). The specimens were also compared with the reference collections at the Insect Museum, Faculty of Agriculture, Khon Kaen University. The Shannon-Wiener's diversity index (Krebs, 1999), was used to calculate the diversity of aquatic insects. The formula of the Shannon-Wiener's diversity index (*H´)* used is presented as follow

$$H' = \sum_{i=1}^{s} (pi)(\ln pi)$$

Where *H*' is species diversity index, *s* is number of species and *pi* is proportion of the total sample belonging to *i* th species. The evenness index (J´) (Krebs, 1999) was calculated to determine the equal abundance of aquatic insects in each study site as follows:

$$J' = \frac{H'}{H'\mathrm{MAX}}$$

Where *H´* is observed index of species diversity and *H´*MAX is maximum possible index of diversity. Shannaon-Wiener Index (H') which accounts for both abundance and evenness was used to characterize species diversity. Diversity values may very directly with water quality and low diversity may indicate an unstable community (Chiangthong and Phalaraksh, 2007).

## RESULTS AND DISCUSSION

A total of 951 individual of aquatic insects from six orders (Hemiptera, Diptera, Coleoptera, Odonata, Ephemeroptera and Collembola) and twenty-three different families were recorded in this study. The order Hemiptera was the highest in abundance groups (8 families included Hydrometridae Mesoveliidae Micronectidae Notonectidae Veliidae Nepidae Gerridae and Pleidae) followed by Coleoptera (5 families included Dytiscidae Norteridae Hydraenidae Hydrophilidae and Scirtidae), Diptera (4 families included Ceratopogonidae Chironomidae Culicidae and Stratiomyidae), Odonata (3 families included Coenagrionidae Libellulidae and Protoneuridae) Ephemeroptera (2 families of Baetidae and Caenidae) and Collembola was the lowest in abundance (1 unidentified family). Table 1 shows the insect composition for two sampling periods of two studied sites. The most abundance of aquatic insect was found in mid period than the early period. The richness of aquatic insects in the organic site was found slightly higher than the conventional site. The dominant aquatic insects found in this study were from the Micronectidae with 21 percentage of abundance followed by Baetidae (18.30 %) and Coenagrionidae (6.73%). In organic rice field, the Order Hemiptera was found highest in number of taxa followed by Odonata and Diptera in early period (30DAT). Order Hemiptera was also the highest of number taxa in the mid period (60 DAT) followed by Ephemeroptera and Diptera respectively. Meanwhile, order Collembola was found only in mid period (Fig. 1). In conventional rice field, order Odonata was found highest of number taxa in early period followed by order Hemiptera and Diptera respectively while order Ephemeroptera was found highest of number taxa in mid period

followed by order Coleoptera and Hemiptera respectively. In this study, order Collembola was found only in mid period similar to the organic rice field. The Collembola is dominant group of scavenger in the rice field. They are known as an important source prey for predator insect (Alvarez et al , 1997) The collembolan are more abundant in moist rice soil rich in organic matter and may decrease abundant in rice field after pesticide application. Moreover, the different species react differently to the changing conditions as the plant grows and canopy close (Takagi et al., 1996).


**Fig. 1 Taxonomic of aquatic insects in conventional rice field**

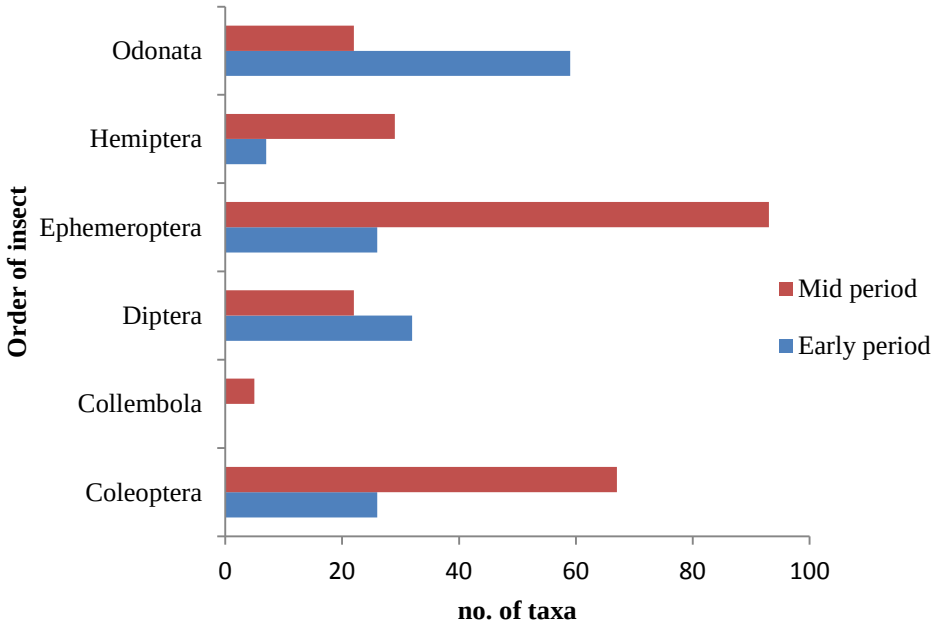


**Fig. 2 Taxonomic of aquatic insects in the conventional rice field**

**Table 1 Relative proportion of aquatic insects in the organic rice field (ORG) and the conventional rice field (CON) at Khon Kaen province Thailand**

| | | | Early Period | | Mid Period | | total | %abundance |
|---|---|---|---|---|---|---|---|---|
| Order | Family | Genus | ORG | CON | ORG | CON | | |
| Coleoptera | Dytiscidae | unknown | 2 | 0 | 5 | 6 | 13 | 1.37 |
| Coleoptera | Dytiscidae | *Hydaticus sp.* | 0 | 23 | 0 | 1 | 24 | 2.52 |
| Coleoptera | Dytiscidae | *Hydrovatus sp.* | 1 | 0 | 1 | 8 | 10 | 1.05 |
| Coleoptera | Dytiscidae | *Hydroporus sp.* | 0 | 0 | 1 | 0 | 1 | 0.11 |
| Coleoptera | Dytiscidae | *Hyphydrus sp.* | 9 | 0 | 7 | 0 | 16 | 1.68 |
| Coleoptera | Dytiscidae | *Eretes sp.* | 1 | 0 | 0 | 0 | 1 | 0.11 |
| Coleoptera | Norteridae | unknown | 0 | 0 | 2 | 2 | 4 | 0.42 |
| Coleoptera | Norteridae | *Hydrocanthus sp.* | 0 | 0 | 0 | 1 | 1 | 0.11 |
| Coleoptera | Hydraenidae | *Hydraena sp.* | 2 | 0 | 0 | 1 | 3 | 0.32 |
| Coleoptera | Hydrophilidae | unknown | 1 | 2 | 0 | 31 | 34 | 3.58 |
| Coleoptera | Hydrophilidae | *Hydrobiomorpha sp.* | 0 | 1 | 0 | 4 | 5 | 0.53 |
| Coleoptera | Scirtidae | unknown | 0 | 0 | 8 | 12 | 20 | 2.10 |
| Collembola | | | 0 | 0 | 38 | 5 | 43 | 4.52 |
| Diptera | unknown | | 0 | 0 | 1 | 0 | 1 | 0.11 |
| Diptera | Ceratopogonidae | *Bezzia sp.* | 1 | 0 | 23 | 1 | 25 | 2.63 |
| Diptera | Chironomidae | *Chironominae* | 12 | 0 | 22 | 4 | 38 | 4.00 |
| Diptera | Chironomidae | *Tanypodinae* | 8 | 21 | 6 | 0 | 35 | 3.68 |
| Diptera | Culicidae | unknown | 12 | 8 | 0 | 17 | 37 | 3.89 |
| Diptera | Stratiomyidae | *Odontomyia sp.* | 1 | 3 | 4 | 0 | 8 | 0.84 |
| Ephemeroptera | Baetidae | *Cloeon sp.* | 26 | 0 | 57 | 91 | 174 | 18.30 |
| Ephemeroptera | Caenidae | *Caenodes sp.* | 0 | 26 | 1 | 2 | 29 | 3.05 |
| Hemiptera | Hydrometridae | *Hydrometra sp.* | 0 | 0 | 2 | 1 | 3 | 0.32 |
| Hemiptera | Mesoveliidae | *Mesovelia sp.* | 0 | 0 | 1 | 7 | 8 | 0.84 |
| Hemiptera | Micronectidae | *Micronecta sp.* | 105 | 1 | 90 | 10 | 206 | 21.66 |
| Hemiptera | Notonectidae | *Notonecta sp.* | 0 | 3 | 5 | 0 | 8 | 0.84 |
| Hemiptera | Notonectidae | *Aphelonecta sp.* | 7 | 0 | 0 | 0 | 7 | 0.74 |
| Hemiptera | Notonectidae | *Nychia sp.* | 0 | 0 | 9 | 0 | 9 | 0.95 |
| Hemiptera | Veliidae | *Pseudovelia sp.* | 0 | 0 | 0 | 1 | 1 | 0.11 |
| Hemiptera | Nepidae | *Ranatra sp.* | 3 | 0 | 0 | 0 | 3 | 0.32 |
| Hemiptera | Nepidae | *Laccotrepes sp.* | 1 | 1 | 0 | 0 | 2 | 0.21 |
| Hemiptera | Gerridae | *Amemboa sp.* | 0 | 2 | 0 | 0 | 2 | 0.21 |
| Hemiptera | pleidae | *Paraplea sp.* | 1 | 0 | 0 | 0 | 1 | 0.11 |
| Odonata | Coenagrionidae | unknown | 0 | 0 | 5 | 22 | 27 | 2.84 |
| Odonata | Coenagrionidae | *Agrionemis sp.* | 63 | 0 | 1 | 0 | 64 | 6.73 |
| Odonata | Libellulidae | *Brachythemis sp.* | 1 | 33 | 0 | 0 | 34 | 3.58 |
| Odonata | Libellulidae | *Crocothemis sp.* | 24 | 0 | 0 | 0 | 24 | 2.52 |
| Odonata | Libellulidae | *Orthemis sp.* | 0 | 24 | 0 | 0 | 24 | 2.52 |
| Odonata | Libellulidae | *sympetum sp.* | 0 | 1 | 0 | 0 | 1 | 0.11 |
| Odonata | Protoneuridae | *Prodasineura sp.* | 4 | 1 | 0 | 0 | 5 | 0.53 |
| | | total | 285 | 150 | 289 | 227 | 951 | 100 |

The highest Shannon-Weiner Index in organic rice fields which was 2.02 in mid period. The lowest indexes were found in conventional rice fields and organic rice which was 1.92 in early period (Fig. 3). In this study the diversity index of aquatic insects is no different between organic and conventional rice field were similar to those recorded by Rozilah and Ali (1998), where no significant in diversity or abundance of aquatic insects when insecticide treated and untreated rice fields were compare. This study showed that the number of families in aquatic insects from organic cultivation (15 families) was less than conventional cultivation (16 families) in mid period, but found that Shannon-Weiner Index average score was higher in organic site than conventional site and found the populations of aquatic insects were higher in the fields. Roger (1996), maintain that the dominance of faunal assemblages by one or two taxa and lowered species richness is likely to indicate community disturbance by agrochemicals in rice field environments. In this study, the insect samples taken from the organic rice field in mid period assemblages with greater richness and slightly higher Shannon diversity indices than those collected from the conventional rice field. The major distinction between these management regimes was the application of agrochemicals exclusively to the conventional rice fields. According to Settle et al., (1996) demonstrated that the loss of species richness and decreased faunal assemblage evenness after pesticide applications.

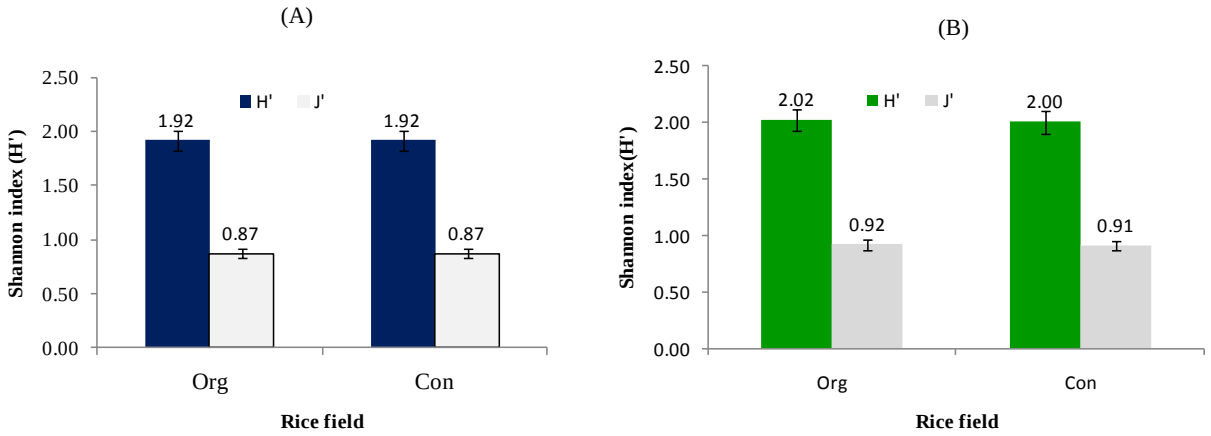


**Fig. 3 Comparison between Shannon index and Evenness of aquatic insects in organic rice field (org) and conventional rice field (Con): (A) early period, (B) mid period**

## CONCLUSION

This study concluded that the organic cultivation method was recommended to apply in rice fields. Although, Shannon-Wiener diversity index showed no significantly difference between two rice cultivation practices. The interesting point arising from this study is that the aquatic insects representative of the Coleoptera, Hemiptera and Odonata were all beneficial insects as predator of rice pest. The result from this study indicates that the aquatic insect communities are important factors for check and balance in rice fields thereby controlling increase in insect pest populations. This condition is important in understanding ecological rice pest management. For the further work, the water parameters should be included.

## ACKNOWLEDGEMENTS

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Research article

# Variation in Grain Morphology of Upland Rice Varieties from Luang prabang Province Lao PDR

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**Abstract** Luang prabang province is recognized as a major area of the diversity of *Oryza sativa* L. in Lao PDR. Grain morphological characteristics can be used as the primary information of genetic variation among different rice varieties in the local germplasm which can be a source of value adding traits for rice breeding programs. The purpose of this study was evaluated variation in grain morphological characteristics of upland rice varieties from Luang prabang province, Lao PDR. The samples were collected from three districts, Ponxay (PX), Pak Ou (PO) and Xieng Ngeun (XNg), two villages each. Grain morphological characteristics were measured including grain size (length, width, and thickness), weight, shape, and endosperm type and pericarp color. The total of 60 samples were collected which was separated into 26, 10, and 24 samples from PX, PO, and XNg, respectively and among these samples 42 and 18 samples were glutinous and non-glutinous endosperm types, respectively. The 51 samples were found in non-pigmented, 4 in red and 5 in black pericarp colors. There was variation of grain size among 60 samples. Grain length, width and thickness were ranging from 8.61-11.63, 2.67-4.27 and 1.97-2.47 mm, respectively. Grain shape was determined by using the ratio of grain length/width and most samples (58 varieties) were distinguished as large grain type and the rest in slender type. One hundred grain weight was also varied from 2.05-4.04 g among brown rice of 60 samples. The grain weight was varied with grain length, width and thickness in multiple regression of y = 0.39 (grain length) + 0.53 (grain width) + 1.42 (grain thickness) – 5.52 at $R^2$ = 0.89 ($p < 0.05$). This study demonstrated the variation in grain morphological characteristics of upland rice varieties from Luang prabang province, Lao PDR. The variation of nutritional quality was subjected to evaluate in the further investigation which can be used as the basic information for the selection traits of rice varieties in the further breeding program.

**Keywords** Luang prabang, rice varieties, rice grain morphological characteristics, color, weight, village

## INTRODUCTION

Grain morphological characteristics especially size and shape is an important component of grain yield and quality which have been used as the criterion of selection since cereals were first domesticated (Wang et al., 2012). Preferences for grain size and shape vary from one group of consumers to another. Some ethnic groups prefer short bold grains, some prefer medium-long grains, and other highly prize long slender grains. In general, long grains are preferred in the Indian subcontinent, but medium to medium-long rice are preferred in Southeast Asia (IRRI, 2002).

Globally, improving quantity and quality of rice grain have been approached to solve several problems among the world population such as decreasing the number of hidden hunger and malnutrition (Burchi et al., 2011). Breeding for high yielding and nutritional quality has been suggested as strategy to solve the problems (Marie and Howarth, 1997), especially in Laos where malnutrition problems are wide spread among the population due to consumption of low nutritional value rice (WHO, 2011). On the other hand, rice is an important source of energy, iron, calcium, vitamins, and protein in the diet of the Asian population, including Laos (IRRI, 1993). However, a wide variation of grain morphological characteristics will be required as source of genetic materials in breeding for some specific traits as it would be effect on consumer's acceptance at the end of processes.

Luang prabang is one of the provinces in the northern of Lao PDR and it has been reported to be rich in genetic diversity among rice germplasms. A total of 13,192 samples of traditional varieties were collected in Lao PDR since 1995 to 2000, it was found the largest germplasm of 5,915 (44.8%) varieties in the northern region and Luang prabang had 1,243 samples (9.4% of the total) and 85.5% of the collected samples were glutinous rice (Appa Rao et al., 2002). Therefore, Luang prabang has been recognized as rice diversity areas in Lao PDR and it is approximately 25% of the total upland rice production area of the country, where rice is cultivated on sloping land using slash-and-burn methods without tillage and input fertilizers (World Bank, 1995). However, there has not been reported yet in detail on variation of some useful traits among this germplasm and grain morphology are the characters that easy and rapid to determine.

Previous studies reported that seed of local rice varieties maintained by farmers are genetically diverse (Dennis, 1987). Different varieties can be given similar names and different names can be applied to the same varieties (Harlan, 1992). Diversity analyses may be based on morphological characteristics such as shape, size and pigmentation of plant parts that local farmers use to distinguish different rice varieties (Morishima et al., 1980). Molecular techniques such as AFLP, ISSR and SSR (Saini et al., 2004) allow variation to be evaluated between individual plants. Grain morphological characteristics can be used as the primary information of genetic variation among different rice varieties in the local germplasm.

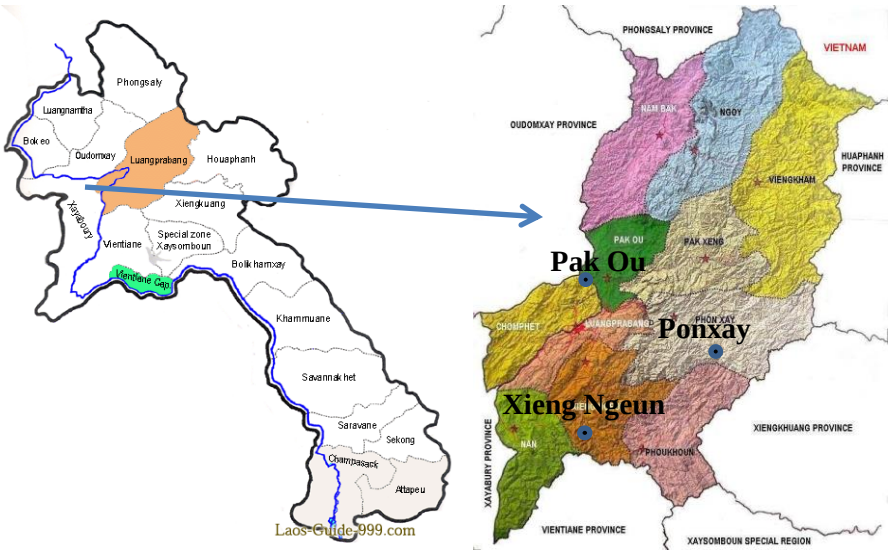


**Fig. 1 Map of Luang prabang province, Lao PDR and the detail location of 3 districts (Ponxay, Pak Ou and Xieng Ngeun), where the upland rice samples were collected**

## OBJECTIVE

This study was attempted to identify grain morphological characteristics of upland rice varieties collected from different locations at Luang prabang province, Lao PDR.

## METHODOLOGY

Rice samples were collected among 3 districts, Ponxay (PX), Pak Ou (PO) and Xieng Ngeun (XNg) with 2 villages each from Luang prabang Province, Lao PDR (Fig. 1). The totals of 60 rice samples were collected from farmers. Grain morphological characteristics were determined among each sample of the total collection. Seed size (grain length, width, and thickness) of the unhusked seed was measured by digital Vernier caliper (50 seeds for each sample). The unhusked seeds were dehusked manually by hand to separate between the husk and brown rice. The 100 grains weight of unhusked and brown rice grains was weighed in 3 independent replications. The color of hull and pericarp was also recorded. The analysis of variance was used to determine the significant difference of each morphological characteristic among rice varieties at $p<0.05$ by statistical analysis software STATISTIX 8.0. The Least Significant Difference was used to indicate the difference of grain size, weight and shape among varieties.

## RESULTS AND DISCUSSION

The total of 60 upland rice samples (42 glutinous and 18 non-glutinous endosperm types) were collected from three districts with 2 representative villages each of Luang prabang province, Lao PDR. 26 samples from PX (14 in Chomchieng (CC) and 12 in Houameuang (HM)), 10 samples from PO (6 in Hoi-Oth (HO) and 4 in Hoi-Loh (HL)) and 24 samples from XNg (10 in Phasanine (PSN) and 14 in Phouthat (PT)). Luang Prabang has been designated as one of the center diversity of *Oryza sativa* L. in Laos (Appa Rao et al., 2002). Even though many characteristics have not been evaluated the variation yet, but genetic diversity among the germplasm has been declared in this area. The variation of endosperm type is depending on the usual consumption and traditional preference among consumers in each area. It has been reported that Hmong ethnic group preferred to consume non-glutinous rice rather than glutinous rice, while Khamu ethnic group preferred glutinous rice (Sengxua, 2006; Roder et al., 1996).

### Grain Morphological Characteristics

51 samples found in off white pericarp color (non-pigmented color) (33 in glutinous and 18 in non-glutinous), 4 in red and 5 in black color (glutinous). This suggests that the highland rice germplasm is mostly in white pericarp color which may not depend on the satisfying on the demand market, but their consumption preference. However, special quality rice, e.g. varieties with pigmented pericarp with black and red color has been found and recognized as high antioxidative properties which can protect against oxidative damages in a range of diseases such as cardiovascular and cancer diseases (Cicero and Derosa, 2005). Unlike grain shape and size, these properties can be varied according to the interaction between rice varieties x growing condition which should carefully pay attention when dealing with these properties in the future (Nkori Kibanda and Luzi-Kihupi, 2007).

Grain weight and size of brown rice was varied among different rice samples collected ($p < 0.05$) (Table 1). 100-grain weight was ranged from 2.05-4.04 g. The grain weight was varied with the heaviest and lightest grains weight found in varieties *Mai-hoke* (4.04 g) from HM and *Kao siew* (2.05 g) from HL, respectively. The grain length ranged from 8.61-11.63 mm with the average of 10.00 mm. The shortest and longest grains were found in varieties *Chao khao 2* (8.61 mm) from PSN and *Leum*

*poua* (11.63 mm) from HM, respectively. The grain width ranged from 2.67-4.27 mm with the average of 3.51 mm. The narrowest and widest grains found in varieties *Kao siew* (2.67 mm) from HL and *Luang leuang* (4.27 mm) from HM, respectively. The thickness of individual unhusked grain ranged from 1.97-2.47 mm. The thinnest and thickest grains found in *Kao siew* (1.97 mm) and *Niew mad-deng* (2.47 mm) from PSN, respectively. Grain size and shape are associated with milling quality, grain weight and proportion of the main growth axes of the grain (Gegas et al., 2010). The grain size and shape can be effectively used to improve yield and grain quality (Wang et al., 2012), and are among the first quality characteristics considered in developing new commercial varieties (Webb, 1980). Therefore, breeding for specific grain weight together with some other useful traits should carefully consider of grain size as it was found in this study. Thus, a diverse range of grain size and shape among these germplasms will be useful in breeding program as source of genetic materials when dealing with specific shape for consumer's demand.

**Table 1 Grain morphological characteristics of the collected 60 rice samples**

| Collection place | Variety | Type of rice | Grain Morphological Characteristics | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Length (mm) | Width (mm) | Thickness (mm) | L/W ratio | 100-grain weight | pericarp color |
| Chomchieng village | Parker | G | 11.23 | 3.86 | 2.36 | 2.92 | 3.77 | white |
| | Hom-ma-li | NG | 11.20 | 2.99 | 2.11 | 3.75 | 2.82 | white |
| | Bor-ta | G | 11.09 | 3.73 | 2.35 | 2.97 | 3.32 | white |
| | Kam leuang-yao | G | 10.43 | 3.59 | 2.18 | 2.91 | 2.76 | black |
| | Kao peing | G | 10.15 | 3.59 | 2.29 | 2.83 | 3.25 | white |
| | Chao dam | NG | 9.73 | 3.19 | 2.19 | 3.06 | 2.82 | white |
| | Kam mad-dam | G | 10.07 | 3.90 | 2.22 | 2.58 | 2.79 | black |
| | Kam leuang-dam | G | 9.14 | 3.73 | 2.18 | 2.46 | 2.42 | black |
| | Kao din | G | 9.08 | 3.30 | 2.12 | 2.75 | 2.48 | white |
| | Niew mad-pom | G | 9.90 | 3.82 | 2.37 | 2.60 | 3.36 | white |
| | Chao khoon | NG | 9.62 | 3.32 | 2.12 | 2.90 | 2.77 | white |
| | Chao deng | NG | 9.46 | 3.18 | 2.16 | 2.98 | 2.36 | white |
| | Kao wai | G | 11.02 | 3.34 | 2.28 | 3.32 | 3.07 | white |
| | Chao leuang | NG | 10.45 | 3.41 | 2.27 | 3.07 | 3.27 | white |
| Houameuang village | Kao paie | G | 9.50 | 3.24 | 2.20 | 2.94 | 2.33 | red |
| | Kam khao-dam | G | 9.89 | 3.79 | 2.32 | 2.61 | 2.88 | black |
| | Kao ngeun | G | 10.27 | 3.72 | 2.32 | 2.77 | 3.33 | white |
| | Ki-kung | G | 9.82 | 3.87 | 2.38 | 2.54 | 3.35 | white |
| | Pa-ya | G | 10.48 | 4.02 | 2.39 | 2.61 | 3.41 | white |
| | Leum-poua | G | 11.63 | 3.90 | 2.33 | 2.99 | 3.78 | white |
| | Kao Chuk | G | 9.45 | 4.08 | 2.37 | 2.32 | 3.40 | red |
| | Mai-hoke | G | 11.52 | 3.81 | 2.44 | 3.03 | 4.04 | white |
| | Kao hoke | G | 8.67 | 3.68 | 2.24 | 2.36 | 2.70 | white |
| | Chao leuang 2 | NG | 10.12 | 3.32 | 2.09 | 3.06 | 2.77 | white |
| | Kai-noi | G | 10.49 | 3.23 | 2.17 | 3.26 | 2.74 | white |
| | Luang leuang | G | 9.28 | 4.27 | 2.42 | 2.18 | 3.55 | white |
| Hoi-Oth village | Kam dor | G | 9.40 | 3.68 | 2.18 | 2.56 | 2.48 | black |
| | Chao khao | NG | 9.56 | 3.26 | 2.09 | 2.94 | 2.68 | white |
| | Niew valee | G | 10.95 | 3.57 | 2.25 | 3.08 | 3.24 | white |
| | Niew leuang | G | 10.10 | 3.22 | 2.15 | 3.15 | 2.76 | white |
| | Chao peak-peing | NG | 9.17 | 3.43 | 2.20 | 2.68 | 2.75 | white |
| | Kao ying | G | 10.17 | 3.21 | 2.15 | 3.17 | 2.84 | white |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Hoi-Loh village | Chao valee | NG | 10.87 | 3.02 | 2.12 | 3.61 | 2.85 | white |
| | Chao mad-pom | NG | 9.22 | 3.50 | 2.15 | 2.64 | 2.53 | white |
| | Mak-kheua | G | 8.76 | 4.14 | 2.34 | 2.12 | 2.99 | white |
| | Kao Siew | G | 10.33 | 2.67 | 1.97 | 3.88 | 2.05 | white |
| Phasanine village | Leuak-yai | NG | 9.50 | 3.07 | 2.06 | 3.10 | 2.61 | white |
| | Chao khao 2 | NG | 8.61 | 3.09 | 2.14 | 2.79 | 2.47 | white |
| | Kao yuak | G | 11.59 | 3.71 | 2.26 | 3.14 | 3.63 | white |
| | Sia-cha | NG | 9.26 | 3.11 | 2.09 | 2.98 | 2.43 | white |
| | Luang deng | G | 9.21 | 4.17 | 2.42 | 2.22 | 3.56 | white |
| | Chao dam 2 | NG | 9.72 | 3.16 | 2.21 | 3.08 | 2.80 | white |
| | Kao peing 2 | G | 10.14 | 3.51 | 2.31 | 2.90 | 3.12 | white |
| | Niew mad-deng | G | 9.56 | 4.13 | 2.47 | 2.32 | 3.36 | red |
| | Chao-leuang 3 | NG | 10.03 | 3.26 | 2.12 | 3.09 | 2.63 | white |
| | Kao din 2 | G | 9.56 | 3.18 | 2.08 | 3.03 | 2.51 | white |
| Phouthat village | Kao tam | G | 8.92 | 3.51 | 2.39 | 2.55 | 2.53 | white |
| | Ka-yoke | G | 11.33 | 3.61 | 2.28 | 3.16 | 3.55 | white |
| | Kao Kang | G | 10.86 | 2.97 | 2.16 | 3.68 | 2.82 | white |
| | Niew leuang 2 | G | 9.36 | 3.42 | 2.30 | 2.76 | 2.87 | white |
| | Nam-manh | G | 9.36 | 3.99 | 2.40 | 2.35 | 3.23 | white |
| | Niew peak-peing | G | 9.27 | 3.68 | 2.35 | 2.53 | 2.86 | white |
| | Poua-mia | G | 10.07 | 3.50 | 2.27 | 2.89 | 2.75 | white |
| | Kao peing 3 | G | 10.95 | 3.66 | 2.37 | 3.01 | 3.31 | white |
| | Ma-ma | G | 10.24 | 3.62 | 2.24 | 2.84 | 2.92 | white |
| | Niew mad-deng 2 | G | 9.39 | 3.93 | 2.40 | 2.41 | 3.18 | red |
| | Chao khao 3 | NG | 9.70 | 3.03 | 2.12 | 3.21 | 2.60 | white |
| | Leuak-yai 2 | NG | 10.20 | 3.13 | 2.20 | 3.27 | 2.75 | white |
| | Leuak-noi | NG | 9.61 | 3.06 | 2.12 | 3.15 | 2.61 | white |
| | Kao yai | G | 11.32 | 3.73 | 2.44 | 3.04 | 3.89 | white |
| n | | | 60 | 60 | 60 | 60 | 60 | |
| min | | | 8.61 | 2.67 | 1.97 | 2.12 | 2.05 | |
| max | | | 11.63 | 4.27 | 2.47 | 3.88 | 4.04 | |
| mean | | | 10.00 | 3.51 | 2.24 | 2.88 | 2.96 | |
| SD | | | 0.78 | 0.36 | 0.12 | 0.38 | 0.43 | |
| CV (%) | | | 1.47 | 1.59 | 2.05 | 1.68 | 1.36 | |
| F-test | | | ** | ** | ** | ** | ** | |
| LSD (0.05) | | | 0.24 | 0.09 | 0.07 | 0.08 | 0.07 | |

*** Significant difference at p< 0.01; CV= coefficient of variation; SD= standard deviation; n= number of sample; min= minimum; max= maximum; LSD= least significant difference at p< 0.05; G: Glutinous; NG: Non-glutinous*
*The value of grain size in each sample is averaged from 50 grains.*

The ratio of grain length/width was used to separate grain shape of unhusked rice. Most samples (58 varieties) were distinguished as large grain type and the others 2 samples are slender type (Fig. 2). Grain weight was varied with grain length, width and thickness in multiple regression of y = 0.39(grain length) + 0.53(grain width) + 1.42(grain thickness) – 5.52 at $R^2 = 0.89$ ($p < 0.05$).

## CONCLUSION

A wide variation of grain morphological characteristics has been found among the local upland rice as it was expected among the collected samples.

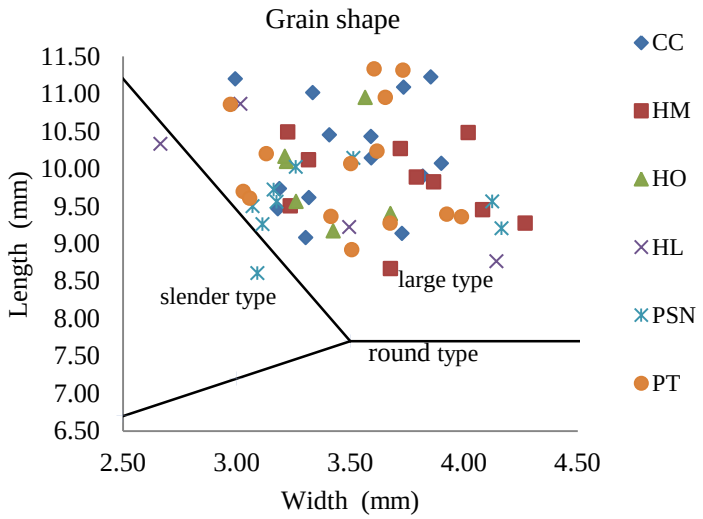


**Fig. 2 The grain shapes of unhusked grain among rice samples**

Most of rice samples are in a large grain shape with only few samples are slender type. Grain weight is an important characteristic in commercial networks as it is used to determine the production and price of rice. In this germplasm, Grain weight was varied with grain length, width and thickness in multiple regression of y = 0.39 (grain length) + 0.53(grain width) + 1.42(grain thickness) – 5.52 at $R^2$ = 0.89 ($p < 0.05$). The results of this study can be used as the basic database of rice germplasm in Luang prabang province for the selection of rice varieties in further breeding program. However, other useful traits of nutritional qualities such as iron, zinc, protein, silicon and antioxidant properties should be further evaluated.

## ACKNOWLEDGEMENTS

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Research article

# Influence of Coral Nursery Units on Fish Assemblage

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**Abstract** Since 2012, the Department of Science and Technology-Philippine Council for Agriculture and Natural Resources Research and Development (DOST-PCAARD) has been funding a coral reef restoration project, conducted by different universities in the Philippines. As part of this project, coral nursery units (CNUs) have been deployed to supply high quality coral nubbins aimed at reducing the dependence of coral fragments from wild coral populations. Changes in the reef fish assemblage were assessed after four months to find out whether fishes are attracted to and produced at the CNUs. Six CNUs were deployed at 30 m apart from each other. Fishes were counted and identified using the fixed-point technique. Fish density and species richness were compared before and after CNU installation. Both production and attraction of reef fishes were evident, notably, by the abundance of Apogonidae. The high concentrations of secondary consumers are the main evidence for the attraction of the CNUs. Our results indicate that CNUs can be used as an effective management and restoration tool for improving the local fishing yields.

**Keywords** coral cover, fish assemblage, marine protected areas, nursery

## INTRODUCTION

The Philippines is one of the world's centers of marine biodiversity and multi-taxa marine endemism (Roberts et al., 2002). However, the country's marine resources are also experiencing the highest level of anthropogenic and climatic threats. The anthropogenic threats include fishing overcapacity; overfishing and destructive fishing practices; increased domestic, agricultural, and industrial runoff from a burgeoning population; poor land use; and increased sedimentation from forest deforestation and un-regulated mining activities (Cabral et al., 2014).

One of the ecosystems in the Philippines that are in serious deterioration-suffering massive, long-term declines in abundance and diversity of species are the coral reefs. In order to save our reefs, the Department of Science and Technology-Philippine Council for Agriculture and Natural Resources Research and Development (DOST-PCAARD) provided funds for different universities in the Philippines to implement a coral reef restoration project which started in the year 2012. One of its objectives is to establish demonstration for coral nursery units (CNUs). The main purpose of establishing and deploying CNUs is to supply high quality coral nubbins for transplantation and to reduce the dependence of coral fragments from wild coral populations (Pub. Project 6: Pilot Testing, 2014). As the project proceeded, projects staff, volunteers, and project implementers observed fishes

that were not around in the area in the past. CNUs have literally become an artificial reef for these species. In general terms, the artificial reefs are man-made habitats placed at the sea bottom that provide a framework for marine life to develop. Such habitats have several benefits including: providing food, shelter, protection, and spawning areas for fish and marine life, as well as, relieving natural reefs from user pressure by providing alternative recreational areas (Bohnsack and Sutherland, 1985). Intrigued by the observed fishes around the CNUs, we proposed this study in order to assess the influence of the CNU's on fish assemblage.

## OBJECTIVES

This study investigated the influence of coral nursery unit (CNUs) deployed in the Roll-out Coral Restoration Project in Anda, Bohol on fish assemblage. Specifically, this study compared the fish abundance and species richness before and four months after installation of the CNUs by determining the occurrence, frequency, and abundance of fish species by trophic levels.

## METHODOLOGY

This study was conducted in the Marine Protected Area (MPA) of Suba, Anda, Bohol (Fig. 1) to ensure safety of the CNUs. Six CNUs (dimension = 3 m L x 1 m W x 0.5 H), made up of ropes and reinforcing bars, were deployed in the sandy portion of the MPA at 30 m apart from each other to avoid overlapping. Fishes in the CNUs were counted and identified visually using the fixed-point technique (Hackradt et al., 2011) every month. Observations were made within an imaginary cylinder that has a radius of 3 m. There was a 5-min interval before and after census to minimize interference. The census was done for 10 minutes at each CNU. Monthly dive was done to remove fouling organisms (Aaron-Amper et al., 2015).

The fish assemblages were characterized in terms of: 1) fish abundance and species richness, 2) four classes of frequency occurrence of species (permanent 75-100%, frequent 50-75%, scarce 25-50%, and rare < 25%), 3) and trophic level of each fish species following the procedures described by Romanuk et al. (2011) wherein an omnivore was assigned to trophic positions between 2.2 and 2.79, secondary consumer to > 2.8, and tertiary consumer to > 4.

Statistical analysis was performed using Systat 12. The data were log transformed based on the paired t-test.

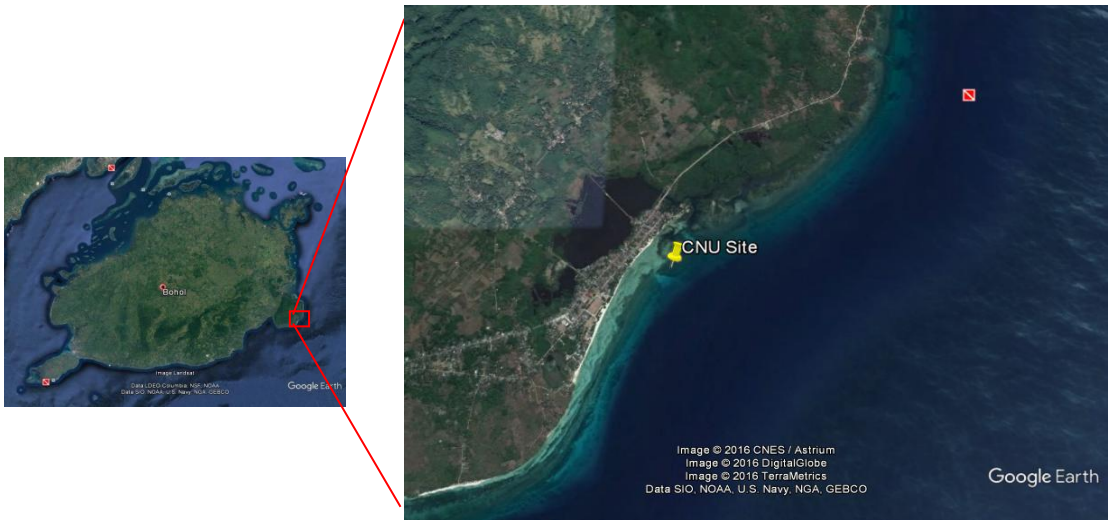


**Fig. 1 Map of Bohol, Philippines showing the CNU site**

## RESULTS AND DISCUSSION

Overall, 41 species belonging to 12 families were recorded from the two sampling periods combined (Table 1). Of these, 38 (93% of the whole species pool) were recorded four months after deployment of the CNUs.

**Table 1 Fish species composition, abundance, and richness before and four months after deployment of coral nursery units**

| Family | Species | Abundance | |
|---|---|---|---|
| | | before | after 4 months |
| Acanthuridae | *Acanthurus grammoptilus* | 0 | 2 |
| Apogonidae | *Apogon bandanensis* | 0 | 400 |
| | *Apogon griffini* | 5 | 0 |
| | *Apogon moluccensis* | 40 | 260 |
| | *Apogon monospilus* | 70 | 365 |
| | *Apogon perlitus* | 30 | 100 |
| | *Apogon quadrifasciatus* | 10 | 265 |
| | *Apogon sealei* | 110 | 380 |
| | *Archamia melasma* | 0 | 115 |
| | *Cheilodipterus singapurensis* | 0 | 40 |
| Blenniidae | *Centropyge multifasciatus* | 0 | 1 |
| Chaetodontidae | *Chaetodon ocellicaudus* | 0 | 2 |
| | *Chaetodon selene* | 0 | 1 |
| | *Chaetodon vagabundus* | 0 | 2 |
| | *Heniochus acuminatus* | 0 | 1 |
| | *Petroscirtes breviceps* | 70 | 16 |
| Labridae | *Coris dorsomacula* | 2 | 17 |
| | *Coris pictoides* | 0 | 1 |
| | *Halichoeres leucoxanthus* | 12 | 7 |
| | *Halichoeres scapularis* | 0 | 6 |
| | *Oxycheilinus bimaculatus* | 0 | 11 |
| | *Thalassoma lunare* | 0 | 12 |
| Mullidae | *Upeneus moluccensis* | 1 | 0 |
| Ostraciidae | *Ostracion cubicus* | 0 | 1 |
| Pomacanthidae | *Genicanthus watanabei* | 0 | 1 |
| Pomacentridae | *Altrichthys curatus* | 5 | 0 |
| | *Amblypomacentrus clarus* | 6 | 15 |
| | *Amphiprion polymnus* | 0 | 5 |
| | *Chromis analis* | 0 | 1 |
| | *Chrysiptera parasema* | 11 | 45 |
| | *Chrysiptera springeri* | 5 | 2 |
| | *Dascyllus aruanos* | 0 | 6 |
| | *Dascyllus reticulatus* | 1 | 6 |
| | *Dascyllus trimaculatus* | 5 | 11 |
| | *Dischistodus perspicillatus* | 1 | 1 |
| | *Pomacentrus philippinus* | 16 | 30 |
| | *Pomacentrus proteus* | 0 | 5 |
| Serranidae | *Pseudanthias huchti* | 5 | 70 |
| Scorpaenidae | *Pterois volitans* | 2 | 7 |
| Tetradontidae | *Canthigaster solandri* | 0 | 5 |
| | *Canthigaster valentini* | 0 | 2 |
| Total abundance | | 407 | 2217 |
| Total no. of species | | 20 | 38 |

Only 20 species were common and the Apogonidae dominated the community. During the second survey, four species were not found while 21 species were recorded. The total abundance of fish assemblage showed a highly significant increase ($p = 0.001$). The experimental results indicate the complex role of the CNUs as an effective way in increasing species richness and abundance of fish assemblage, and corroborate with the statement of Charbonnel et al. (2002) that habitat complexity has a prominent role on the ecological effectiveness of artificial reefs.

Changes in the frequency of occurrence demonstrate the relationship between habitat complexity and temporal variability in the fish assemblage (Fig. 2). Four months after the deployment of CNUs, the contribution of the permanent species (11% vs. 5%), frequent (13% vs. 10%), and scarce (50% vs. 26%) increased while the rare species decreased (26% vs. 60%). The "new" frequent species included *Oxycheilinus bimaculatus* and *Thalassoma lunare* of Labridae. This result may suggest higher temporal stability of the species assemblage.

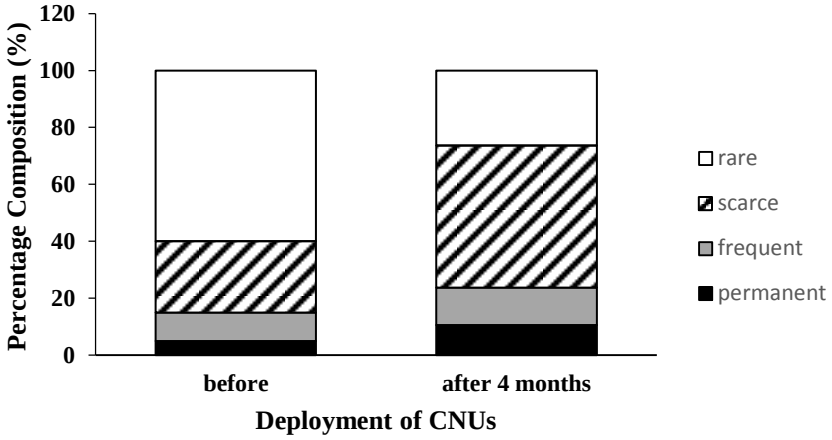


**Fig. 2 Percentage composition of frequency of occurrence classes of the fish species before and four months after deployment of coral nursery units**

Regarding the trophic levels, secondary consumers represented the greatest part of species composition and have increased after deployment of the CNUs (Fig. 3). Food availability, one of the main constraints to the optimal foraging of the predators (Simon et al., 2011) will not become a limiting factor within the CNUs, at least for some species. This may explain the increase of tertiary consumers during the second survey because these predators can encounter food at lower cost of search.

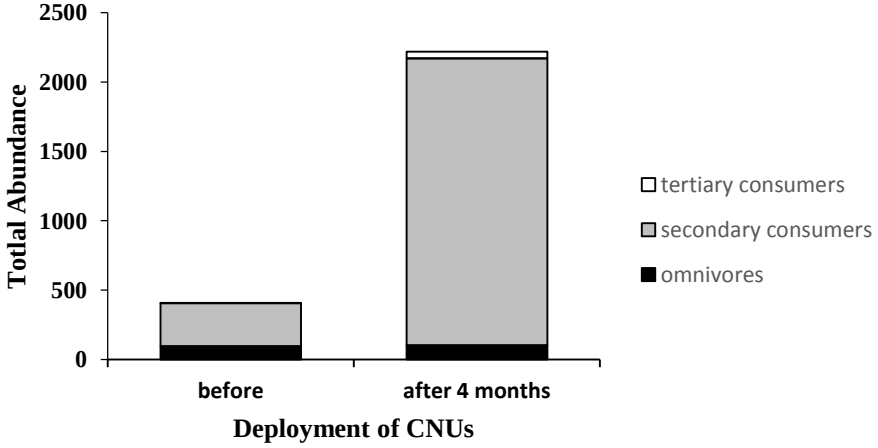


**Fig. 3 Total abundance of fish species by trophic levels**

## CONCLUSION

The deployed CNUs undoubtedly offer suitable habitats to a number of fishes. In such habitats, these fishes can find food in abundance and this hypothetically would benefit their reproductive output and spillover. The sea is continuously subjected to stressors. Thus, even if the CNUs have not been planned for sustaining fisheries, they still need shelter and protection against undesirable impacts.

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Research article

# Utilization of Corncob as Feedstuff on Growth Performance, Feed Utilization and Carcass Composition of Nile Tilapia (*Oreochromis niloticus*)

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**Abstract** The utilization of corncob as feedstuff was investigated to examine the diet contained corncob in the fingerling Nile tilapia *Oreochromis niloticus* (L.). The initial weight of Nile tilapia fingerlings ranged from 14.66 – 16.66 g/fish. The experiment was divided into four groups by the levels of percentage of fiber were 0%, 5%, 10% and 15% and conducted for 120 days. At the end of experiment, the results showed that the growth performance and feed utilization each groups were not significant different ($P > 0.05$). In addition the carcass composition and composition of edible flesh have no difference ($P > 0.05$). On the other hand, the feed cost was decrease by variation with the level of corn cob in diet were 0.14, 0.56 and 1.05%, respectively. Moreover, the water qualities of fish fed with feed contained corncob at different levels were in range of water quality standard. The study indicated that the diets containing corncob at 15% of fiber no negative effect on growth, feed utilization, carcass composition and edible flesh quality. Moreover, it's affected on cost - effectiveness.

**Keywords** Nile tilapia, corncob, feed, growth performance

## INTRODUCTION

Corn production of Thailand is revived up significantly to 4.9 million metric tons in 2014. The average corn yield is estimated to increase to approximately 700 kilogram per rai (4.38 metric tons per hectare), up 2 to 3 percent from the previous year due to favorable weather conditions (Prasertsri and Santella, 2014). High yield of corn followed with the great corn cob that is agriculture waste which eradicated by burned in Thailand. In addition, yield of corn cob in each country are prodigious. The tremendous corn cob is used for many things such as; carbon adsorbent (Tsai et al., 2001), bacterial cellulose (Huang et al., 2015) carbon fuel cell (Jinshuai et al., 2014) and Acetone-Butanol (Kumar et al., 2014). The corn cob composition are a lignocellulosic material composed of cellulose, hemicellulose and lignin were detected: cellulose: 38.8%, hemicellulose: 44.4% and lignin: 11.9% (Pointner et al., 2014) protein, fat, moisture and ash were 4.10, 9.96, 5.42 and 4.46%, respectively (Olagunju et al. 2013). Cellulose, hemicellulose and lignin are embedded in a complex matrix which is very resistant to enzymatic degradation (Mosier et al., (2005); Menon and Rao, (2012); Pointner et al., (2014) and affected on fish digestion because it lack of the enzymes to degrade cellulose, and lignin (Halver and Hardy, 2002). Nevertheless, fiber resist digestion property is benefit to control rate of food in digestion tract to slow down that improve the digestion. Moreover, some species of fish have specialized for

herbivorous and many species for instance Cichlidae (Nile tilapia) are able to ingest and digest quantities of plant material. Because the intestine of herbivorous fish are longer relative to organismal size than are those of omnivours and carnivorous fish. The capacity for carbohydrate digestion shows a certain plasticity, particularly in omnivorous fish. Tilapia modify their secretion of digestive enzyme when their diet is valid (Halver and Hardy, (2002); Jobling, (1995); Klahan et al., (2009)).

## OBJECTIVES

The aim of this study were to apply the corncob as the feedstuff to improve the cost effectiveness of culturing Nile tilapia (*Oreochromis niloticus* L.) and reducing the environment pollution from corncob burning.

## METHODOLOGY

### Experimental Fish

Nile tilapia (*O. niloticus*, L.) were obtained from commercial farm at Phayao province, Thailand. Fish were acclimated in net cage on earth pond for 1 weeks by control diet containing 30% crude protein (CP) (no corncob contain) before start the experiment. Fingerling (14 – 16 g) were randomly stocked into 1*1*1.5 $m^3$ net cages at a density of 50 fish per net cage.

### Experimental Diet

The corncobs were collected from the local farm in Phayao province, Thailand. Corncobs (Fig. 1a) were blended to small pieces with grinding machine (Fig. 1b). Take small piece of corncob (Fig. 1c) to mixed with other feedstuff of feed formula. Four isonitrogenous (30% crude protein (CP)) and isocaloric (3000 $KcalKg^{-1}$) diets were formulated and contained corn cob that effected on the fiber level at 0, 5, 10 and 15% (Table 1). The feedstuff of each diet were mixed together for 20 min with horizontal mixing and took to extruder for floating pellet feed. The diets were dried at room temperature for 12 h and stored in plastic bags at room temperature.


**Fig. 1 Corncob (A), grinding machine (B) and small piece of corncob (C)**

### Experimental Procedure

The experiment design was completely randomized design (CRD) included 4 treatments. Each of the 4 experimental diets was randomly assigned to triplicate groups of fish and all the groups were fed with their respective diet at 3% body weight day twice daily for 120 days. Also, water is changed for every two - three days for 30% throughout the study.

**Table 1 Feed formulation of the experimental diets (on dry matter basis)**

| Feedstuff (g/100) | Dietary corncob contain (%) | | | |
|---|---|---|---|---|
| | 0 | 5 | 10 | 15 |
| Fishmeal | 25 | 25 | 25 | 25 |
| Soybean meal | 32 | 32 | 32 | 32 |
| Rice bran | 19 | 17 | 11 | 4 |
| Corncob | 0 | 2 | 8 | 15 |
| Cassava | 15 | 15 | 15 | 15 |
| Vegetable oil | 3.5 | 3.5 | 3.5 | 3.5 |
| Fish oil | 3.5 | 3.5 | 3.5 | 3.5 |
| Premix[1] | 1 | 1 | 1 | 1 |
| α - starch | 1 | 1 | 1 | 1 |
| Total | 100 | 100 | 100 | 100 |
| Chemical analysis (%) | | | | |
| Moisture | 2.26 | 2.37 | 2.69 | 3.06 |
| Protein | 30.48 | 30.29 | 29.74 | 29.10 |
| Fat | 9.59 | 9.56 | 9.48 | 9.38 |
| Fiber | 3.69 | 5.20 | 9.71 | 14.98 |
| Ash | 9.42 | 9.35 | 9.16 | 8.94 |
| GE (Kcal100g-1)[2] | 292.25 | 295.07 | 303.53 | 303.40 |

[1]*premix: each 0.5 kg contain vitamin A 500,00 IU, Vitamin D3 100,000 IU, Vitamin E 10,000 IU, Vitamin K 800 mg ,Vitamin B1 250 mg, Vitamin B2 200 mg, Vitamin B2 750 mg ,Vitamin B12 5 mg ,pantothenic acid 3,000 mg, niacin 2,150 mg , folic acid 300 mg, inositol acid 25,000 mg, biotin 25 mg, selenium 30 mg, iron 20,000 mg, zinc 32,000 mg, copper 2,000 mg and feed preservative 50 mg*

[2] *GE (gross energy): calculated followed NRC =(% protein x 5.64 (+ )% lipid x 9.44 (+ )% NFE x 4.11)*

## Analytical Method

During experiment, the mortality was recorded daily and fish in each tank were counted and weighed individually at a monthly. Growth rate were monitored to determine the final weight, weighed gain, specific growth rate (SGR), average daily gain, survival rate, feed intake, feed conversion ratio (FCR) and protein efficiency ratio (PER) were calculated according to Castell and Tiews (1980). At the start of experiment, 10 fish randomly were dried for the determination of body proximate composition. At the end of the feeding trial, 5 fish from each group (n = 15 fish/group) were collected blood for blood analysis of red blood cell, heamatocrit and hemoglobin with auto blood cell count and analyzed for final whole body proximate composition. Proximate composition of body was analyzed following AOAC (2002) methods.

## Statistical Analysis

In the experiment, all data were assessed by one-way analysis of variance (ANOVA) followed by Duncan's multiple range tests. A significance level of $P < 0.05$ was used.

## RESULTS AND DISCUSSION

## Growth Performance

The result of the growth trial showed that all groups were not significantly different ($P > 0.05$) (Table 2). The mean final weight, weigh gain, ADG and SGR of different experimental diets ranged between 68.86 - 75.00 g/f, 53.19 - 59.00 g/f, 0.59 - 0.65 g/f/d and 1.59 - 1.74 % respectively. In addition, survival rate in all groups were not significantly different also ($P > 0.05$). Feed utilization of Nile

tilapia fed with contain corncob diet at different level for 120 days showed that not significantly different (P > 0.05). The feed intake. feed conversion ratio and feed conversion efficiency of different experimental diets ranged between1.05 - 1.10 g/f/day, 1.65 - 1.79 and 57.62 - 60.53%, respectively

**Table 2 Growth performance of Nile tilapia fed with corncob contain diet at 120 days**

| Growth performance | Dietary corncob contain (%) | | | |
|---|---|---|---|---|
| | 0 | 5 | 10 | 15 |
| Initial weight (g/f) | 16.00 ± 2.00 | 16.66 ± 1.15 | 15.33 ± 2.30 | 16.66 ± 1.15 |
| Final weight (g/f) | 75.00 ± 0.87 | 74.15 ± 0.77 | 72.99 ± 4.01 | 69.86 ± 6.10 |
| Weight gain (g/f) | 59.00 ± 2.18 | 57.49 ± 1.50 | 57.66 ± 1.78 | 53.19 ± 7.09 |
| Average daily gain (g/f/day) | 0.65 ± 0.02 | 0.64 ± 0.02 | 0.64 ± 0.02 | 0.59 ± 0.08 |
| Specific growth rate (%/day) | 1.72 ± 0.14 | 1.66 ± 0.07 | 1.74 ± 0.10 | 1.59 ± 0.16 |
| Survival rate ( % ) | 98.66 ± 1.15 | 98.00 ± 2.00 | 98.66 ± 1.15 | 94.00 ± 8.71 |
| Feed utilization | | | | |
| Feed intake (g/f/day) | 1.10±0.02 | 1.07±0.02 | 1.06±0.06 | 1.05±0.09 |
| Feed conversion ratio | 1.68±0.08 | 1.68±0.02 | 1.65±0.04 | 1.79±0.10 |
| Feed conversion efficiency (%) | 59.57±2.86 | 59.54±0.97 | 60.53±1.81 | 57.62±0.19 |

The growth performance of fish depend on two systems; digestion and absorption. The digestibility of corncob diets of Nile tilapia from the previous study showed curtailing while the digestibility and absorption of other feed stuff or nutrients were in normal stage by observation from feed utilization data ie. feed intake, feed conversion ratio and feed conversion efficiency. These data were not significant different among groups that effected on growth performance not difference also. Furthermore, the prebiotic attribute of corncob that is the one of reasons make the not difference on growth performance. The property of prebiotic are a nondigestible food ingredient that beneficially affects the host and resistance to gastric acidity and to gastrointestinal absorption (Gibson et al., 2004; Yousefian and Amiri, 2009) The result from this study was the same line with Ren et al. (2015) who found that the growth performance and survival rate of blunt snout bream (2 g/f) fed with diet contained different carbohydrate sources namely wheat flour, maize flour, dextrin, maltose, glucose and cellulose for 3 months were not different. Additionally, this is in agreement with the finding of Dalsgaard et al., (2012) that supplementation of β – glucanase and protease in juvenile rainbow trout diet increased the feed utilization.

## Carcass Composition

**Table 3 Carcass composition of Nile tilapia fed with corncob contain diet at 120 days**

| Carcass composition (%) | Dietary corncob contain (%) | | | |
|---|---|---|---|---|
| | 0 | 5 | 10 | 15 |
| Edible flesh | 35.17 ± 0.69 | 35.05 ± 2.71 | 35.00 ± 2.07 | 32.07 ± 0.71 |
| Bone and skin | 45.10 ± 0.26 | 47.74 ± 3.47 | 45.99 ± 1.25 | 47.78 ± 1.88 |
| Viscera and fat | 7.44 ± 0.48[c] | 8.84± 0.58[b] | 9.07 ±0.69[a] | 9.79 ± 0.31[a] |

[a,b,c] *Means within a row with common superscript are significantly different (P<0.05). n = 30*

The effect of different corncob contained on carcass composition of fish showed in Table 3. The results showed that there was no significant difference on percentage of bone and skin and edible (P > 0.05) but it effected on percentage of viscera and fat (P < 0.05) that showed the highest on 10 and 15% of corncob in diet and control group. For HSI of control group were highest but lowest in 15% corncob

contained in diet group (P > 0.05). The similar data of carcass composition among groups is meaning that the nutrient intake and nutrient deposit in muscle between groups of fish were close.

### Blood Analysis

The result of blood analysis of Nile tilapia fed with contain corncob diet at different level for 120 days showed that not significantly different (P > 0.05). The red blood cell, hematocrit and hemoglobin of different experimental diets ranged between 2.0 - 2.43 cell x$10^6$/µl, 32.25 - 37.60% and 10.75 - 12.40 g/dl, respectively (Table 4). These data were all in normal range of healthy Nile tilapia.

**Table 4 Blood analysis of Nile tilapia fed with corncob contain diet at 120 days**

| Carcass composition (%) | Dietary corncob contain (%) | | | |
|---|---|---|---|---|
| | 0 | 5 | 10 | 15 |
| Red blood cell (cell*$10^6$/µl) | 2.19 ± 0.16 | 2.24 ± 0.34 | 2.14 ± 0.55 | 2.00 ± 0.18 |
| Hematocrit (%) | 32.95 ± 1.20 | 34.10 ± 3.95 | 34.30 ± 5.93 | 34.150 ± 2.61 |
| Hemoglobin (g/dl) | 11.05 ± 0.06 | 12.30 ± 0.14 | 11.85 ± 0.21 | 11.45 ± 0.77 |

Corncob is the toxic without feed stuff that no effected on fish health. This reason made the blood data showed no difference. These blood data according to Rungkan (2009), the red blood cell, hematocrit and hemoglobin were 2.78 x$10^6$/µl, 21.11% and 11.82 g/dl, respectively. The comparison of red blood cell, hematocrit and hemoglobin with other fish were in normal range were 0.973 - 2.75 x106/µl, 20 - 51% and 5.46 - 101.33 g/dl, respectively (Duy et al., 2008; Min and Kang, 2008; Pérez et al., 2008). Hence, the wide range depends on the varity of size, type and strain of fish.

## CONCLUSION

The corn cob can be as feed stuff for Nile tilapia diet by contained in feed formula 15%. These no negative effected on growth performance, feed utilization and fish health including the flesh quality also. Moreover, the feed cost of 15% corncob group was cheaper than control group about 1.50 Baht/Kg feed (0.04 USD/kg feed).

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Research article

# Characteristics of Transformation of Traditional Upland Farming System in Cambodia: A Case Study of Snuol Commune, Kratie Province

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**Abstract** The main objective of this study is to compare the characteristics between the local farmers who conduct traditional upland farming without chemical fertilizer and the local farmers who depend on chemical fertilizer. The results of the analysis are summarized as follows. 1) According to the results of Multiple Correspondence Analysis, it was clear that the preference divisions of the local farmers who depend on chemical fertilizer were “Gender”, “Age”, “Family number”, “Duration of residence”, “Irrigation facility” and “Multiple cropping” as important characteristics for the classification. 2) The results from the Biological and Chemical Technology Method indicated that chemical fertilizers were applied intensively in farmlands with low soil fertility. Therefore, it was considered that the contribution of the current capital, such as chemical fertilizer, was not effectively conducted. 3) In the research site, the estimated value of technical efficiency showed the existence of technical inefficiency in upland farming systems.

**Keywords** traditional farming system, chemical fertilizer, biological and chemical technology, production function

## INTRODUCTION

In Cambodia the amounts of applying agricultural chemicals, such as chemical fertilizer and pesticide, have rapidly been increasing in recently years (Fujimoto and Miyaura, 1966). Although it contributed to increase the agricultural productivity, the amounts of applying agricultural chemicals caused environmental disruptions, such as soil and water quality degradation, and decreased land productivity in the long term. Based on the above mentioned backgrounds, the main objective of this study is to compare the characteristics between the local farmers who conduct traditional upland farming without chemical fertilizer and the local farmers who depend on chemical fertilizer. At first, the approach was to clarify the characteristics of the local farmers who depend on chemical fertilizer through evaluating factor inputs by the estimated production function based on the Biological and Chemical Technology Method. In addition, the technical efficiency is evaluated by the estimated stochastic frontier production function.

## METHODOLOGY

The research site is the Snuol Commune, Kratie Province. The research site is a well-known area where a variety of upland crops are produced in Cambodia. The urgent expansion of a variety of upland crop production creates an issue of environmental disruptions, such as soil and water quality degradation, and decreases land productivity by the amounts of agricultural chemicals which are applied. In addition, in this site, the Institute of Environmental Rehabilitation and Conservation carried out the project "study on sustained utilization of the natural resource" (3/2015 – 4/2016). The first problem is to clarify the characteristic of the farm household using agricultural chemicals. The second problem is to clarify factor input structures by estimated the production function that was based on the Biological and Chemical technology (Egaitu and Shigeno, 1983). In addition, the third problem is to clarify technical efficiency by estimating the stochastic frontier production function.

Kratie Province is located in the northeastern part, where development is the slowest, in Cambodia, and the compared difference with other areas is large. In Snuol village, Snuol district, Kratié Province, 170,000 ha, equal to 65%, is used in the total area, 260,000 ha is forest, and 14,000 ha, equal to 5%, is used as agricultural land. The questionnaire survey was entitled "Baseline investigation for sustainable rural development in Snuol village, Snuol district, Kratié Province (2011, April)". The target area of the questionnaire survey consisted of six villages: Kbal Snuol, Thpong, Snuol Kert, Snuol Lech, Kathdai and Prek Kdey. The numbers of useful responses received per area are as follows: Kbal Snuol Village: 46 respondents (25.0% of the total respondents), Thpong Village: 42 respondents (22.8%), Snuol Kert Village: 23 respondents (12.5%), Snuol Lech Village: 33 respondents (17.9%), Kathdai Village: 21 respondents (11.4%) and Prek Kdey Village: 19 respondents (10.3%). There were 184 respondents in total.

## RESULTS AND DISCUSSION

Table 1 shows the respondent profiles. Almost 51% were "male" and about 48% were "female." About the age of the respondents, the majority of respondents were between the ages of "More than 50 years" (41.0%), followed by "40-49" years (27.5%) and "30-39" years (18.0%). The lowest percentage was aged "Less than 20 years" old. About the number of family members, the majority of respondents had a family number of "3-5" people (55.0%), followed by "6-8" people (34.3%) and "Less than 2 people" (5.3%). The lowest percentage was "More than 10 people." About the residing number of years, the majority of respondents had resided in the area "More than 41 years" (54.7%), followed by "36-40" years (9.4%) and "31-35" years (8.8%). The lowest percentage was "Less than 20 years" old.

**Table 1 Demographic Information of Respondents**

| Gender | | | Age | | | Numbers of family persons | | | Family living years in this village | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | numbers of responses | | | numbers of responses | | | numbers of responses | | | numbers of responses | |
| | (n) | (%) | | (n) | (%) | | (n) | (%) | | (n) | (%) |
| Male | 95 | 51.6 | Less than 20 years | 2 | 1.1 | Less than 2 persons | 9 | 5.3 | Less than 2 years | 1 | 0.6 |
| Female | 89 | 48.4 | 20 - 29 years | 22 | 12.4 | 3-5 | 93 | 55.0 | 3-5 | 6 | 3.5 |
| | | | 30 - 39 years | 32 | 18.0 | 6-8 | 58 | 34.3 | 6-10 | 3 | 1.8 |
| | | | 40 - 49 years | 49 | 27.5 | 9-10 | 5 | 3.0 | 11-15 | 5 | 2.9 |
| | | | More than 50 years | 73 | 41.0 | More than 10 | 4 | 2.4 | 16-20 | 13 | 7.6 |
| | | | | | | | | | 21-25 | 9 | 5.3 |
| | | | | | | | | | 26-30 | 9 | 5.3 |
| | | | | | | | | | 31-35 | 15 | 8.8 |
| | | | | | | | | | 36-40 | 16 | 9.4 |
| | | | | | | | | | More than 41 years | 93 | 54.7 |
| Total | 184 | 100.0 | Total | 178 | 100.0 | Total | 169 | 100.0 | Total | 170 | 100.0 |

*Source:Survey Data*

Table 2 shows the using of the chemical fertilizer and the organic fertilizer becoming the core of the BC technology with land. About using chemical fertilizer, almost 76% were “No” and about 27% were “Yes.” About using chemical pesticide, almost 64% were “Yes” and about 36% were “No”. About using organic fertilizer, almost 50% were “No” and about 50% were “Yes.” About using organic pesticide, almost 97% were “No” and about 3% were “Yes”. The inhabitants continue Cambodian-style traditional lifestyle depending on natural resources.

**Table 2 Using of the chemical fertilizer and the organic fertilizer**

| Using chemical fertilizer | numbers of responses | | Using chemical pesticide | numbers of responses | | Using organic fertilizer | numbers of responses | | Using organic pesticide | numbers of responses | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (n) | (%) | | (n) | (%) | | (n) | (%) | | (n) | (%) |
| Yes | 37 | 23.6 | Yes | 98 | 64.5 | Yes | 78 | 49.7 | Yes | 4 | 2.6 |
| No | 120 | 76.4 | No | 54 | 35.5 | No | 79 | 50.3 | No | 152 | 97.4 |
| Total | 157 | 100.0 | Total | 152 | 100.0 | Total | 157 | 100.0 | Total | 156 | 100.0 |

*Source:Survey Data*

In the Snuol District, Kratie Province, this area uses a high level of chemical fertilizer and pesticide. However, there are many local farmers which apply fertilizers without knowing the usage of appropriate chemical fertilizers and pesticides. Using an attribute from Table 1, this part clarifies the characteristic of the local farmers using the chemical fertilizer and the local farmers not using chemical fertilizer. In this analysis, Multiple Correspondence Analysis was employed. According to the results of Multiple Correspondence Analysis, it was clear that the preference divisions of the local farmers who depend on chemical fertilizer were “Gender”, “Age”, “Family number”, “Duration of residence”, “Irrigation facility” and “Multiple cropping” as important characteristics for the classification.

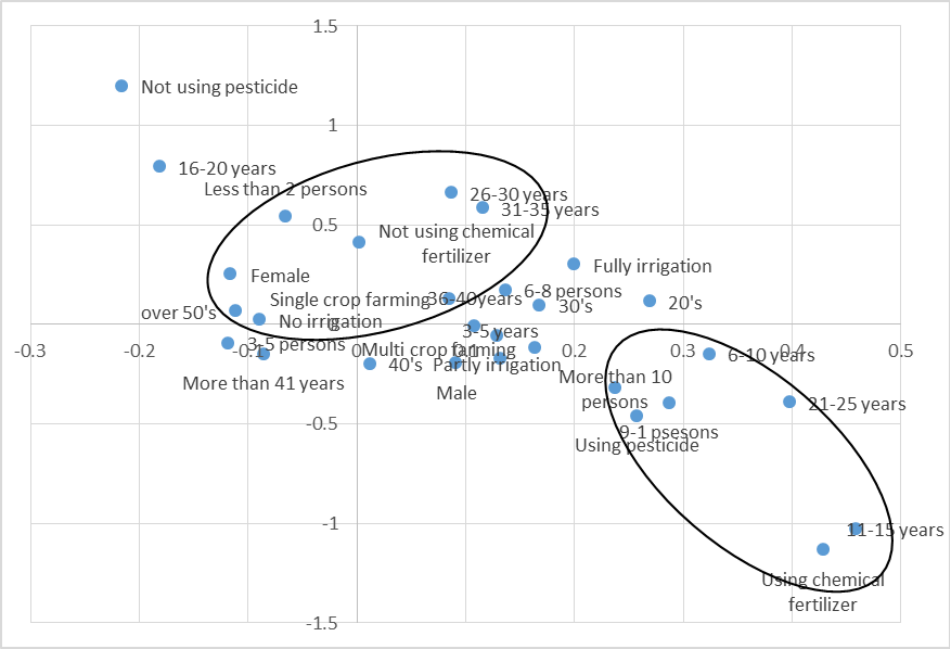


**Fig.1 The result of Answer Pattern for using of chemical fertilizer and organic fertilizer by Correspondence Analysis**

Figure 1 shows the result of the answer pattern for “Not using chemical fertilizer”, as well as “Using chemical fertilizer”. The answer pattern of “Using chemical fertilizer” is similar to the answer pattern of family number of 9-10 persons, more than 10 persons, duration of residence of 6-10 years, 11-15 years, 16-20 years, and using pesticide. Also, the answer pattern of “Not using chemical fertilizer” is similar to the answer pattern of female, aged more than 50 years old, family number of less than two persons, duration of residence of 26-30 years, 31-35 years, irrigation not improved, and single-crop farming.

BC process production technology functional model for the estimation is shown by Model 1 and Model 2.

Model 1: $Yn = AX1^{\alpha}X2^{\beta}$
Model 2: $Yn = AX2^{\beta}$

Where Yn is the average annual income from agricultural activity (riel), X1 is the total chemical fertilizer inputs, and X2 is the upland area (ha). At the same time, A, α, β is the estimation parameter. The estimation sample is the unit of the farm. Model 1 is the farmers using chemical fertilizers, and Model 2 is the farmers not using chemical fertilizers. The estimated parameter introduces a dummy variable of OID and VDn. OID is organic input dummy (input: 1, no input: 0) and VDn is village dummy, n is each village (Thpong: 1, Snuol Kert: 2, Snuol Lech: 3, Kathdai: 4, Prek Kdey: 5). The ordinary least squares (OLS) method was employed in the estimation of regression model.

**Table 3 Estimation results of BC process production technology function**

| Chemical Input : Model 1 (N=33) | | | | | | | Non Chemical Input : Model 2 (N=86) | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | | | | | Coefficient | t-value | Coefficient | t-value | |
| Constant | | | : | C | 12.44 | 23.77 *** | 14.39 | 76.92 *** | |
| Chemical Input | kg | X1 | : | α | 0.42 | 5.59 *** | | | |
| Upland and Paddy field | Area (ha) | X2 | : | β | 0.54 | 3.44 *** | 0.61 | 5.99 *** | |
| Organic Input | Dummy | OD1 | : | γ | -0.43 | -0.15 | -0.10 | -0.61 | |
| Thpong | Dummy | VD1 | : | δ | 1.09 | 2.72 *** | 0.34 | 1.23 | |
| Snuol Kert | Dummy | VD2 | : | ε | 0.38 | 0.60 | 0.53 | 1.92 * | |
| Snuol Lech | Dummy | VD3 | : | ζ | 0.68 | 1.62 * | 0.22 | 0.81 | |
| Kathdai | Dummy | VD4 | : | η | 0.79 | 1.66 * | 0.51 | 1.75 * | |
| Prek Kdey | Dummy | VD5 | : | θ | 1.15 | 1.90 ** | -0.11 | -0.30 | |
| R2 | | | | | 0.68 | | 0.46 | | |
| Adj.R2 | | | | | 0.57 | | 0.42 | | |
| F-value | | | | | 6.28 | | 9.65 | | |
| p-value | | | | | 0.00 | | 0.00 | | |

*Note:***1% level of significance,**5% level of significance,*10% level of significance*
*Source:Survey Data*

In Table 3, the estimation results are shown of the BC process production technology function of upland farming systems in the research-site area.

Estimation results of Model 1 and Model 2 are as follows. According to the measuring results of Model 1, indicating the farmer using the chemical fertilizer inputs, the value of production elasticity of chemical fertilizer inputs (α) is 0.3596. Moreover, the value of production elasticity of the land area (β) is 0.6060. The statistical significances of the value of α, β are satisfactory. Adjusted R-squared as statistical goodness-of-fit shows 0.6190. In the estimation results of Model 1, no statistical significance is recognized of the estimation parameter of the organic input dummy (OID) (γ) and village dummy of Snuol Lech (VD2) (ε). The value of α+β is 0.9656. BC process production technology in Model 1 has diminishing returns to scale. Furthermore, the value of α/β shows 0.5933. This means that the land use

and the chemical fertilizer inputs saving technology have been applied in BC process production technology.

According to the measuring results of Model 2 indicating the farmers not using the chemical fertilizer inputs, the value of production elasticity of the land area (β) are 0.6123. The statistical significance of the value of β is satisfactory. Adjusted R-squared as statistical goodness-of-fit shows 0.4413. In the estimation results of Model 1, the statistical significance is not recognized of the estimation parameter of the organic input dummy (OID) (γ) and village dummy of Thpong (VD1)(δ), Snuol Lech (VD3)(ζ) and Prek Kdey (VD5)(θ).

From these estimation results, observation facts of the BC process production technology function are as follows.

First observation fact, the BC process production technology have diminishing returns to scale ($\alpha+\beta<0$).

Second observation fact, when examining routine charge wealth (α) and land area (β), element contribution for the production of the element was not a high value.

Third observation fact is related to the value of land area (β). The values of β are mode 1:0.541 and mode 2:0.612. The contribution degrees of the land as the agricultural production inputs are more than 0.5 with both models. With the value of β being high, regardless of having chemical fertilizer in use or not, farmers performed the agricultural production which depended on the land. Regarding the value of land area (β), even if the land's fertile soil under the present conditions was a high level, in such condition of land area, the current inputs were intensively utilized. Therefore, element contribution of current inputs to production became a low level. It gradually strengthens a tendency as the productivity of the land is a low level. This tendency occurs if the soil fertility is a low level and soil erosion is a high level.

Fourth observation fact did not recognize a statistically significant recurrence relation in the organic input dummy (OID) (γ). This means that the introduction of the sustainable farming system based on natural resource circulation for the purpose of a decrease in chemical fertilizer and the decrease in chemical pesticide is difficult.

At first the estimation of the technical efficiency is as follows. Difference of the technology efficiency defines the residual from the actual value and estimated value. Difference of the technology efficiency is as follows with the index. Difference of technology efficiency index of the average annual income from an agricultural activity base:

EFFICIENCY = (income actual value / income estimated value) × 100

This means that EFFICIENCY is the technology efficiency of a high level in the time over 100, and the technology efficiency is a low level in times fewer than 100.

**Table 4 The results of estimated of EFFICENCY**

| Using chemical fertilizer | | | Using chemical pesticide | | | Using organic fertilizer | | | Using organic pesticide | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | numbers of responses | | | numbers of responses | | | numbers of responses | | | numbers of responses | |
| | (n) | (%) | | (n) | (%) | | (n) | (%) | | (n) | (%) |
| Yes | 37 | 23.6 | Yes | 98 | 64.5 | Yes | 78 | 49.7 | Yes | 4 | 2.6 |
| No | 120 | 76.4 | No | 54 | 35.5 | No | 79 | 50.3 | No | 152 | 97.4 |
| Total | 157 | 100.0 | Total | 152 | 100.0 | Total | 157 | 100.0 | Total | 156 | 100.0 |

*Source:Survey Data*

In Table 4, the results of the estimated EFFICIENCY by analysis of variance (Multiple Range Tests: Modified LSD (Bonferroni) test with a significance level 0.05), in the villages Kbal Snuol,

Thpong, Snuol Kert, Snuol Lech, Kathdai, and Prek Kdey, the difference of the mean of the index of EFFICIENCY is not confirmed statistically.

Therefore, it confirms the influence that EFFICIENCY gives to agriculture income (Y: the average annual income from agricultural activity (riel)). The results of the regression model by estimation are as follows.

［Using chemical fertilizer of farmer］

$Y = -233{,}717 + 55{,}438.94\ \text{EFFICIENCY} \quad \overline{R^2} = 0.6377$

［Non-using chemical fertilizer of farmer］

$Y = -1{,}357{,}258 + 48{,}388.51\ \text{EFFICIENCY} \quad \overline{R^2} = 0.7671$

With both farmers using chemical fertilizers and those which do not, EFFICIENCY shows that it has a positive influence on agriculture income. It also shows that the existence of the technical inefficiency has a negative influence on agriculture income at the same time. The growth of technical efficiency of farm productivity rises and realizes an increase in agriculture income.

## CONCLUSION

The main objectives of this study are tp clarify the character of the upland farming system in Snuol village, Snuol district, Kratié Province. The first objective is to clarify the characteristic of the farm households using agricultural chemicals. The second is to clarify factor input structures by estimating the production function that was based on the Biological and Chemical technology. In addition, the third objective is to clarify technical efficiency by estimated the stochastic frontier production function.

The results of this analysis are summarized as follows.

According to the results of Multiple Correspondence Analysis, it will be clear for the preference of the farm household using the agricultural chemicals, the divisions of “Gender,“ “Age,“ “Family number,“ “Duration of residence,“ “Irrigation facility“ and “Multiple cropping“, as important characteristics for the classification.

The Biological and Chemical technology process is a condition of the diminishing returns to scale. The technology process intensively utilizes the agricultural chemicals in farms with low soil fertility. Therefore, contribution to the current capital such as chemical fertilizer is not high. Under the traditional cultivation method, depending on soil fertility, the upland farming system of the productivity has been realized by lands using chemicals and the agricultural chemicals saving production technology.

The estimated value of the technical efficiency shows existence of the technical inefficiency in upland farming systems of the research site.

As a result of the analysis, in the future, introduction of the environmental preservation farming systems are necessary for the sustainable development of the upland farming system.

Toward realization of the environmental preservation farming systems, it is suggested that agricultural education be part of life-skill education and networking for promoting sustainable agriculture.

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Research article

# Comparison of Rice Plant Development with Different Transplanting Density under SRI Practices in the Lysimeter

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**Abstract** Transplanting a single young rice seedling is one of the common methods in SRI practices. However, farmers in some lowland areas hesitate to apply this method due to the threats such as seasonal floods, birds and pests. Most of the farmers are more comfortable with transplantation of two or more seedlings per hill. Thus, an experiment was conducted in the lysimeter at the rooftop of the University of Tokyo in 2015 to compare the rice plant development with different transplanting density. As an experimental design, two sets of single seedling transplantation were applied with alternative wetting and drying irrigation as replications; the same irrigation condition was applied to other transplantations with two, three and four seedlings per hill. The plant height, number~~s~~ of leaves and tillers, dry biomass, and grain yields were selected as the main factors for the comparison of rice plant development. As a result, no difference was observed for the development of height across all transplantation density treatments during the vegetative phase. However, during the reproductive and ripening phases, single-seedling transplantation reached greater height. For the development in number of tillers and leaves, three and four seedlings produced more tillers and leaves than one and two seedlings. We found that the grain yield is significantly higher in three and four seedlings rather than one seedling.

**Keywords** system of rice intensification, young seedling, transplanting density, plant development

## INTRODUCTION

Rice is a major staple crop in the world. About 90% of all rice production and consumption takes place in Asian countries (FAO, 1998). Moreover, rice is also an important food in these areas, inter-connected with culture and eaten in festivals and other important events. While both the world population and the food demand is increasing, rice production is fluctuating due to the climate change and shifts in rice cultivation methods. Varieties of rice with high yield and climate tolerance have been discovered in recent years according to the International Rice Research Institute (IRRI, 1998). The varieties of rice and its cultivation differ by the climatic differences from region to region. The use of inorganic fertilizer in the paddy field is a common agricultural practice today in order to achieve high yields, but the excessive use of inorganic fertilizer have had negative impacts on the environment (Gimeno-Garcia et al., 1995). As a result, concerns with human health and interests in organic farming have risen. A new method of plant management, organic fertilizer application, water management, and

resultant high yields in rice production was found in Madagascar in 1983 by Father Henri de Laulanı´e, a French Jesuit priest, and later disseminated worldwide by the Cornell International Institute for Food, Agriculture and Development. This method, called the system of rice intensification (SRI) today, is considered to save water yet achieves high-yield compared to the conventional method (Thakur et al., 2010; Chapagain and Yamaji, 2009). Stoop et al. (2002) reviewed the SRI method practiced around the world explaining how high yields are achieved through SRI's key principles through a range of environmental factors and agronomic management practices including variety selection.

There are several definitions of SRI based on the climatic features of the countries. We applied the irrigation management called alternative wetting and drying irrigation (AWDI), which is also known as the intermittent irrigation. SRI method is considered as a water-saving method with high yields. At the same time, water management by AWDI reduces the methane gas emission from rice cultivation (Pun and Yamaji, 2014), which is one of the major contributors to the potential global warming. With respect to the worldwide dissemination of SRI, there are nonetheless many issues with regards to its method of application. One such issue is the farmers' hesitation to transplant single rice seedling per hill, which is considered a key principle of SRI, due to the concerns over threats from floods, pests and birds to name a few. Instead, these farmers prefer to transplant two or more seedling per hill. Such tendency among the farmers and their challenges in protecting young seedlings in lowland areas is one of the reasons why the dissemination of SRI as a single-seedling transplantation method has been limited.

The experiment conducted in lysimeter 2014, transplanting single seedlings were cultivated under both AWDI and continuous flooding conditions. The plant development was significantly higher in non-SRI method than in SRI method. But there was no significant difference between the two methods in terms of grains produced. It is because of same transplanting density of rice seedling. In this study, we investigated the rice plant development with different transplanting density under SRI practices. The aim of this study is to find adequate recommendations to farmers who hesitate~~s~~ to transplant single seedling in lowland areas as well as some uplands.

## MATERIALS AND METHODS

The lysimeter experiment was conducted on the rooftop of the University of Tokyo Kashiwa campus, Chiba Prefecture, Japan during the rice growing season in 2015. The study aimed to verify the difference in rice plant development by different transplanting density. The size of lysimeter was 495 cm in length and 158 cm in width. The lysimeter consists of a drainage valve on the right border and an irrigation facility from tap water on the left border (Fig. 1). The soil was puddled homogeneously for two weeks before transplanting. The organic fertilizer (2,200 gram) was also mixed homogeneously into the entire soil. The composition of organic fertilizer was 1.3% nitrogen 0.6% phosphorus, and 1.8% potassium, with C/N ratio of 22. We also installed a water tube with 13.5 cm diameter and 25 cm length to measure the ponding depth. Ponding depth was measured using data logger LR5042 (Hioki E.E. Corporation, Japan) over the course of the experiment. The water depth sensors inside the water tube were fixed at 15 cm deep from the soil surface. Data logger LR5042 measures water pressure in voltage ranging from -5.000 V to 5.000 V which is converted to the height of water in lysimeter with a calibrated equation. Water pressure data was collected every sixty minutes. The transplanted rice in the nursery was a 24-days old Japanese rice variety *koshihikari*. A total of 160 rice nurseries were transplanted on 12 May 2015. A single factor experiment method was utilized for this experiment, in which a single factor varied (density of rice seedlings while other factors remained constant (e.g. fertilizer, water management). The experiment followed the completely randomized design (CBD) with four treatments (number of rice seedlings per hill) with two replication. The randomization was done as shown in Fig. 1. The numbers indicated in Fig. 1 are a) SRI method with *one seedling per hill*, 2) SRI

method with *two seedlings per hill*, 3) SRI method with *three seedlings per hill*, and *4*) SRI method with *four seedlings per hill.*

Rice plant height and the number of tillers and leaves were recorded once every week during the vegetative phase. During the reproductive phase, the plants were covered with a net to protect from birds, and were measured twice a month. The water management applied was AWD (alternative wetting and drying) irrigation. Water was drained by using a hand pump when there was the excess rainfall.

The collected data was tested by ANOVA (Analysis of Variance) using R statistical software (R Core Team, 2014). Later, Tukey's HSD test was conducted to identify the differences in development among different treatments.

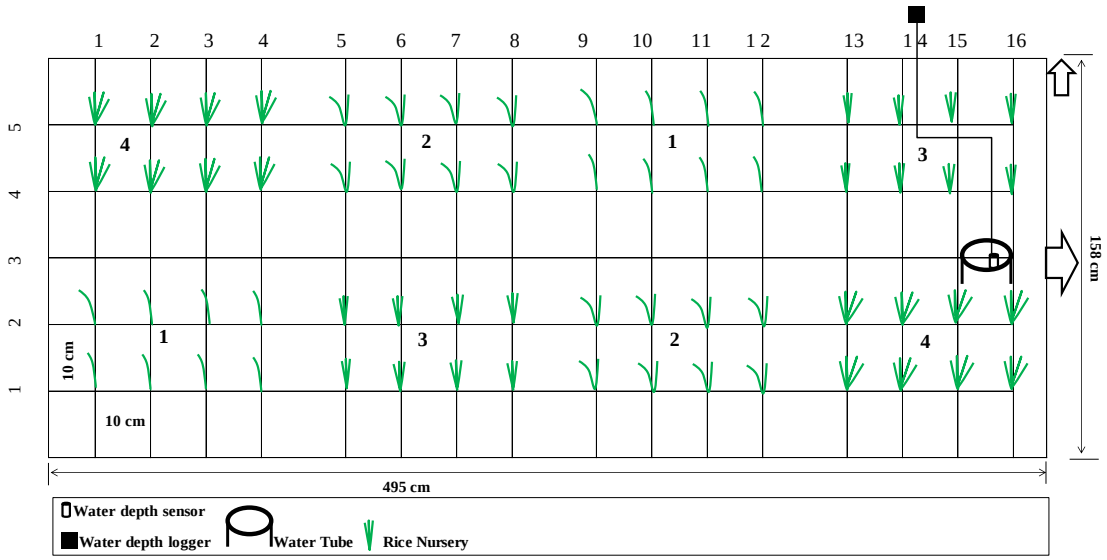


**Fig.1 Schematic diagram of the Lysimeter**

## RESULTS AND DISCUSSION

### Water Management and Climatic Condition

There are four seasons in a year in Japan. Paddy is cultivated only in summer seasons. Japanese rice farmers prepare the paddy field in late spring by flooding the field and applying fertilizers. Likewise, lysimeter was also prepared with flooding and fertilizer application at the end of April. The first rice was transplanted on the 12$^{th}$ of May. The method of water management was alternative wetting and drying irrigation (AWDI). We maintained the shallow ponding condition above the soil surface starting from the day of transplantation to 26$^{th}$ may until the rice plant became stronger. The maximum water level was 7.59 cm and minimum level was 0.24 cm from the soil surface (Fig. 2). The drainage valve was opened to reduce the water level in the lysimeter down to -13.10 cm from 27$^{th}$ May to 5$^{th}$ June. AWDI method was also applied based on the rainfall event in the study area (Fig. 2). The maximum rainfall in the study area occurred during the first 10 days of September at 249 mm (Japan Meteorological Agency, 2015). The comparison of rainfalls by 10-day intervals (start- first 10 days, mid-second 10 days, end-last ten days) during rice cultivation period revealed that the minimum rainfall (4 mm) was recorded at the start of August (10 days). Maximum temperature was also recorded during the cultivation period (36.7°C). If there was no rainfall event, tap water was used for irrigation. During the ripening phase, lysimeter was kept dry to prepare for the harvest.

## Rice Plant Development

The rice plant height and the number of tillers and leaves were measured once every week during the vegetative phase. However, measurements were taken only once a month during the reproductive phase, because the lysimeter was covered with a net to protect the rice plants from birds.

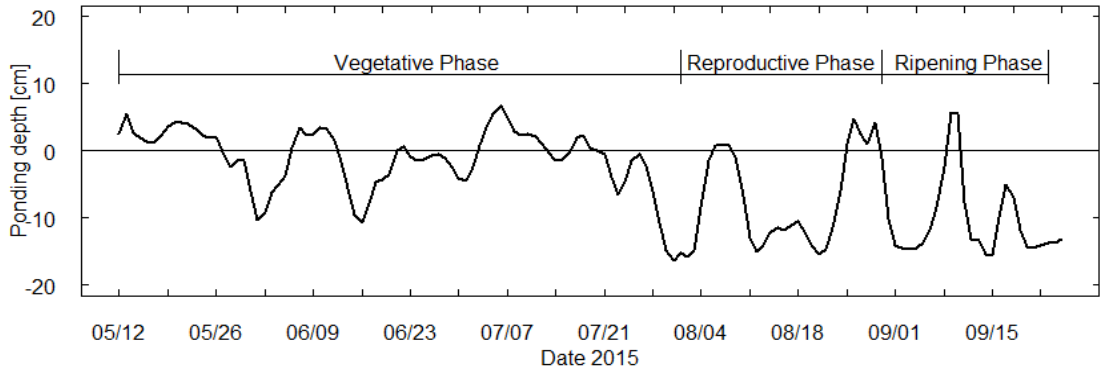


**Fig. 2 Water management during the rice cultivation in the lysimeter**

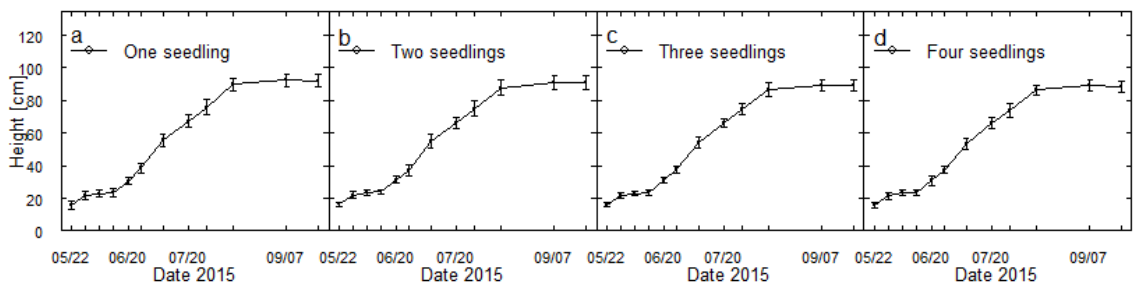


**Fig. 3 Rice plant height development in all treatments**

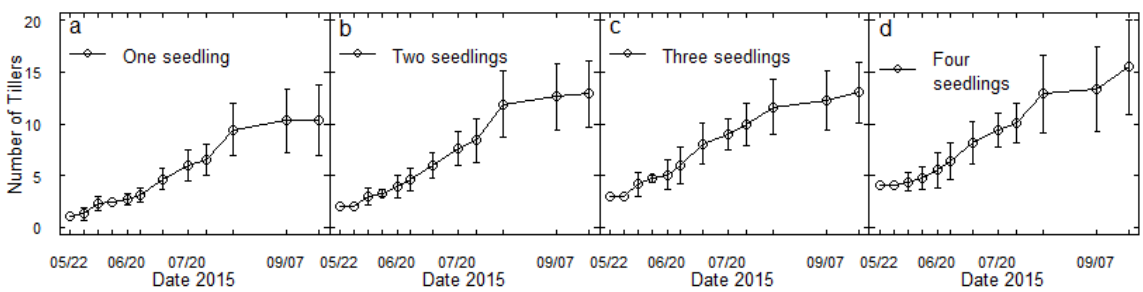


**Fig. 4 Rice tillers development in all treatments**

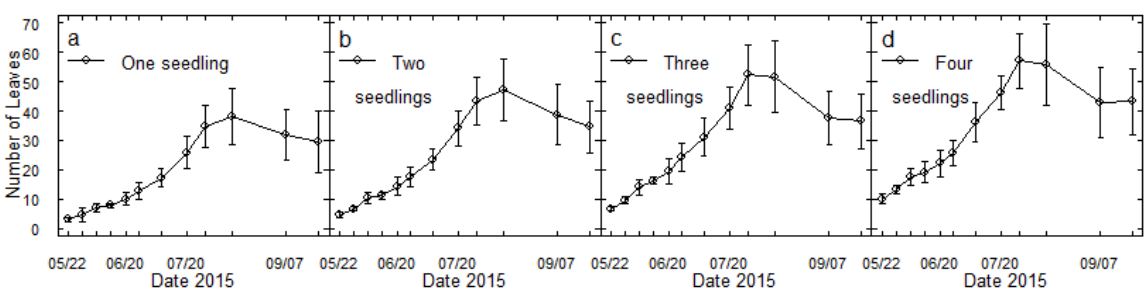


**Fig. 5 Rice plant leaves development in all treatments**

After the rice was transplanted on 12th of May, the first height was measured on 22nd of May by a measuring tape. Fig. 3 shows that the average height in centimeters for two, three, and four seedlings per hill were 16.34 ± 1.21, 16.03 ± 1.34 and 16.03 ± 1.53, respectively, but the average height for one seedling per hill was only 15.69 ± 2.26, Fig. 4 shows the development of tillers, which was observed in every seedling density after the 29th of May. Fig. 5 shows the development of rice plant leaves counted altogether, where the maximum number of leaves was counted in four seedlings, followed by three, two, and one seedling. During the vegetative phase, numbers of leaves were similar in three and four seedlings. Number of tillers and leaves were also higher in three and four seedlings than one and two seedlings. The rice was harvested on 23rd of September. Maximum height across all four treatments were observed in one and two seedlings, while the heights for three and four seedlings were similar to each other but less than that of the one and two seedling densities. The number of leaves decreased because lower leaves decayed. Some leaves decayed and dried but were not included in the count. The number of tillers increased at the end of the vegetative phase because of the emergence of small branches. However, formation of panicles was not observed for the small branches.

**Table 1 Details of the rice plant development**

| Measured Variables | 1 T (One Seedling) | | 2 T (Two Seedlings) | | 3T (Three Seedlings) | | 4 T (Four Seedlings) | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **Height (Centimter)** | 92.13 | 2.88 | 91.00 | 89.25 | 89.25 | 2.63 | 88.56 | 2.19 |
| **Stem (Number)** | 10.38 | 2.36 | 12.88 | 2.15 | 13.06 | 1.45 | 15.25 | 2.41 |
| **Green Leaves (Number)** | 29.69 | 7.21 | 34.63 | 6.44 | 36.50 | 4.64 | 43.25 | 6.69 |
| **Dead Leaves (Number)** | 13.44 | 2.26 | 19.56 | 2.99 | 20.13 | 3.52 | 20.81 | 3.40 |
| **Panicle (Number)** | 9.75 | 1.67 | 11.94 | 2.35 | 11.94 | 1.32 | 13.25 | 2.62 |
| **Dry Stem (Gram)** | 9.61 | 0.89 | 13.04 | 0.74 | 13.39 | 2.35 | 14.39 | 2.04 |
| **Dry Leaves (Gram)** | 4.14 | 0.41 | 5.55 | 0.51 | 5.76 | 0.86 | 5.84 | 0.73 |
| **Good Grain (Number)** | 647.75 | 162.97 | 798.00 | 64.39 | 752.88 | 85.18 | 681.13 | 75.21 |
| **Bad Grain (Number)** | 8.50 | 1.08 | 16.75 | 8.45 | 15.75 | 1.50 | 13.00 | 9.88 |
| **Dry Spikelet (Gram)** | 0.95 | 0.15 | 1.03 | 0.15 | 0.98 | 0.13 | 1.07 | 0.20 |
| **Grain Weight (Gram)** | 15.89 | 2.31 | 18.20 | 3.15 | 19.83 | 2.55 | 20.49 | 4.39 |

*SD: Standard Deviation*

**Table 2 Comparison between indicators using T-test**

| | 1 T | 2 T | 3 T | 4 T |
|---|---|---|---|---|
| **Dead Leaves** | | | | |
| 1 T | | | | |
| 2 T | *** | | | |
| 3 T | **** | ** | | |
| 4 T | | | | |
| **Dry Stem** | | | | |
| 1 T | | | | |
| 2 T | * | | | |
| 3 T | ** | | | |
| 4 T | | | | |
| **Dry Leaves** | | | | |
| 1 T | | | | |
| 2 T | * | | | |
| 3 T | ** | | | |
| 4 T | | | | |
| **Dry Spikelet** | | | | |
| 1 T | | | | |
| 2 T | | | | |
| 3 T | * | | | |
| 4 T | | | | |
| **Grain Weight** | | | | |
| 1 T | | | | |
| 2 T | ** | | | |
| 3 T | *** | | | |
| 4 T | | | | |

T: Seedling, * Significant level at 0.1, ** Significant level at 0.05, *** Significant level at 0.01, **** Significant level at 0.001

## Grain Yield and Biomass

We harvested rice on the 23rd of September. To study the grain yields and total biomass development within four treatments, four rice plants were selected from the middle of each treatment. Height, the number of stems, green leaves, dead leaves, and panicles were measured for a total of 64 rice plants. Moreover, in order to study the details of rice plants, the number of grains (good and bad), dry stems and leaves, and spikelets were counted from selected 32 plants. The grain weight at 14% moisture level

was measured from all rice plants (Table 1). The result of height among the treatments showed the mean difference is higher in one seedling but without significant difference. In case of stems, one seedling was lower than the two, three, and four seedlings. The number of green leaves at the time of the harvest were counted, but the number was lower for one seedling case.

The dead leaves were recorded just after the harvest. In comparison with other treatments, three seedlings showed a significantly higher level of dead leaves compared to one seedling treatment, as shown in Table 2 ($p < 0.05$). The four seedlings also had a greater number of dry leaves than one and two seedlings ($p < 0.001$ for comparison with one seedling treatment; $p < 0.01$ for comparison with two seedling treatment). The number of dry stems and leaves were higher for four seedling treatment than for one seedling treatment ($p < 0.05$). For other comparisons, differences in dry stems and leaves were not significant. The spikelets without grains were also higher for two, three, and four seedling treatments. The grain weight at 14% moisture level was measured. The grain weight (i.e. yield) was significantly higher for three and four seedlings compared to one seedling treatment ($p < 0.05$). However, there was no significant difference in grain weight (yield) among the two, three, and four seedling treatments.

## CONCLUSION

We conducted the lysimeter experiment to clarify the difference in rice plant development by different transplanting density under the SRI practices. The common method of rice transplanting by SRI is single young rice seedling. However, famers in some lowland areas hesitate to transplant single seedlings by the SRI method because of the threats from birds, flood and insects to name a few, causing a dilemma for the farmers over the implementation of the SRI method. We found that the grain yield is significantly higher for transplantation treatment with three and four seedlings rather than one seedling, validating the farmers' confidence in their way of applying the SRI method. This study thus suggests that farmers can transplant more than one seedling in lowland areas. The study used a Japanese koshihikari rice nursery. It is highly recommended to test with the local rice variety, climatic condition, and agronomical practices for a more precise confirmation of optimal seedling densities.

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Research article

# Adaptation Strategies to Changing Environment by an Organic Farm in Laguna, Philippines

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**Abstract** With the increasing awareness of consumers for alternative lifestyle and the enactment of the Organic Agricultural Act of 2010, more and more farmers are expected to shift to organic farming (OF) in the Philippines. However, shifting to OF and maintaning an organic farm are not easy tasks due to various issues such as lack of knowledge on suitable production technologies, unstable supply, lack of markets, intensive labor inputs and difficulty in controlling weeds, pests and diseases to name a few. Despite these issues, some organic farms were able to sustain operations. This study aims to determine the farm business strategies that enabled C Farm (CF) to stay in business and grow given the changing business environment. This paper does not limit its scope to the strategies adopted by CF to cope with climate changes, but this also focuses on the changes in business strategies given the challenges in the economic, technological, socio-cultural and demographic business environment. The case study approach done through in-depth interviews with company owners and multiple site visits and observations was mainly used. Moveover, evaluation of the opportunities and threats in a business environment was done to determine the match of strategies implemented by CF. Potential OF investors may find this study useful in determining best practices in the OF business. Farm visits and key informant interviews revealed that CF was able to adapt innovative production, marketing, financing and community relationship strategies, which are key ingredients in business survival and growth. Positioned as an agritourism farm, it was able to deal with the presssures of the external environment by integrating farm operations, crafting strategies to increase and sustain production through ecological means, adopting keen market sensing strategies, increasing financing through joint ventures and strengthening community relations by involving them in the various financing and operations activities.

**Keywords** organic farming, investment strategies, extension services, Philippines

## INTRODUCTION

Conversion to organic farming (OF) has become a prevalent trend all over the world due to increasing market awareness, growing demand for organic products, and support of the government through government policies and push for organic agriculture. Moreover, more stakeholders of the food chain, including the farmers have become involved. However, Gliessman (2009) explains that success in conversion is based on ability of the farmer to operate the farm and to adjust to other factors (e.g. extension, market development, prices) of the food system, which are often beyond his/her control. In other words, it is more than just changing the inputs. This also entails changes in strategies in the food chain and compliance with regulatory and certification policies. In the case of the Philippines, organic certification is not an easy process. Amekawa (2013) adds that certification does not generally

guarantee market access. In most cases, access to market is ensured even before organic farms apply for certification.

OF has been practiced in the Philippine since early 60s, however, the advent of Green Revolution in the mid 60s has successfully influenced many farmers to use chemical fertilizers and pesticides to increase farm productivity. Renewed OF interest started in the 1980s initially by NGOs, farmers, and academe (Nakanishi, 2014). Since then, more and more nicher farms have been developed. This has caught the attention not only of the health enthusiasts but also the government, which recognized the importance of OF. With the recent enactment of the Organic Agricultural Act of 2010, more and more farmers are expected to shift to OF. According to the National Organic Agriculture Program (NOAP), organic agriculture covers about 40,000 has, which are managed by about 76,500 farmer-beneficiaries in 2013 (Caneda, 2014). Although the scale is still considered small, NOAP added that its main targets are to increase total area, increase production volume, expansion in markets, increase number of certified farms and processors, and increase number of organic agriculture adopters. However, shifting to OF and maintaining an organic farm are not easy tasks due to various issues such as lack of knowledge on suitable production technologies, unstable supply, lack of markets, intensive labor input, difficulty in controlling weeds, pests and diseases. Another issue related to shifting to OF is the availability of the organic farm to sustain operations and be resilient given the demands and challenges of the new business environment. According to Milestad and Darnhofer (2003), resiliency will highly depend on the learning and adaptation ability from current issues and conditions.

## OBJECTIVE

This study aims to determine how an organic farm business was able to cope with the various challenges and the strategies that the farm implemented to sustain operations despite changes in the business environment. It should be noted that environment refers not only to natural environment but also includes socio-cultural and economic environments, which affect the farm (Fujimoto, 2014). Lessons from these experiences may help other farmers to attain growth and resilience in their OF business. Moreover, potential OF investors may find this study useful to determine best practices in the OF business. It should be noted that this paper may not be able to thoroughly explain all aspects, but aims to provide an outline for further research.

## METHODOLOGY

This study used the case study approach using qualitative and quantitative data. This focuses on the experience of C Farm (CF), which has been operating in the town of Majayjay, Laguna Philippines since 2006. The town of Majayjay, which is located about 120 km South of Metro Manila, is endowed with characteristics that are favorable for vegetable production. Primary data were gathered from farm visits and key-informant interviews conducted in February and May 2014. The May 2014 interview was recorded using an IC recorder, and transcribed in order to fully capture the details.

## RESULTS AND DISCUSSION

### Profile of C Farm

Table 1 shows the development of CF, which was initially established in 2006 as a hobby farm towards achieving an alternative lifestyle. Located near the Majayjay falls, CF started in a 0.77 ha farm lot. Without any knowledge and experience on farming, the family initially planted fruit bearing trees such as *santol* (*Sandoricum koetjape*), *makopa* (*Syzygium samarangense*), *bayabas* (*Psidium guavaya*),

*dalandan* (*Citrus aurantium*), mangosteen (*Garcinia mangostana*), langka (*Artocarpus heterophyllus*) and sampalok (*Tamarindus indica*) among others.

While waiting for the trees to bear fruit and so as not waste the time and space, CF started producing traditional vegetables and herbs for home consumption. The vegetables produced then (e.g. eggplant, okra, squash, bitter gourd) were mainly used for *Ilocano* dishes such as *pinakbet* (i.e. mixed vegetables sauteed/steamed with shrimp or fish paste), which is highly preferred by the household head, who hails from the province of Ilocos located in Northern region of the Philippines.

By 2008, the farm also started planting salad greens (e.g. lettuce) initially for home consumption but expanded towards commercial farming for all its farm produce in response to the demand. Relatives, friends and friends of the friends frequently visited the farm and it is through these visits that the company owner of a group of restaurant chains became CF's first partner in 2009. This initial partnership involved supplying four (4) branches of its Italian restaurant for the vegetables and herbs demand. By 2010, CF was able to penetrate and establish a market in Mercato Central, Taguig City, Metro Manila. In the same year, CF was also duly accredited by the Department of Tourism as the *First Agritourism Destination in the Philippines*, since they also have been offering recreational activities (e.g. pick-and-pay, fish-and-pay, feeding the animals) and accommodation facilities. These have resulted to more partnerships with other hotel, restaurant and catering service (HORECA) outlets and other initiatives (e.g. life at the farm tour, wellness tour).

Currently, CF has expanded to 5 hectares, and more expansion is on the way to keep up with the increasing demand. It produces 20 tons of vegetables and herbs per month, of which lettuce accounts for 80%. It is a common practice of CF to produce vegetables based on the contract with the clients. In other words, there is assured market for whatever they plant. Production is planned for each client. However, CF also allots about 20% of production as buffer for new clients. With regards to organic certification, CF is duly certified by the Negros Island Organic Certification Services (NICERT).

**Table 1 Highlight on the Development of C Farm**

| Year | Events |
|---|---|
| 2006 | Established as a hobby farm |
| 2008 | Started commercial production of organic produce |
| 2009 | Supplied a restaurant for the first time (4 branches to 18 branches in 2014) |
| | Achieved "Zero-Waste Farming" |
| 2010 | Started marketing at Mercato Central, Global City, Taguig |
| | Accredited as the *First Agritourism Destination in the Philippines* |
| 2012 | Ventured on more partnerships with other HORECA outlets |
| | Established a website |
| | Started the "Building a Greenhouse" program |
| | Awarded as the Most Outstanding Farm in the Philippines by President Aquino |

*Source: Key Informant Interview, May 2014*

## Adaptation Strategies

Since its establishment, CF has been facing a host of opportunities and threats that it has successfully responded to. It has been able to adapt to its environment, hence its growth, sustainability and resilience through the years.

### *Integrated Farming Operations*

CF meets market demands, and grows and sustains its business through integrated farming operations. This is also a way of dividing risks and keeping costs to a minimum since all businesses in the farm support each other. The farm does not incur logistics and transaction costs in sourcing organic

fertilizers because this is also produced in the farm. Some raw materials for organic fertilizers come from the crops and animals that the farm grows. It was observed that the output of one business group (organic fertilizer) is used as inputs to another business group (crop production). The integrated farm consists of high value crop production, culinary herbs, free-range poultry and livestock, aquaculture, vermiculture and orchard. It also has service facilities such as restaurants, training rooms and lodging areas, which support their tour and private extension activities. Fig. 1 shows the organizational structure showing the different businesses.

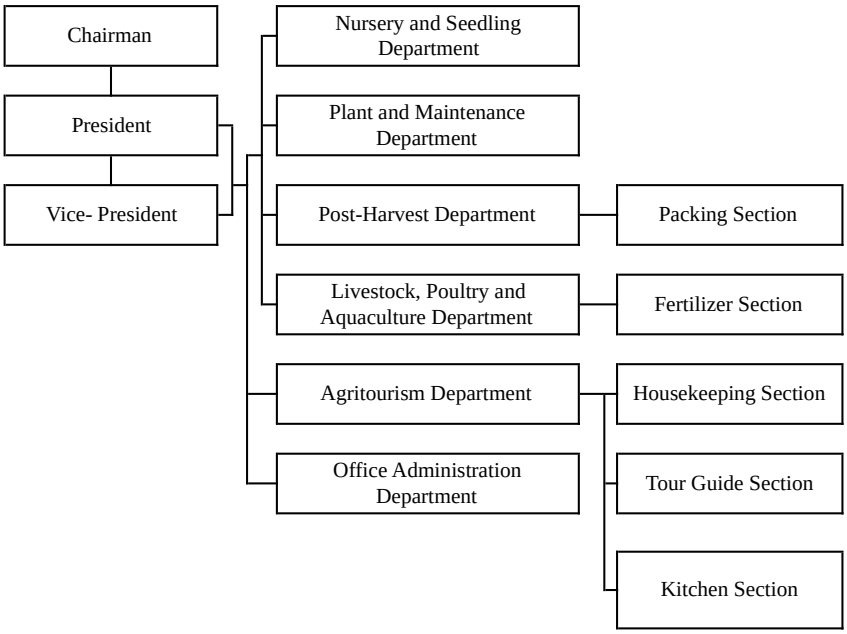


**Fig. 1 Organizational Structure of C Farm**
*Source: Key Informant Interview, May 2014*

*Market Networking Strategies*

One of the challenges in the OF business is keeping connected with good markets. CF is able to maintain good relationships with a group of restaurants chain-company, which is its first institutional buyer. CF also formed a marketing partnership with a high-end retail chain store selling organic products. CF exclusively supplies organic pork, chicken and eggs to this company. Aside from these two big buyers, they also serve prominent hotels and other smaller regular buyers in Metro Manila. Keeping connected with these markets and continuous search for future markets are some advantages of CF.

*Sharing of Information and Technologies*

Traditionally, Filipino farms do not often share trade-secrets such as farm technologies and other information. This is not the case with CF as this farm openly shares its OF experience and business. CF builds relationships with communities and potential organic farmers by sharing technologies and market information. Seminars and trainings are conducted in the farm where OF as a business and lifestyle is showcased. This is a farm extension activity where CF as a private entity actively takes part since 2010. With this strategy, CF is also able to source agricultural produce from these new farmers during times when the farm produce cannot meet the volume requirements of the market. Moreover,

CF is creating more impact in the community as more and more local and foreign people from all walks of life learn the OF processes and their long-term benefits to health and the ecology as a whole.

In addition, with its accreditation as the private extension service provider of the Agricultural Training Institute (ATI) under the Department of Agriculture (DA), CF is in the position to also further expand its networks with the government, educational institutions and other agencies interested in the OF system.

*Investment Partnering through Joint Venture Arrangements*

Majayjay Town, where the farm is located is characterized with 10 months of rain. This kind of weather adversely affects vegetable production. To meet the increasing demand for vegetables, CF realized the need to find alternative ways to adapt to the condition of the natural environment by putting up greenhouses. However, the family was not financially capable due to limited own capital. One growth and sustainability strategy that they implemented at this point is to encourage investment into the farm.

In 2012, CF initially targeted and invited Overseas Filipino Workers (OFWs) to be business partners for its "Building a Greenhouse" program under joint venture (JV) arrangements, since OFWs have the capital, the willingness to invest and the interest in organic production, but do not have the time and knowledge to engage in farming. In this JV arrangement, investors fund the building of greenhouses within the farm, while CF does the actual production and marketing operations. CF and the investors share the profit 50:50 every quarter. The advantage of this arrangement aside from profit share is that the investor does not do actual farming operations while CF does not need to invest in greenhouse facilities. In six (6) months after the announcement in its official website, CF was able to fill up its farm with greenhouses. The first venture partners were an engineer in Africa and a doctor in USA, both of whom, the owners do not know personally. Investment partnering, an innovation strategy adopted by CF, is now being practiced by other organic farms.

Recent JV offerings are agritourism development and multi-purpose hall project in response to the need for expansion of the farm and agritourism operations, and establishing a training center, respectively. Through investment partnering, organic farms are able to cope with the financial challenges in business operations.

*Capitalizing on and Promoting Health Consciousness*

The trend towards a healthy and alternative lifestyle is what prompted CF to invest in OF. It is forecasted that this trend will continue in the several decades to come. Consumers are realizing the importance of good health and are more conscious of the negative effects of chemicals used in agricultural production. The green revolution that was previously seen as the solution to food crisis is now being associated with many health issues. This is also demonstrated in India where the Green revolution increased productivity and export potential to the detriment of the ecosystem. It has caused irreversible poisoning of the environment and is seen to adversely affect future generations (Vaarst, 2010). CF continuously promotes health consciousness among its network of buyers and the larger community as well. Health consciousness campaign is part of the overall OF showcase, which is emphasized in the seminars and farm tours that CF is conducting.

*Positioning the Farm as an Agritourism Farm*

The change in the positioning of CF from just an organic farm to an agritourism farm has provided opportunities for the farm to widen its reach and serve more people through community activities. CF

is able to showcase its OF model, which it willingly shares with its thousands of visitors. As an agritourism farm, it offers tour and learning packages for OF enthusiasts.

## CONCLUSION

An organic farm's growth and sustainability is determined by its ability to adapt to the challenges of the external environment. A key adaptation strategy implemented by CF is integrating farm business operations. Small organic farmers may not be able to adapt this strategy but there is always that possibility that they can connect with CF or similar farms by participating in their farm extension program. An innovation that CF adapted to enable the farm to grow and respond to its increasing demand is through investment partnering. CF as an agritourism farm has a strategic advantage, since trend towards ecology-based farming and health consciousness will continue in the next several decades.

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Research article

# Diversity of Plant Growth Promoting Rhizobacteria Communities Associated with Thiamethoxam in Cassava Production Systems

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**Abstract** The use of chemical pesticide always leaves chemical residues on soil and may affect the population, function and diversity of soil microorganisms. Therefore, the aim of the study was to determine the effect of thiamethoxam, pesticide in the group of neonicotinoid to control insect pest, on diversity of plant growth promoting rhizobacteria (PGPR) communities in cassava production systems. Bacteria were isolated from rhizosphere of cassava grown in the field of 5 treatments, including cassava production system without thiamethoxam and fertilizer application, cassava production system with thiamethoxam application, cassava production system with thiamethoxam and organic fertilizer application, cassava production system with thiamethoxam and chemical fertilizer application, and cassava production system with thiamethoxam, organic and chemical fertilizer application, and then screened for plant growth promoting traits. The genotypic diversity of isolates was determined on a basis of amplified rDNA restriction analysis (ARDRA). The findings of this study indicated that the majority of bacteria were found to belong to the genera of *Bacillus*, *Ochrobactrum*, and *Brevibacillus*. Interestingly, the application of thiamethoxam in cassava production system has no effect on PGPR diversity.

**Keywords** Plant Growth Promoting Rhizobacteria (PGPR), Thiamethoxam, Cassava

## INTRODUCTION

Plant growth promoting rhizobacteria (PGPR) represent numerous species of soil bacteria which, when grown in association with a host plant, result in stimulation of growth of their host. PGPR are used as inoculants for biofertilization, phytostimulation, biocontrol (Bloemberg and Lugtenberg, 2001) and bioformulation (Prathap and Ranjitha Kumari, 2015). PGPR can directly benefit plant growth by fixing nitrogen, which can subsequently be used by the plant, thereby improving plant growth when the amount of nitrogen in the soil is limited (Vessey and Buss, 2002), produce phytohormone such as indole-3-acetic acid (IAA) (Ahemad and Khan, 2012; Sachdev et al., 2009) and phosphorus uptake (Rodriguez and Fraga, 1999). Indirectly, by increase resistance to pathogen, PGPR may suppress plant pathogens by producing antimicrobial metabolites (Duffy et al., 2004) as well as by producing enzymes and/or fungicidal compounds (Bloemberg and Lugtenberg, 2001; Haas and Défago, 2005). In addition, PGPR can produce siderophore induced disease resistance, which can be enhanced by the simultaneous activation of induced systemic resistance (ISR) and systemic acquired resistance (SAR)

pathways (Duffy and Défago, 1999). However, accumulation of chemical pesticides into the soils beyond certain threshold levels due to its frequent application in the fields to overcome plant pests damages the rhizosphere microorganisms and their activities (Wani et al., 2005) and may alter diversity of the microorganism. Nowadays, thiamethoxam, pesticide in the group of neonicotinoid, was normally used for cassava stake soaking to control aphids. However, the data of whether thiamethoxam affects soil microorganism diversity remains scarce.

## OBJECTIVE

The purpose of this study was to investigate the influence of chemical pesticide (thiamethoxam) on the diversity of PGPR communities in cassava production systems.

## METHODOLOGY

### Study Sites and Soil Sampling

Study sites used in this study were selected from Kalasin province (N16°38'3", E 103° 15 '15"), Thailand. This experiment has been designed as the randomized complete block design (RCBD). A sampled area was set up at 5m x10 m for each block. Soil samples were collected from rhizosphere of cassava cultivar Kasetsart 50 (KU50) at a spacing of 1m x 1m with three replications at 0, 15, 30, 45 and 60 days after planting (DAP). Thiamethoxam 25 WG was used in this study for cassava stake soaking at the rate 4g/20 liters of water. Five treatments used in this study, including cassava production system without thiamethoxam and fertilizer application (T1), cassava production system with thiamethoxam application (T2), cassava production system with thiamethoxam and organic fertilizer application (T3), cassava production system with thiamethoxam and chemical fertilizer application (T4), and cassava production system with thiamethoxam, organic and chemical fertilizer application (T5). Organic fertilizer used in this study is chicken manure mixed with rice husk, 1000 kg/1,600 $m^2$ and chemical fertilizer used in this study is formula 15-7-18, 50 kg/1,600 $m^2$. The rhizosphere samples were placed in plastic bags and stored at 4°C for further microbial analysis.

### Isolation of PGPR from Cassava Rhizosphere

Bacterial strains were isolated from cassava rhizosphere by serial dilution plate technique on nutrient agar medium (NAM). The bacterial colonies were isolated and maintained on NAM slants at 4°C. One hundred isolates obtained from serial dilution plate technique of each treatment were screened for their plant growth promoting factors included production of indole-3-acetic acid (IAA), phosphate solubilizing activity and their ability to grow in N-free medium. In addition, their biocontrol activity included protease enzyme production as well as siderophore production was investigated.

### Assays for Growth Promoting Abilities of Isolates

**Indole-3-acetic acid (IAA) production:** IAA production was determined using the method described by Lawongsa et al. (2008) with slight modification. Bacterial isolates were cultured in Tris-TMRT (D-mannitol 10 g, yeast extract 0.2 g, $CaCl_2.2H_2O$ 0.2 g, $MgSO_4.7H_2O$ 0.25 g, tris-base 1.21 g, pH 6.8) supplemented with tryptophan 0.5 mM for 48 h. The measurement of IAA was done by adding 2 ml of 0.01 M $FeCl_3$ in 35 % $HClO_4$ into 1 ml of Tris-TMRT culture broth. The mixture was incubated in the dark at 30 °C for 30 min. The detection of IAA was determined by the development of pink color.
**Phosphate solubilizing assay:** Solubilization of tricalcium phosphate was detected in national botanical research institute's phosphate growth medium (NBRIP) agar plate supplemented with 1.5 %

(w/v) agar (Nautiyal, 1999). Five microliters of each bacterial culture was dropped on NBRIP agar plates. Plates were incubated for 7 days at 28˚C. The development of halo zone around the bacterial colony was considered as positive for phosphate solubilizing activity.

**Nitrogenase activity:** For rapid determination, nitrogenase activity was assayed after bacterial strains were streaked onto N-free minimal medium supplemented with 1.5 % (w/v) agar and incubated at 28 ± 2 °C for 3 days (Desnoues et al., 2003). Bacterial growth indicated nitrogenase activity.

**Protease assay:** Bacteria were isolated for protease enzyme (casein degradation) using a method described by Sjödahl et al., (2002). Samples were inoculated on Luria-Bertani (LB) agar plates containing skim milk (20 %), then incubated at 28 ± 2 °C for two days (Uyar et al., 2011). The development of clear zone around the bacterial colony indicated protease enzyme activity.

**Siderophore assay:** Siderophore was determined by chromazurol sulphonate agar (CAS) using the method described by Clark and Bavoil (1994). Bacterial inoculum was spotted into the center of a CAS agar plate. After incubation at 28°C for 5 days, siderophore production was assayed by clear zone formation around the cell.

### Total Genomic DNA Isolation

PGPR isolates were grown in a nutrient broth at 28°C overnight and then were harvested by centrifugation at 5,000xg for 5 min and washed twice in 500 µl of TEN buffer (0.1 M Tris-Cl, 0.01 M ethylenediaminetetraacetic acid (EDTA), and 1 M NaCl, pH 8.0). Cell lysates were prepared by mixing the cell pellet with 200 µl of 20% (w/v) sucrose in TEN buffer to this 20 µl of 2 mg/ml of lysozyme and 20 µl of 10 mg/ml of RNase was added. Cell mixtures were incubated at 37°C for 60 min. Then 75 µl of 5 M NaCl and 100 µl of 10% Sodium dodecyl sulfate (SDS) were added before gentle mixing. The solution was purified twice by using phenol:chloroform:isoamyl-alcohol (25:24:1, by volume). The upper phase was collected and precipitated by using isopropanol and 3 M sodium acetate. The DNA pellet was resuspended in sterilized deionized-water and total genomic DNA was kept at -20°C before use (Sambrook and Russell, 2001).

### Amplified rDNA Restriction Analysis (ARDRA)

The 16S rDNA universal primers fD1 (5'-AGAGTTTGATCCTGGCTCAG-3') and rP2 (5'-AAGGAGGTGATCCAGCC-3') (Weisburg et al. 1991) were used to amplify a 1.5-kb internal region of the 16S rRNA gene. An initial denaturation at 95°C for 5 min was followed by 35 cycles with denaturation at of 95°C (30 s), annealing at 58°C (1 min) and extension at 72°C (2 min), and a final extension at 72°C for 7min. Restriction analysis was performed with 5 µl of amplified product and 10 µl of restriction buffer containing 2 U of either the restriction enzymes *Alu*I. After a 4 h digestion at the appropriate temperature, the enzyme was inactivated by heating the preparations at 65°C for 20 min. For each isolate, PCR amplification and restriction analysis were performed at least three times. Calculation of the pair-wise coefficients of similarity was based on the presence or absence of bands. A cluster analysis with the UPGMA algorithm was performed with the NTSYS-pc numerical taxonomy and multivariate analysis system. Then, Representatives of each group were selected for cloning and partial 16S rRNA gene sequencing to retrieve sequence similarity and bacterial identity from nucleotide sequence databases.

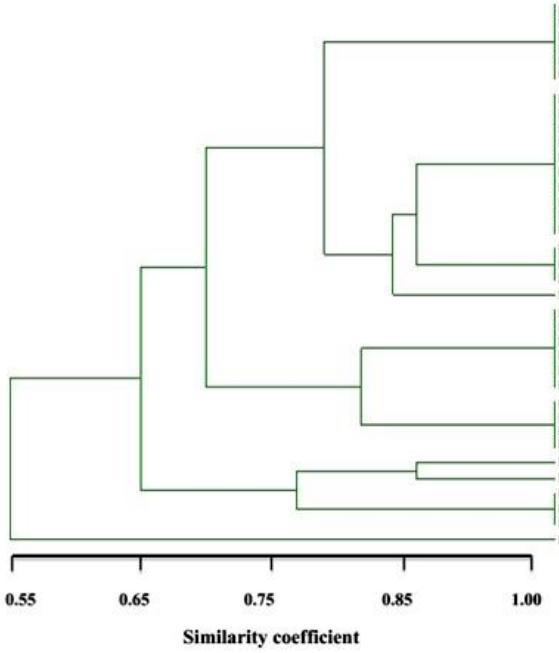
## RESULTS AND DISCUSSION

### Plant Growth Promoting Properties of Bacterial Strains

A total of 100 cultivable bacterial isolates of each treatment obtained after serial dilutions were screened for plant growth promoting traits. Subsequently, community of representatives of PGPR genera/species of each treatment was distinguished by ARDRA analysis. Detailed data of the phenotypic characterization of these isolates are shown in Fig. 1. Ninety five percentage of PGPR isolates obtained from ARDRA cluster I showed the ability to solubilize phosphate and 85% of PGPR isolates showed the ability to produce IAA. In ARDRA cluster II, 100% of PGPR isolates obtained from ARDRA cluster I showed the ability to solubilize phosphate and 90% of PGPR isolates showed the ability to produce IAA. In ARDRA cluster III, 100% of PGPR isolates obtained from ARDRA cluster I showed the ability to solubilize phosphate, 80% of PGPR isolates showed the ability to produce IAA and 80% of PGPR isolates showed the ability to grow in N-free medium. Meanwhile, in ARDRA cluster IV, PGPR isolate showed the ability to produce IAA, protease can solubilize phosphate and be able to grow in N-free medium but did not show the ability to produce siderophore.

**ARDRA Analysis and 16S rRNA Gene Partial Sequencing on PGPR Isolates**

The cluster dendogram of ARDRA analysis of PGPR isolates obtained from cassava rhizosphere is illustrated in Fig. 1. Digestion of amplified 16S rDNA with AluI revealed four main clusters of ARDRA dendogram. Cluster I and II of ARDRA dendogram showed representative of genera/species from all treatment. Cluster III contained representative of PGPR genera/species from T1 (cassava production system without thiamethoxam and fertilizer application), T2 (cassava production system with thiamethoxam application) and T4 (cassava production system with thiamethoxam and chemical fertilizer application) while, cluster IV showed representative of PGPR genera/species only from T2.




| ARDRA group | Isolates | Plant growth promotion characteristics | | | | |
|---|---|---|---|---|---|---|
| | | IAA | Phosphate solubilization | Nitrogenase activity | Protease | Siderophore |
| I | KU0T1 | + | + | + | + | + |
| | KU0T2.1 | + | + | + | + | - |
| | KU15T2.1 | - | + | + | + | + |
| | KU15T3 | + | + | + | + | - |
| | KU30T2 | - | + | + | + | - |
| | KU45T1.1 | + | + | + | + | - |
| | KU0T2.2 | + | + | + | + | + |
| | KU0T3 | + | + | + | + | + |
| | KU0T4 | + | + | + | - | + |
| | KU0T5 | + | + | + | + | + |
| | KU15T1.1 | + | + | - | + | - |
| | KU15T4 | + | + | - | + | - |
| | KU15T5 | + | + | + | - | - |
| | KU30T5 | + | + | + | + | + |
| | KU45T1.2 | + | + | + | - | - |
| | KU45T2.1 | + | - | + | - | - |
| | KU15T1.2 | + | + | - | - | + |
| | KU45T3 | + | + | + | + | - |
| | KU45T5 | + | + | + | - | + |
| | KU45T2.2 | - | + | - | + | - |
| II | KU15T1.3 | + | + | - | + | + |
| | KU15T2.2 | + | + | - | - | + |
| | KU45T1.3 | + | + | + | + | - |
| | KU60T1.1 | + | + | + | - | - |
| | KU60T2.1 | + | + | + | - | - |
| | KU60T2.2 | + | + | + | + | - |
| | KU30T3 | - | + | - | + | + |
| | KU30T4 | + | + | + | + | + |
| | KU60T3 | + | + | + | - | - |
| | KU60T5 | + | + | + | - | - |
| III | KU30T1 | + | + | + | - | - |
| | KU45T4 | + | + | + | - | - |
| | KU60T1.2 | + | + | + | - | - |
| | KU60T2.3 | - | + | - | + | - |
| | KU60T4 | + | + | + | - | - |
| IV | KU60T2.4 | + | + | + | + | - |

**The different isolates were designated KU followed by the time after planting (0, 15, 30, 45 or 60), treatment number and by progressive numbers of PGPR isolation.*

**Fig. 1 Dendogram of PGPR isolates representing each ARDRA group and plant growth promotion characteristics presented by bacterial isolates and their ARDRA groups**

Interestingly, no representative of PGPR genera/species isolated at 60 DAP was observed in cluster I of ARDRA dendogram. In addition, no representative of PGPR genera/species isolated from 0 DAP was observed in cluster II of ARDRA dendogram. In ARDRA cluster III, no PGPR genera/species isolates at 0 and 15 DAP was obtained. Moreover, In ARDRA cluster IV, only PGPR genera/species isolates at 60 DAP from T2 was found. Additionally, PGPR isolates from treatment applied with organic fertilizer were not found in ARDRA cluster III and IV.

On the basis of the 16S rRNA gene sequence analysis, in excess of 1 kb fragments were sequenced for most of isolates, with similarities ranging between 95 and 99%. Six isolates were identified as *Ochrobactrum anthropi*, three as *Ochrobactrum ciceri*, One as *Ochrobactrum intermedium*, fifteen as *Bacillus* spp., one as *Bacillus silvertri*, four as *Bacillus thuringiensis*, two as *Bacillus megeterium* and four as *Brevibacillus reuszeri* (Table 1). Interestingly, *Brevibacillus* spp. was not found at 0, 15, 30 and 45 DAP, but was only obtained at 60 DAP.

**Table 1 Similarity analysis based on 16S rRNA gene partial sequences of PGPR isolates by comparing to the GenBank and their ARDRA groups**

| ARDRA group | Isolates | Homology | % identity | Accession No. |
|---|---|---|---|---|
| I | KU0T1, KU0T2.1, KU15T2.1, KU15T3, KU30T2, KU45T1.1 | *Ochrobactrum anthropi* DJ3 | 97 | KC992296.1 |
| | KU0T2.2, KU0T3, KU0T4, KU0T5, KU15T1.1, KU15T4, KU15T5, KU30T5, KU45T1.2, KU45T2.1 | *Bacillus* sp. SGE119 | 99 | HM566648.1 |
| | KU15T1.2, KU45T3, KU45T5 | *Ochrobactrum ciceri* L22 | 96 | JX646649.1 |
| | KU45T2.2 | *Ochrobactrum intermedium* SYF-18 | 98 | JN048652.1 |
| II | KU15T1.3 | *Bacillus* sp. DoB56 | 98 | JQ359104.1 |
| | KU15T2.2 | *Bacillus* sp. SGE39 | 99 | HM566736.1 |
| | KU45T1.3 | *Bacillus silvestris* SAFN-010 | 95 | AY167818.1 |
| | KU60T1.1, KU60T2.1, KU60T2.2 | *Bacillus* sp.YY-13 | 99 | JX575604.1 |
| | KU30T3, KU30T4, KU60T3, KU60T5 | *Bacillus thuringiensis* Ou2 | 98 | KP128698.1 |
| III | KU30T1 | *Bacillus megaterium* H2 | 99 | JQ579631.1 |
| | KU45T4 | *Bacillus megaterium* ML257 | 98 | KC692200.1 |
| | KU60T1.2, KU60T2.3, KU60T4 | *Brevibacillus reuszeri* NBRC15719 | 99 | AB680946.1 |
| IIII | KU60T2.4 | *Brevibacillus reuszeri* BCX-22 | 98 | KM378576.1 |

**The different isolates were designated KU followed by the time after planting (0, 15, 30, 45 or 60), treatment number and by progressive numbers of PGPR isolation.*

These findings clearly showed that thiamethoxam had no effect on PGPR diversity as ARDRA cluster 1, 2 and 3 shared the same soil bacterial ribotypes including PGPR isolated from T1 and PGPR isolated from T2. This could be certified to the fact that certain soil bacteria can degrade pesticides. *Bacillus* spp., *Ochrobactrum* spp. and *Brevibacillus* spp. are common soil bacteria easily cultured from most agricultural soils. The previous study showed that *Bacillus megaterium* has potential application in bioremediation of contaminated soil and water system (Sogani et al., 2014). *Ochrobactrum* spp. is also found to be able to degrade pesticide in neonicotinoid group such as imidacloprid (Hu et al., 2013). In addition to species of the *Ochrobactrum* genus, many individual isolates have been found to be able to degrade pesticide in neonicotinoid group, such as *Bacillus* spp. and *Brevibacterium* spp. (Sabourmoghaddam et al., 2015). Moreover, certain soil bacteria might have utilized pesticide as energy sources as well (Ahemad and Khan, 2011).

## CONCLUSION

In this study, thirteen bacterial strains isolated from cassava KU50 were characterized. Most of the bacteria were member of the Bacillaceae, Brucellaceae and Paenibacillaceae families. The bacterial communities were dominated by *Bacillus* spp. (61.11%), *Ochrobactrum* spp. (27.78%) and *Brevibacillus* spp. (11.11%). Interestingly, the findings of diversity analysis of thirty six bacterial isolates selected at random but representing each field site by ARDRA suggested that thiamethoxam had no effect on PGPR diversity as application of thiamethoxam was not be able to distinguish soil bacterial ribotypes.

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Research article

# Impact Assessment of Land Use Change on Ecosystem Services and Livelihood Security of Rural Highland Communities in Saysathan District, Sayaboury Province, Lao PDR

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**Abstract** It is widely recognized that land use changes are affecting provision of ecosystem services as well as people's livelihoods, especially in rural areas where people are highly dependent on local ecosystem services. This study developed an integrated methodological framework by combining a diversity of corresponding frameworks and concept, such as Driver-Pressure-State-Impact-Response (DPSIR), Ecosystem Services (ES), Sustainable Livelihood Framework (SLF) and Agro-Ecosystem Analysis (AEA). This integrated framework was used together with a combination of Participatory Rural Appraisal (PRA) method and spatiotemporal analysis. The objectives of this study aimed at detecting land use change and identifying its drivers; and assessing the impact on provisioning ES and livelihood security of rural highland communities in Saysathan district, Sayaboury province, Lao People's Democratic Republic (Lao PDR). Land use change analysis highlighted a large decrease in forest areas during the past decade. The reduction of forest cover was associated with significant decline of provisioning ES, and the decline in provisioning ecosystem services also influenced the state of livelihood security of the local communities, especially natural capital. By taking the trajectory of forest cover change and the importance of provisioning ES into account, it is essential for stakeholders to integrate ES indicators into land use management planning as well as socio-economic development to maximize benefits from natural resources to the communities.

**Keywords** land use change, ecosystem services, livelihood security, integrated methodological framework, rural highland communities, Lao PDR

## INTRODUCTION

In the Lao PDR land use change has been recognized for several decades which mostly driven by related government policies, such as Land and Forest Allocation (LFA), land concession, and others (Thomas, 2003; Saphangthong and Kono, 2009; Baird, 2010). Consequences of land use change have resulted in degradation of natural resources i.e. changes in ecosystems causing negative impacts not only on agricultural land and livelihood but also on forest covers and long-term environmental degradation (PEI, 2012). For instance, a reduction of shifting cultivation land and shortened fallow period, increased weed population, depleted soil fertility, and reduced crop productivity as well as labor productivity (Takahashi and Liang, 2010), and a continuous reduction of forest cover from 70% of the national land in 1940 to 64% in the 1960s, to 49.2% in 1982, to 47.1% in 1992, 41.5% in 2002 and 40.29% in 2010 (UNEP, 2001; World Bank, 2001; Bouahom, 2009; DOF, 2003; 2005; 2011).

Although impacts of land use changes have been widely studied, there is still a need to investigate drivers that have led to change in land use, and how ecosystem services (ES) and livelihood security (LS) are affected by land use change, especially at local level in rural context.

## OBJECTIVE

This study aimed at (1) detecting land use change and identifying its drivers during 2005 to 2014; and (2) assessing the impacts of land use change on provisioning ecosystem services and livelihood security of local community.

## METHODOLOGY

### Study Site

Saysathan is a rural highland district of Sayaboury province, located in the north-central part of the Lao PDR between latitudes 19°13'12"N and 19°33'15"N and longitudes 101°11'11"E and 101°31'47"E, with elevations ranging from 324 to 2,061 meters above sea level. In order to get insight information of this area, two villages (Doykao and Paklong) with a diversity of agroecosytem and livelihood contexts (traditionally relying on shifting cultivation and natural resources as for maintaining their livelihoods; being in the transition of land use, natural resources and livelihood, and facing land use management problems; and others) were selected for this study.

### Data Collection

This study developed an integrated methodological framework from various frameworks and concepts, such as DPSIR, ES, SLF and AEA, which have been effectively applied in rural research perspectives. This integrated framework was used to support the data collection process so that all activities could be conducted systematically and logically. PRA method with a series of activities, for example, key informant interview, focus group discussions (FGDs), resource mapping, livelihood analysis, historical profile, etc., and spatiotemporal analysis were also used to conceptualize, diagnose and synthesize the interconnectedness of land use change, ES and livelihood security of the local communities.

A total of thirty-three indicators of livelihood security (ten of provisioning ES, the italicized texts) were collectively developed and categorized into five main groups as follows:

- Human capital: (1) health; (2) children's school enrollment; (3) adult literacy; (4) labor availability
- Natural capital: (5) land holding size; (6) soil fertility; (7) *rice yield*; (8) *timber*; (9) *bamboo*; (10) *firewood*; (11) *broom grass*; (12) *bamboo shoots*; (13) *wild mushroom*; (14) *wild vegetables*; (15) *wildlife* (e.g. bird, rat, squirrel, etc.); (16) *aquatic species* (e.g. fish, frogs, crab, etc.)
- Financial capital: (17) household income; (18) land ownership; (29) cattle holding; (20) house quality; (21) access to credit
- Physical capital: (22) access to clean water; (23) access to road; (24) access to school; (25) access to hospital/healthcare center/dispensary; (26) access to electricity; (27) access to market; (28) access to information and communication services
- Social capital: (29) capacity of village authority; (30) community participation; (31) woman' role in village organization; (32) woman' role in household decision-making; (33) traditional worshiping

The majority of indicators were determined using critical values representing three different degrees, including 0.33, 0.66 and 1 to replace, for example, "Poor", "Average" and "Good", respectively (Muangkaew and Shivakoti, 2005). Another form of "Yes" and "No" answers, the values of 1 and 0 were used respectively. Two temporal Landsat images, including Landsat 5 Thematic

Mapper (TM) and Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) acquired on February of 2005 and 2014 respectively were used for land use change analysis. In addition, household survey with a total of 70 sampled households (purposively selected using on a quota sampling method), were also conducted in December, 2014.

### Data Analysis

Landsat imageries were classified, analyzed and visualized using a combination of remote sensing (RS) and geographical information system (GIS) techniques. The developed indicators were standardized into the values ranged from 0 to 1 using the min and max normalization method. Ranking and scoring methods were applied to reflect the importance of indicators. The capital index values were also aggregated for the "Composite Index" which was used to imply states of livelihood security of the studied communities. The normalized and weighted data were then analyzed, and the asset pentagon (DFID, 1999) was created to visualize various aspects of livelihood assets. Finally, the aggregated capital values as well as the composite index were interpreted using the rating scale of "0-0.33", "0.34-0.66" and "0.67-1" for "Poor", "Average" and "Good" conditions, respectively.

## RESULTS AND DISCUSSION

### Changes in Land Use between 2005 and 2014

The results of this study (Table 1 and 2) assert that, in both Doykao and Paklong villages, forest area and upland rice field were obviously decreased between the year 2005 and 2014. In contrast, the results also reveal significant increases in fallow and urban areas similarly in the two villages (Figs. 1 and 2).

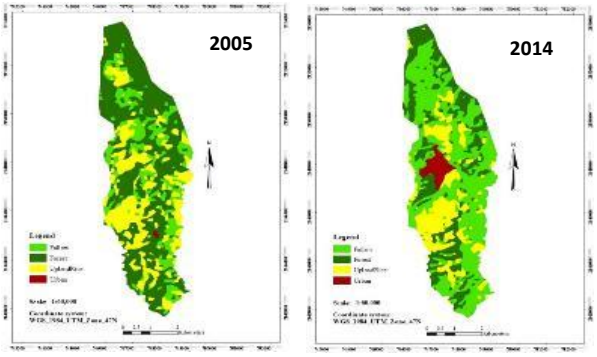


**Fig. 1 Land use classification of Doykao village in 2005 and 2014**

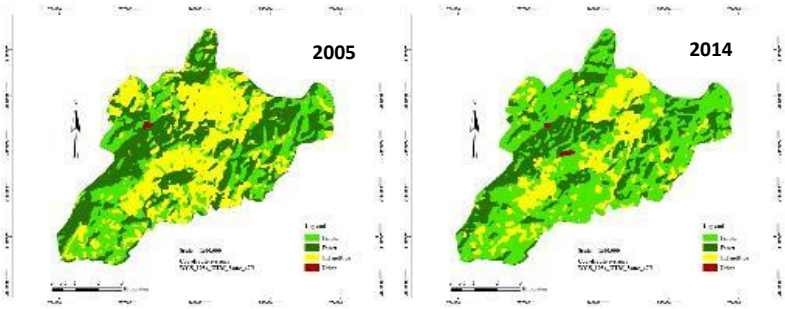


**Fig. 2 Land use classification of Paklong village in 2005 and 2014**

The decreases in forest area are consistent with the study of Eickhoff et al., (2012) that highlights a continuous reduction of forest cover in this area. However, when considering with a reduction of upland rice field, these results seem to disagree with other findings which mostly reveal that upland rice agriculture is the major cause of deforestation. Nevertheless, the results are consistent with CPI (2005) which notes that a reduction of shifting cultivation and a decrease in forest area occurred concurrently. In this regard, the finding from the Focus Group Discussions (FGDs) addressed that a reduction of upland rice field was mainly related to recognition of village boundary which encourages farmers to cultivate specifically in their village areas unlike years ago that anyone could farm anywhere they preferred. The decrease in forest area was associated with upland rice farming. The forest was transformed into upland rice field (at the time the upland rice area increased), then most of them was left fallow due to the land use policy particularly LFA, and the farmers had to cultivate in the limited allocated land.

**Table 2 Land use change matrix for Doykao village from 2005 to 2014**

| From land use 2005 (ha) | | Into land use 2014 (ha) | | | | Loss into 2014 (ha) | Land use 2014 (ha) | Area net changes | | Type change rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | 2,629.26 | Fallow | Forest | Upland rice | Urban | | | (ha) | (%) | |
| Fallow | 524.09 | 402.09 | 2.34 | 110.91 | 8.75 | 122.00 | 1,330.11 | 806.02 | 59.11 | 23.28 |
| Forest | 1,388.34 | 571.77 | 615.84 | 167.12 | 34.01 | 772.91 | 670.66 | -717.68 | -52.63 | 55.67 |
| Upland rice | 712.19 | 356.25 | 52.99 | 248.21 | 54.85 | 463.98 | 530.87 | -181.32 | -13.30 | 65.15 |
| Urban | 4.64 | - | - | 4.64 | - | 4.64 | 97.61 | 92.98 | 6.82 | 100.00 |
| Gain into 2014 (ha) | | 928.02 | 55.23 | 282.67 | 97.61 | 1,363.53 | 2,629.26 | | | |

*Source: Data analysis*

**Table 3 Land use change matrix for Paklong village from 2005 to 2014**

| From land use 2005 (ha) | | Into land use 2014 (ha) | | | | Loss into 2014 (ha) | Land use 2014 (ha) | Area net changes | | Type change rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | 5,753.63 | Fallow | Forest | Upland rice | Urban | | | (ha) | (%) | |
| Fallow | 1,667.47 | 1,359.07 | 28.32 | 279.56 | 0.52 | 308.40 | 3,012.99 | 1,345.52 | 60.87 | 18.50 |
| Forest | 2,069.92 | 609.19 | 1,353.02 | 107.03 | 0.69 | 716.91 | 1,511.24 | -558.69 | -25.28 | 34.63 |
| Upland rice | 2,006.74 | 1,041.58 | 129.11 | 825.70 | 10.36 | 1,181.04 | 1,212.29 | -794.45 | -35.94 | 58.85 |
| Urban | 9.50 | 3.15 | 0.79 | - | 5.55 | 3.95 | 17.11 | 7.62 | 0.34 | 41.56 |
| Gain into 2014 (ha) | | 1,653.92 | 158.22 | 386.59 | 11.56 | 2,210.30 | 5,753.63 | | | |

*Source: Data analysis*

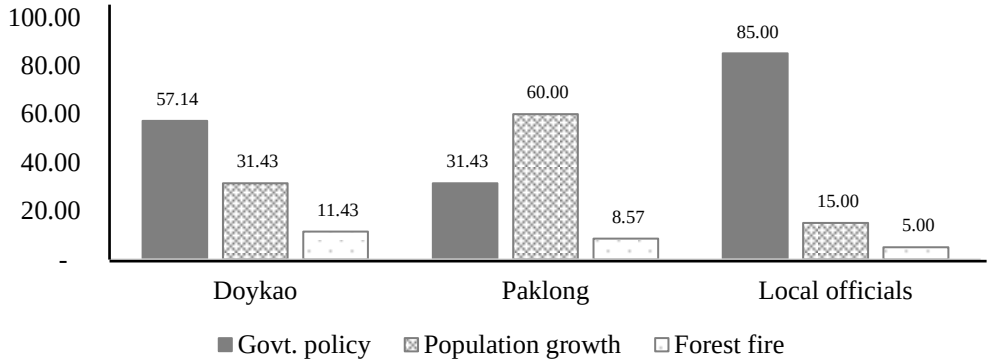


**Fig. 3 Drivers of land use change in the study area given by different stakeholders**

Responses from the FGDs and the household survey (Fig. 3) indicate that these changes in land use have been primarily driven by the government's policies, increasing population and forest fire which actually caused by human's activity, specifically upland rice farming.

## Changes in Provisioning ES and Livelihood Security

*Index Values of Provisioning ES*

Figure 4 illustrates an obvious decline of provisioning ES in both Doykao and Paklong villages from an overall index value of 0.921 and 0.892 in 2005 to 0.426 and 0.450 in 2014 respectively. The broom grass was considered with a slight increase only in Paklong because villagers have gradually maintained and planted this grass in their upland fields.

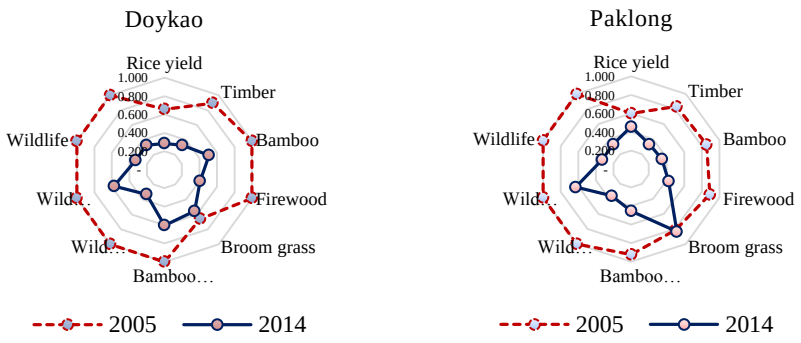


**Fig. 4 Index values of provisioning ES of the selected communities**

*Index Values of Provisioning ES*

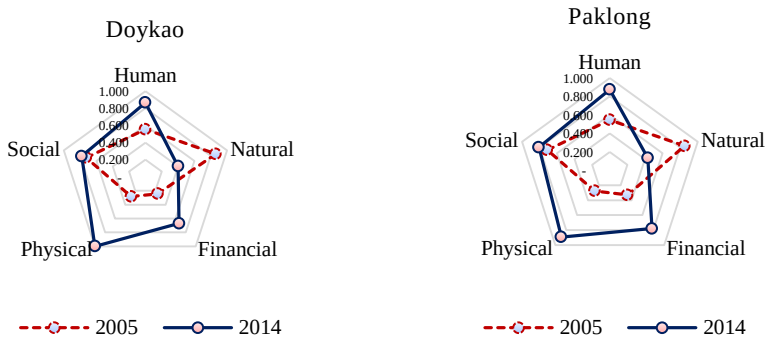


**Fig. 5 Index values within five capitals of the selected communities**

The results illustrated in the Figs. 4 and 5 indicate that in 2005 both studied communities had good states of natural and human capitals but poor in financial and physical accesses, while social assets were at average condition. By 2014, there were predominant increases in physical, financial and human capitals in both communities. However, natural capital was significantly decreased, while social capital was not much changed. These results reveal that the five livelihood capitals of the selected communities were changed in a similar direction.

*Composite Index of Livelihood Security*

Table 3 illustrates that composite indices of both villages were slightly increase from 0.567 and 0.579 in 2005 to 0.757 and 0.740 in 2014 respectively. In general, the results indicate that the condition of livelihood security of the selected communities have considerably improved from "Moderate" to "Good" during the past decade.

**Table 3 Composite indices of livelihood security of the selected communities**

| Capitals | Doykao | | Paklong | |
|---|---|---|---|---|
| | 2005 | 2014 | 2005 | 2014 |
| 1) Human | 0.563 | 0.882 | 0.533 | 0.894 |
| 2) Natural | 0.779 | 0.357 | 0.737 | 0.394 |
| 3) Financial | 0.305 | 0.676 | 0.384 | 0.728 |
| 4) Physical | 0.367 | 1.000 | 0.510 | 0.942 |
| 5) Social | 0.742 | 0.854 | 0.721 | 0.834 |
| Composite index | 0.567 | 0.757 | 0.579 | 0.740 |

*Source: household survey, 2014*

## CONCLUSION

Results from land use change analysis and household survey reveal that land uses in both studied communities have highly changed during the past decade. The main drivers of this change were government policies together with population growth and forest fires. Land use change, specifically a decrease in forest area which is the fundamental stock of ES, has led to a dramatic degradation of provisioning ES. The decline of provisioning ES highly influenced the condition of natural capital which also contributed to an alteration of livelihood security of the local communities. Although the status of livelihood security of Doykao and Paklong villages have improved from "Moderate" to "Good", natural capitals which are mainly made of provisioning ES have dramatically declined during 2005 to 2014. By taking the trajectory of forest cover change and the importance of provisioning ES into account, it is essential for stakeholders to integrate ES indicators into land use management planning as well as socio-economic development to maximize benefits from natural resources to the communities.

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Research article

# Investigation of Vibration Characteristics of a Hand Tractor using MEMS Sensor

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**Abstract** The increase of agricultural mechanization, especially hand tractors has been remarkably emerged in the last decade. It is known as well that agricultural mechanization not only facilitated timely completion of operations but also increased production, labor savings, energy efficiency, productivity, and profitability. With high degree of hand tractor use, providing a safe and comfortable working environment to operators became an important consideration, specifically vibration that is a main cause of early fatigues. In this study focus on measuring translational acceleration and rotational angular velocity at various locations of hand-tractor under stationary and driving modes. Root-mean-squares (RMS) and power-spectrum-density (PSD) were used to investigate vibration magnitude and dominant frequencies, and effective measurements were finally suggested. Results showed that under stationary mode largest vibration acceleration appeared at handgrip in vertical axis of about 8.5m/s$^2$ followed by engine top, gearbox and chassis, respectively. In driving mode, the main vibration magnitude occurs in vertical axis at about 11.8 m/s$^2$. Within 50Hz frequencies, predominant acceleration occurred in longitudinal axis at about 10Hz frequencies at first peak and about 18Hz frequencies at next peak at engine top. Whereas, at handgrip predominant acceleration appeared hugely in vertical axis at about 10Hz frequencies, and at the same frequency was found in pitch axis of rotational angular velocity under stationary mode. However, it appears clearly at about 9Hz frequencies in vertical axis in driving mode. Both conditions, vibration exposures are much higher than that in health risk limitation standard that operators should be prevented effectively; otherwise, to suffer from early fatigue.

**Keywords** agricultural tools, vibration magnitude of translational acceleration and rotational angular velocity, hand-arm vibration, and future development

## INTRODUCTION

Agriculture employs almost 80% of Cambodian rural labor forces. It is considered to strongly support Cambodian people in ensuring food security (Ngo and Chan, 2010) and constitutes a main source of income (Ros et al., 2011). It is the main driver of poverty reduction (Ngo and Chan, 2010), and it has a 29% contribution to the GDP (Chao, 2009; Chan, 2013).

The enhancement of agricultural production through agricultural tools, the use of agricultural mechanization has gradually increased, specifically over the last decade (Chan, 2013). It is evident that the agricultural mechanization not only facilitated timely completion of operations but also increased production, labor savings, energy efficiency, productivity, and profitability (Singh et al., 2011). In Cambodia; therefore, many farmers sold animals to buy mechanized tools for field operations, especially hand tractors (Chao, 2009). Multipurpose uses of mechanization meant that time operation to hold handgrip became longer that induce to vibrated discomfort known as early fatigue. Tiwari et al., (2006) explained that machine vibration was detrimental to agricultural users. Many researchers also confirmed that vibration would be very harmful to health induced such as early fatigues that may cause physical, physiological and musculoskeletal disorders after long-time exposure over months and years (Salokhe et al., 1995, Sam et al., 2006).

This study measures vibration magnitude and vibration transmissibility at various locations of hand tractors such as engine top, chassis, gearbox and handgrip, hand-arm vibration exposure and suggests effective intervention for future development.

## METHODOLOGY

### Experimental Hand Tractor

A 12Hp hand tractor as shown in Fig. 1, under stationary and driving modes in a duration of 30 seconds with the idling speed (5 km/h) was employed in these experiments using MEMS sensor.

**Fig. 1 Transportation-type hand tractor**

### Experimental Instrumentation

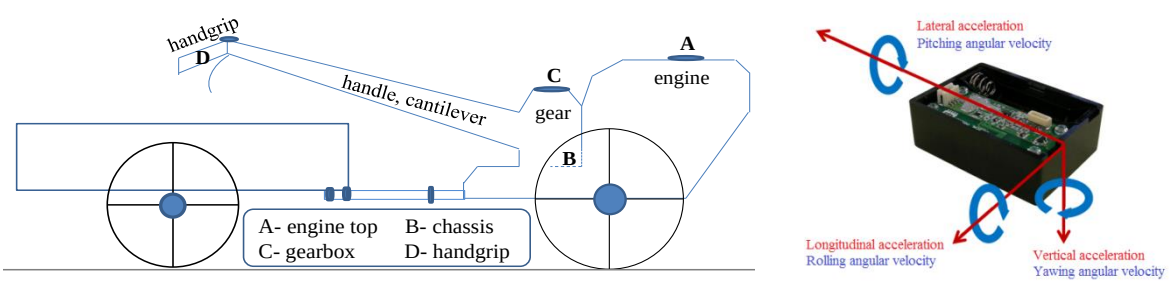


**Fig. 2 Locations of experiment specification and MEMS sensor**

Vibration transmission measurement at various locations of hand tractor had been carried out by many researchers, and strain gage were mostly employed for the experiments (Salokhe et al., 1995, Taghizadeh et al., 2007). However, strain gage were complicate in manipulation such as Strain Amplifier, Chanel-Data-Tape Recorder, Autonomous Data Acquisition Unit and Microcomputer with a limited connected cord. In a modern society; however, a MEMS sensor is very compact, light and easy to use. So it was chosen for this study. The wireless sensor can detect signal within 50 meters, and the output is easy to convert and calculate (Choe et al., 2013).

### Data Outputting and Processing

The characteristics of hand tractor vibration are described in RMS, PSD and dominant frequencies, derived from output generation equations, Eq. (1) and Eq. (2). Vibration transmission is a proportion between engine top, main source of vibration, and connecting parts.

$$\boldsymbol{G} = \frac{(\boldsymbol{V}-\mathbf{1.65}) \times \mathbf{9.8}}{\mathbf{0.19}} \tag{1}$$

$$\boldsymbol{W} = \frac{\boldsymbol{V}-\mathbf{1.35}}{\mathbf{5.6}\times\mathbf{0.00067}} \tag{2}$$

Where V: voltage output when translational acceleration and rotational angular velocity are in G and W, respectively (Choe et al., 2013).

### Root Mean Square and Power Spectrum Density

The RMS was used to obtain vibration magnitudes, and the PSD was employed using Fast Fourier Transform (FFT) function of mathematical computation and signal processing software package to obtain frequency domain (Salokhe et al., 1995). The PSD was plotted against frequency of the signal; therefore, the dominant frequency of vibration was received from the plot.

### Hand-arm vibration exposures

A quantity of three combination axes was recommended by ANSI S2.70-2006 to evaluate hand-arm vibration exposures as expressed in Eq. (3) and Eq. (4).

$$\boldsymbol{a_{hw(rms)}} = \sqrt{\sum_{\boldsymbol{i}}(\boldsymbol{W_{hi}}\boldsymbol{a_{hi(rms)}})^{\mathbf{2}}} \tag{3}$$

$$\boldsymbol{a_{hv(rms)}} = \sqrt{\boldsymbol{a_{hwx}^2} + \boldsymbol{a_{hwy}^2} + \boldsymbol{a_{hwz}^2}} \tag{4}$$

Where $a_{hw(rms)}$: vibration in each direction $a_{hv(rms)}$: vibration combined value, $W_{hi}$: correction coefficient,$a_{hwx}, a_{hwy}, a_{hwz}$: each direction value.

## RESULTS AND DISCUSSION

### RMS of Stationary Hand Tractor

Vibration magnitudes of the 12Hp hand tractor using MEMS sensor are described in Fig. 3. It can be seen that RMS values at handgrip in vertical axis was the biggest followed by those at gearbox, engine

top and chassis, respectively. The high vibration magnitude at handgrip in vertical axis was given that handle acts like a cantilever beam (Salokhe et al., 1995, Bahareh et al., 2013).

At engine top, magnitude is observed higher in longitudinal axis given that it responses to the corresponding of engine power stroke. The excitation of power stroke induces the rotating engines to vibrate in the same direction (Mehta et al., 2000). At the same location, extreme vibration signals predominantly in roll axis. It would be reasonably that engine is the main source of vibration excitation that vibration is movably parallel to the displacement of piston.

As engine is a main source of vibration, the relationship between engine top and other connecting parts were observed. It revealed that engine transmitted vibration slightly to chassis of 0.4 m/s$^2$, and gearbox of about 0.4 m/s$^2$, but largely to handgrip 1.1 m/s$^2$.

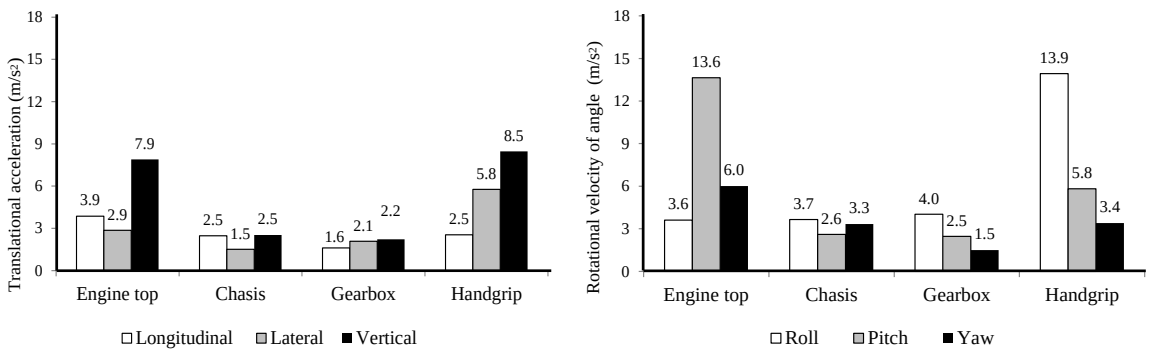


**Fig. 3 RMS of translational acceleration and rotational angular velocity (stationary)**

## RMS of Driving Hand Tractor

Figure 4 represents the RMS of translational acceleration and rotational angular velocity at idling speed. Of the translational acceleration, peak magnitude appears in vertical axis of around 12 m/s$^2$, and it as well occurred hugely at roll axis of about 11 m/s$^2$. The predominant vibration may be caused by cantilever beam the hand tractor acts (Salokhe et al., 1995, Bahareh et al., 2013).

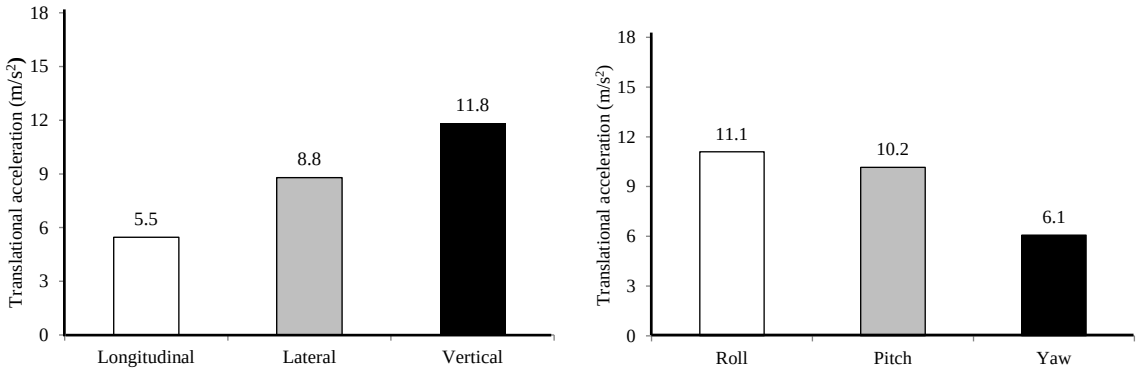


**Fig. 4 RMS of driving hand tractor at handgrip**

## Power Spectrum Density at Stationary and Driving Modes

The results of PSD on the engine top and handgrip were partly represented in Figs. 5 and 6. The sensitivity vibration at 2, 5 or 20Hz may cause severe discomfort or injury but will not produce the nausea, vomiting and color changes so characteristic of motion sickness (M. J. Griffin, 1990).

It is seen in stationary condition that predominant magnitude at the engine top occurred largely at about 10Hz frequencies in longitudinal axis while at about 11Hz frequencies dominantly emerged at handgrip in vertical axis. These may be due to the corresponding to the movement of engine piston and movement of cantilever beam that the handle acts (Salokhe et al., 1995).

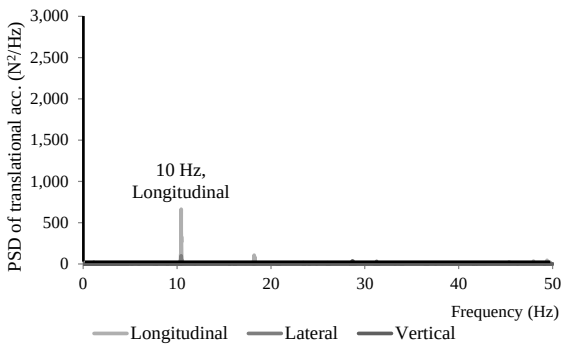


**Fig.5 PSD at engine top (stationary)**

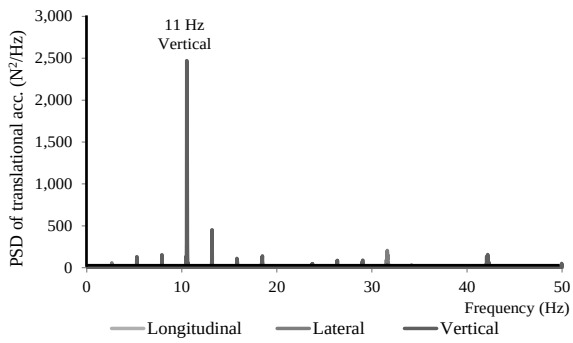


**Fig.6 PSD at handgrip (stationary)**

In driving mode, dominant frequency is found at about 3Hz frequencies first in longitudinal axis and about 9Hz frequencies next in vertical axis. The first frequencies would cause by movement of engine piston and the second peak would cause by cantilever beam that these results also confirmed by Salokhe (1995) and Bahareh et al., (2013).

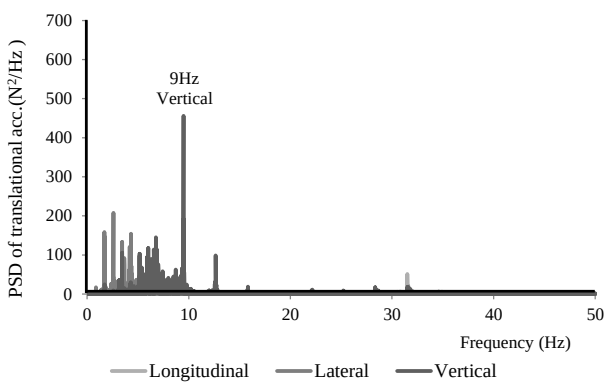


**Fig. 7 PSD at handgrip (driving)**

## Hand-arm Vibration Exposures

The hand-arm vibration exposures were conducted based on RMS of engine vibration magnitude under hand-gripped modes to observe the severity of vibration from hand tractor to the operators, and a picked up frequencies were experimentally needed to compute exposure.

Results appeared that in stationary and driving modes the RMS of hand-arm vibration exposures were extremely higher than those stated in health guidance zone. This means that operators shall be technically advised to stop their operation; otherwise, it would be longer-sooner risky to health.

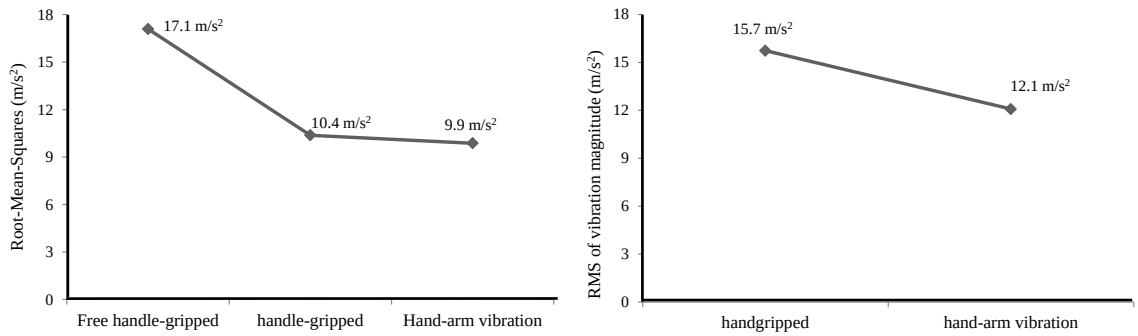


**Fig.8 RMS of hand-arm vibration exposure in stationary and driving modes**

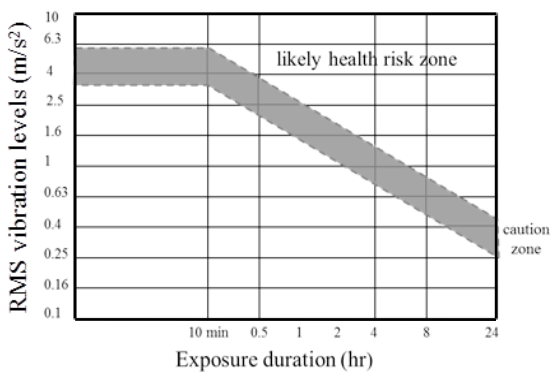


**Fig.9 Health Guidance Zones** (Sayed M.E. *et al.*, 2012)

## Future DEvelopment

To prevent from health risky, an effective interventions such as isolator dampening sleeves, splitting handle arm installed on some locations in between engine and base frame and between handle and gearbox. Some researchers applied successfully with isolators dampening sleeves, splitting handle arm on some locations (Chavan et al., 2013, Charturvedi et al., 2012).

## CONCLUSION

The demand to improve agricultural production through enhancing agricultural mechanization was important for country development, Cambodia. However, with multipurpose uses of mechanization, especially hand tractors, long-time operation would cause discomfort to operator through handgrip vibration. Experiment results showed that the large vibration occurred at the handgrips in vertical axes. The RMS of hand-arm vibrations exposure at the handgrip of the 12Hp hand tractor were much higher than that in health risk limitation standard. Therefore effective intervention should be developed to prevent operator's health.

## ACKNOWLEDGEMENTS

First, I thank to the Japanese Grand Aid for Human Resource Development Scholarship Program (JDS) and Coordinators and Royal Government of Cambodia, who have supported me so far. Second, my profound appreciation extends to my professors, who have supervised, encouraged, and inspired me so much through experimental research and good opportunities in Japan. Third, my warm appreciation goes to all lab-mates and friends for their assistance and for together sharing our knowledge and experience. Finally, I pay gratitude to my host family and wonderful family.

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Research article

# Analysis of Fiscal Gap and Financing of Cambodia's Protected Areas

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**Abstract** The Analysis of Fiscal Gap and Financing of Cambodia's Protected Area (PA) conducted by the Department of International Conventions & Biodiversity, Ministry of Environment (MoE), to identify resource gaps in the management of 23 PAs of Cambodia. The pressure & response indicators have been used to analyze resources gaps. Pressure indicators were population, number of visitors of each PA and roads & hiking trails within PAs; while response indicators include the number of full time staff and operational expenditure. To examine resource gaps for PAs management, all PAs have been classified into three clusters according to size. The comparisons between pressure and response demonstrated trends of existing resources for the management of PAs, therefore they were analyzed in pairs of each pressure vs each response indicator. To calculate resource gaps, two benchmarks were set for each cluster: the average and the highest. Each PA resource gap has been identified based on two rules: 1) bringing the number of fulltime staff & operational expenditure that is below average to the "average benchmark"; 2) bringing the number of fulltime staff & operational expenditure that is higher than the average to the "highest benchmark". As a result, the total gap of full time staff in 2009 was 449 personals, equal to 1/3 of existing staff. However, the gap of full time staff in this context did not take into account their capacity to fulfill PA management tasks. The total operational expenditure gap in 2009 was 1,221,405 USD, equal to 25% of the benchmark estimation of 2,462,881 USD. In conclusion, for better management of 23 PAs, the budget for PAs operation should be doubled, therefore increasing it up to 2.5 million USD per year.

**Keywords** fiscal gap, Cambodia, protected area, financing

## INTRODUCTION

A 1993 degree of the Royal Government of Cambodia designated 23 Protected Areas (PA) comprising approximately 18% of the total land area of the country. Following IUCN (IUCN, 2004) categorization, these PAs can be classified into National Park (7), Wildlife Sanctuary (10), Multiple-use Areas (3), and Protected Landscape (3). Through Royal decree (2001) and Declaration N.4010 (1999) one Biosphere Reserve has been established and three Ramsar sits have been identified in addition to the 23 PAs. Those PAs are managed by the General Department of Administration for Nature Conservation and Protection (GDANCP) of the Ministry of Environment by Law on Protected Areas 2008.

In addition, the Royal Government of Cambodia has designated 6 Protected Forests (PF), which are managed by the Ministry of Agriculture Forestry and Fisheries (MAFF). The management of Protected Forests is regulated under the Forestry law and relevant Royal Decree, Sub-Decree and Declaration of the MAFF.

Each type of PA has a specific inclusion definition and management objective. The management of PAs has complied with the Royal Decree on the Creation and Designation of Protected Areas (1993), the Law on Environmental Protection & Natural Resource Management (1996), the Law on Protected

Areas (2008), which define a framework of PA management, biodiversity conservation, and sustainable use of natural resources within PA. Other PA related legislation and regulations include the Environmental Impact Assessment (EIA) sub-decree (1999), Biosafety reserve (2008), Forestry Law (2002), Fisheries Law (2002), and other relevant law, Royal Decree, Sub-Decree & Declaration. Protected Areas is the main approach to biodiversity conservation in Cambodia. According to data collection and interview in 2012 by Department of International Convention and Biodiversity shown that 23 Protected Areas had residents within or around them; tourism activities, unsustainable use of natural resources, illegal logging, wildlife trade, and insufficient resources are main challenges for PA management. The resources for PA management are generally considered to be insufficient while updated information and practical evaluation are lack to support the argument. This research finding and recommendation options are expected to use by PA responsible institutions to increase budget and sustain finance for effective management of PA System in Cambodia.

## OBJECTIVE

This paper aims to identify the fiscal gap and financing needs for Cambodia's Protected Area management. The overall objective is to analyze the resource gaps in PA management. The research targets for 23 Cambodian PAs under administration and management of the Ministry of Environment (MoE). The data was analyzed based on setting internal & external indicators and relevant criteria as appropriate. The findings of resources gapes and recommendations in filling the gapes by either increase national budgets and recruit more rangers or full time staffs are expected to be used by PA responsible institutions for effective management of PAs in Cambodia.

## METHODOLOGY

Research was conducted using both primary and secondary data/information collected from 23 Protected Areas established by Royal Decree in 1993. The data was collected directly from each PA's manager, key experts, relevant institutions, partners, stakeholders, and any available sources. Analysis of data collection, cluster classification, and benchmark identification was based on the following methodologies:

### Primary Data Collection and Surveys

A research questionnaire was designed in Khmer language for data collection from 23 PAs. It was divided into four parts: part one focused on background information of PA including name, date of establishment, land area, location, IUCN's classification, and its purpose; part two related to the physical characteristics of PA such as access to PA, inhabitants of PA, travelling within PA, and facilities available within PA; part three aimed to gather information on visitor characteristics such as the number of visitors to PA, visitors entry fee, visitor accommodation fee, and activity fee; part four captured information on staffing revenues and costs, number of staff, staff capacity, operation expenditure; fee collection, and annual revenues for an individual PA.

### Secondary Data Collection

Some data could not be collected from the field for which the team communicated directly with relevant institutions, local authorities, and international agencies through available contact persons and sent official letters to request for cooperation in providing data. Data/information from research projects, annual reports, census, materials from workshops and seminars were also collected.

## Data Analysis

To analyze the Fiscal Gap for each PA, pressure and response indicators were identified. The pressure indicators included population within *5 km* radius, visitors, and road & hiking trail; while the number of full time staff and operational expenditures were identified as respond indicators. The analysis of population focused on total population in the 5 most populated villages within a 5 km radius of the boundary and less population was less pressure on natural resources. The total operational expenditure from government budget and other external sources supported activities in some PAs.

The following methods were used to identify resource gaps: analysis presures and respond; and set benchmark.

### *Response*

This study selected the number of full time staff, and operational expenditures in 2009 as response variable to assess the response to the pressure factors including: population, visitors, and road & hiking trails.

### *Benchmarking*

According to size variance of PA and to maximize the accuracy of gap analysis, 23 PAs have been classified into three clusters as follows:

- Cluster 1: PA that has total land area from 0 ≤ 5,000 ha; 2 PAs
- Cluster 2: PA that has total land area > 5,000 ha ≤ 50,000 ha; 6 PAs
- Cluster 3: PA that has total land area > 50,000 ha ≤ 402,500 ha; 15 PAs

A benchmark of response indicators has been identified for each cluster to analyze resource gaps, carried out for full time staff (FTS) per 1000 ha and operational expenditure (OpEx) per ha. The *average* and *highest* indicators of FTS/1000 ha and OpEX/ha within each cluster are used as benchmarking tools to estimate gaps.

### *Resource GAPs*

According to method introduced by the Economy and Environmental Program for Southeast Asia (EEPSEA, 2012) the following rules had been applied for calculation resource gaps:

1. If the Number of Full-Time Staff & Operational Expenditure is lower than the average, bring the value of Full Time Staff & Operational Expenditure to the Cluster *Average (Avr)*.
2. If the Number of Full-Time Staff & Operational Expenditure is higher than average in Cluster, bring the value of Full Time Staff & Operational Expenditure to the *Highest* (*Hst*) value in Cluster.

The resource gap analysis was carried out by comparing existing resource allocation for PAs management with averages & highest of individual clusters. The comparisons present scenarios for looking at how PAs are currently managed, and should stimulate discussion as to whether any action needs to be taken for further improvement.

## RESULTS AND DISCUSSION

The Cambodia Protected Areas have been divided into three clusters based on size: Cluster 1 is for PA that has total land areas from 0 ≤ 5,000 ha; Cluster 2 is for PA with total land area from between 5,000 ha and ≤ 50,000 ha; while Cluster 3 is classified for any PA having land area more than 50,000 ha but less than or equal 402,500 ha (Table 1).

**Table 1 Cluster and benchmark for full time staff and operational expenditure**

| PA total area clustering | | | Full time staff (FTS) | | | Operation expend (OpEx) | | |
|---|---|---|---|---|---|---|---|---|
| Cluster Interval (ha) | No.PA in | Avr.Total Area (ha) | Avr. No. FTS | Avr. No. FTS per 1000 ha | Hst No. FTS per 1000 ha | Avr. OpEx (USD) | Avr OpEx/ha (USD) | Hst OpEx per ha (USD) |
| Total = 23 | | Highest = 402,500 ha | | | Lowest = 2795 ha | | | |
| 0 ≤ 5,000 | 2 | 3,898 | 10.50 | 2.97 | 3.94 | 7,570 | 2.10 | 2.67 |
| > 5,000 ≤ 50,000 | 6 | 28,004 | 30.17 | 1.03 | 1.77 | 17,576 | 0.60 | 0.94 |
| > 50,000 ≤ 402,500 | 15 | 209,919 | 45.93 | 0.25 | 0.52 | 74,725 | 0.30 | 1.24 |

Cluster 3 represents highest number of PA in the amount of 15 PAs out of 23 PAs. According to the data in Table 1, the average total land area in cluster 1 is 3,898 ha, cluster 2 is 28,004 ha, cluster 3 is 209,919, and Kulen-Promtep wildlife sanctuary has highest total land area of 402,500 ha.

In 2009 204,117 Cambodians visited 9 PAs: three national parks, three wildlife sanctuaries, one protected landscape, and two multiple use areas. The same year, 339,199 foreigners visited 10 PAs. Therefore, the total number of tourists recorded in 2009 was 543,316 people. However, Bokor National & Phnom Kulen National Parks, and Ankor Multiple Use Area are not included in this analysis as the information on the number of visitors as these PAs could not be obtained as these are managed by other agencies and private companies.

According to interview information received from PA's directors, deputy directors, rangers, and commune chiefs, the revenue of each PA were through entry fees (0.25 - 0.75 for local visitors & USD 5 for foreigner), accommodation, facilities such as boat rental, car park, guide fee, etc. Tourist facilities and accommodation rates varied from PA to PA depending on customer demand. For PA whose road condition was not so good and far from the town, entry fees were lower e.g. $ 0.12 per person. Some PAs had additional charges for visitors to see rare species.

## Response Indicators

**Number of full time staff in 2009:** The Ministry of Environment set up 32 offices and 78 sub-offices around and within 23 PAs. For daily operations 891 full-time staff were employed by government to work in 23 PAs.

**Operational expenditures in 2009:** The operational expenditure for each PA including staff salary, uniforms, and medicine were covered under the government budget. Other operational costs such as project based activities supported by other donors. The total operation expenditures in 2009 for 23 PAs was USD 1,241,476.

## Pressure Indicators

**Population of five largest villages within 5 km radius in 2009:** The total population in the 5 largest villages in a radius of 5 km from border of each PA was 347,625 people.

**Roads and hiking trails:** Roads & trails in each PA have been constructed for filed monitoring recreation and ecotourism. Phnom Prich wildlife Sanctuary has the largest road (380 km), while Botum Sakor National Park has more trails (1,750 km) compared to other PAs. On the other hand, for Roniem Daun Sam Wildlife Sancturay, no road has been constructed and Preah Vihear Protected Landscape only has a 4 km trail.

## Response vs Pressure

This research has compared pressure with response in pairs of: Population vs Full Time Staff; Population vs Operational Expenditure; Visitor vs Full Time Staff; Visitor vs Operational Expenditure; Road v Full Time Staff; and Hiking Trail vs Full Time Staff. Road and Hiking Trail identified as pressures factors have elaborate in follow paragraph.

**Population vs full time staff:** According to data collection from all PAs (2009) the distribution of population and full time staff in 1000 ha tended to have a positive association in general because the more population is the more full time staff had employed. In this regard, the high pressure by population within 5 km radius in PAs had response with higher number of full time staff, except Angkor Protected Land Scape which had less full time staff (0.93/1000 ha) in proportion to population of 4,212.50 per 1000 ha compared to other PAs.

**Population vs operational expenditure:** The same source of data from directors and rangers in 23 PAs (2009) on the distribution of population and operational expenditure for 23 PAs resulted in positive conditions; the results indicated that the greater the population was the more staff were employed for management. However, distribution of both factors in Prea Vihar Protected Landscape, Phnom Samkos Wildlife Sanctuary, and Kirorom National Park had more response and less pressure, especially Prea Vihea with operational expenditures of 1,533 USD per 1000 ha in 2009 with no population within this PA. Besides, Angkor Protected Landscape had less resources in term of operational expenditures (470.09 USD / 1000 ha) to response with a high population of 4,212.50 per 1000 ha.

**Visitors vs full time staff:** Only 9 PAs had recorded the number of visitors. The distribution of pressures and response factors for visitors and full time staff was the focus for 9 PAs that had data available. The trend of Visitors vs Full Time Staff moved to a positive relationship although three PAs (Preah Vihea Protected Land Scape, Kirirom National Park, and Peam Krosop Wildlife Sanctuary) had high pressure because of the number of full time staff did not fully respond to the number of visitors, so it lead to limited human resources for effective management in those PAs.

**Visitors vs operational expenditure:** The distribution of the number of visitors per 1000 ha and total operational expenditure per 1000 ha in 23 PAs had also a positive trend. Distribution of visitors ranged from 0 to 3,589 per 1000 ha, while operational expenditure had a distribution range from 82.27 USD per 1000 ha in Roniem Daun Sam Wildlife Sanctuary to 2,674.06 USD per 1000 ha in Kep National Park. In general, many distributions of both factors showed on less pressure.

**Roads vs full time staff:** Length of road per 1000 ha had been considered as pressure factor for PA management due to it was potential and easy for poacher to conduct illegal activities within PA. Besides, it could be considered also as respond factor for PA manager or ranger to control other activities. Nevertheless, this study deliberate existing road within PA was a pressure factor, but its distribution tended to be positive respond. According to data in this study there was two contrast outliers at Angkor Protected Land Scape trended to high pressure with road distribution in 13.80 km per 1000 ha, and Kep National Park had high respond within 4 full time staffs per 1000 ha.

**Hiking trails vs full time staff:** Moreover, the length of hiking trails was also considered as pressure factor. The results showed that almost of PAs had enough staff to patrol illegal activities if poachers used only hiking trail.

## Benchmarking

This study set benchmarks of *full time staff / 1000ha* and *operational expenditure / ha* at *average* and *highest* points for each cluster, to estimate and calculate resource gaps with the above rules and methodology. However resource gaps of PAs management did not refer to the quality of full tine staff and sufficient financial resources for *effective* PAs management.

## Resource GAPs

To estimate resource gaps, the number of full time staff / 1000 ha and operational expenditure / ha had been identified as shown in Table 1. The serial number on horizontal axis in figures 1, 2, 3 & 4 represent each PA. The 7 National Parks are: 1- Kirirom, 2- Bokor, 3- Kep, 4- Ream, 5- Botum Sakor, 6- Phnom Kulen, and 7-Virachey; 10 Wildlife Sanctuaries are: 8- Phnom Aural, 9- Peam Krasop, 10- Phnom Samkos, 11- Roniem Daun Sam, 12- Kulen Promtep, 13- Beng Per, 14- Lomphat, 15- Phnom Prich, 16- Phnom Nam Lyr, and 17- Snoul; 3 Ptotected Landscapes are: 18- Angkor, 19- Banteay Chmar, and 20- Preah Vihear; and 3 Multiple Use Areas are: 21- Dong Peng; 22- Samlaut; and 23- Tonle Sap.

*Full Time Staff GAP*

According to the *average* and *highest* benchmark of Full Time Staff (Table 1) and data shown in figure 1, cluster 1 had only one PA below *average* and cluster 2 had four PAs below and one PA above its *average*, while cluster 3 had eight PAs below and six PAs over *average. T*herefore Cluster 1 had 0.97 / 1000 ha or approximately 5 (4.8) full time staff gap, cluster 2 had 1.47 / 1000 ha or 42 full time staff gap and cluster 3 had 1.85 / 1000 ha of 402 full time staff gap. The calculation of full time staff gap in each PA was shown in figure 2. Among 23 PAs, only Tonle Sap multiple use area and Phnom Aural wildlife sanctuary hade high full time staff gap: 82 staff gap were for Tonle Sap and 66 staff gap for Phnom Aural. For other PA the gap was between 0 to 45 staff.

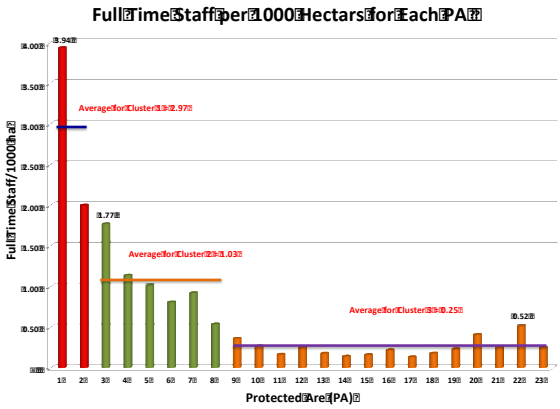


**Fig. 1 Full time staff / 1000 ha**

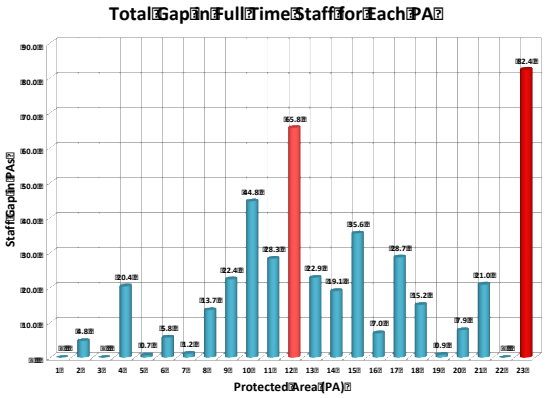


**Fig. 2 Full time staff gap in each PA**

The result of full time staff gap assessement indicated that an additional 448.55 staff needed to be employed to the existing 891 staff to meet the benchmark of 1,339.55 staff. That meant 1/3 of existing staff is required to recruit in addition.

*Operational Expenditure GAP*

The assessment of the financial gap was based on the annual budget (2009) for PA management of the Ministry of Environment. The funding for supporting PA management received from Government was 40 person (equivalent to USD 499,515) and from other external sources was 60 person (equivalent to USD 741,964). This amount of external sources pertained to only nine PAs. There too, not all donors funding is included, as some portion was undisclosed due to the confidential policy of the management. Therefore, this paper focused only donor's funding that works with government or has a joint project through the Ministry of Environment.

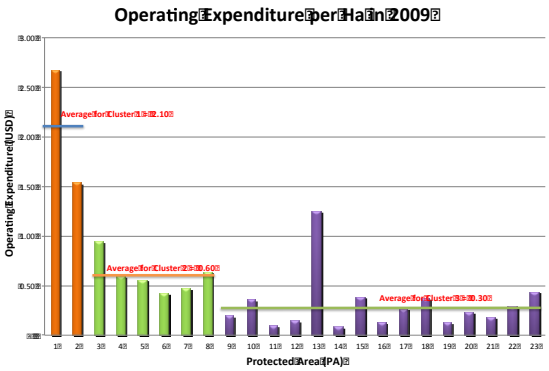


**Fig. 3 Operational expenditure per ha.**

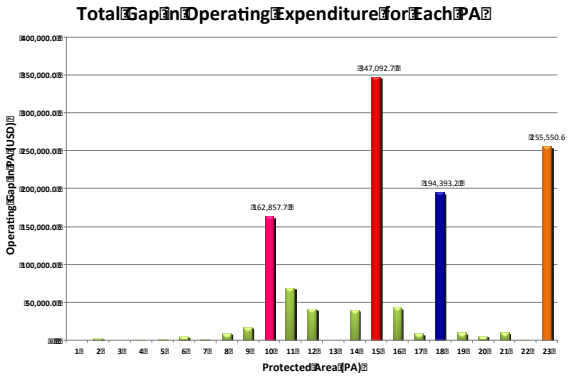


**Fig. 4 Operational expenditure gap**

The operational expenditure for each PA included salary for full time staff, expenditure for uniform medicine and conservation projects. The *average* and *highest* of operational expenditure for each cluster are presented in Table 1. Figure 3 shows that cluster 1 had an *average* expenditure of USD 2.10 / ha and a *highest* expenditure USD 2.67 / ha, so the total gap was USD 2,853. In cluster 2, operational expenditure in six PAs was not very diverse and was below the *average*, only Dong Peng multiple use area was spending above the *average.* Therefore the total gap for this cluster was USD 16,886. Besides, cluster 3 operational expenditure in 15 PAs was variance from one PA to another, and 10 PAs were below the *average*, while 4 PAs were above the *average*. The total operational expenditure for cluster 3 was USD 1,201,666. Total gap for each PA showed in figure 4. It articulated that Kelen Promtep wildlife sanctuary had highest gap (347,092.7 USD) while Tonle Sap multiple use was the second highest gap of operation expenditure in 2009. Phnom Prich wildlife sanctuary and Botum Sakor national park also presented high gaps as noted.

Total gap of operational expenditure in 2009 for 23 PAs was USD 1,221,405 approximate 50 percent of benchmark estimation at USD 2,462,881. For better management of PA system in Cambodia, operational fund should be increased to double of 2009 budget.

As results of assessment, the resources gaps for full time staff & operational expenditure for 23 PAs are shown in table 2.

**Table 2 Resources gap**

| Resources gap assessment | FTS (Number) | OpEx. (USD) |
|---|---|---|
| Existing resources (2009) | 891.00 | 1,241,476 |
| Estimated resources benchmark | 1,339.55 | 2,462,881 |
| Estimated resources gap | *448.55* | *1,221,405* |

## CONCLUSION

The resource gap analysis is reliant on data availability in setting indicators. The gap analysis is based on the *average* & *highest* full time staff per 1000 hectares and operational expenditure per hectare in year 2009. The *average* and *highest* for both indicators vary from cluster to cluster according to the size of PAs. Logically, the bigger size of the PA presents bigger number of full time staff and a bigger operations budget. However, results of this study showed that the smaller PA size had the higher *average* of full time staff, and the higher *average* of operational expenditure. It is more than double expenditure compared with PAs which highest size.

Generally, PAs that had high resource gaps were from cluster 3 as this cluster had very wide gap between *highest* and above *average*. For cluster 1 and cluster 2 each PA was not much different gap in term of proportion.

The full time staff gap in this research did not taking into account the qualification of staff. Therefore, this study focuses on quantity only. To assess the effectiveness of PA management, staff quality should be considered as important indicator and it should be considered for further research.

The protected area that depends on the government budget was only able to support for staff salaries, uniforms, and medicine. This budget is niether adequate for effective management nor to improve facilities for resource mobilization. More than half of the total operational expenditure in 2009 received from external sources, if this study could assessed more information on budgets of conservation projects for PA management that supported and implemented by external partners, the figure of operation expenditure for 23 PAs will be increased.

In conclusion, to assess the resource gaps for effectiveness in PA management, gap of full time staff should examine both quantity and quality, including skills & professional requirements, and other criteria such as management plan, equipment, operation facilities etc. Without quality, motivation, and incentives, even if there is adequate staff, a successful or effective PA management is not guaranteed. Although 1/3 of existing staff is required to filling the gap, if existing staff can improve their capacity with well equip facilities there will improvement in PAs management.

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Research article

# Peanut Yield and Changes of Soil properties by Intercropping in Upland Cropping Systems of Southeast Cambodia

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**Abstract** Successive monocropping with cassava in upland areas of Cambodia has led to a progressive decline in soil fertility. The aim of the present study was to investigate the change of soil properties and examine the growth and yield of peanut in intercropping cultivation in the upland cropping systems of Cambodia. Seven intercropping treatments were studied: T1 (cassava + mungbean + fertilizer rotation with fallowing); T2 (cassava + peanut + fertilizer rotation with fallowing); T3 (cassava + fertilizer rotation with fallowing); T4 (cassava + no fertilizer); T5 (mungbean + fertilizer rotation with cassava + mungbean + no fertilizer); T6 (peanut + fertilizer rotation with cassava + peanut + no fertilizer) and T7 (stylo + fertilizer rotation with cassava + no fertilizer) were designed and conducted in the fields of farmers in Prey Veng and Svay Rieng provinces. Field data indicated that peanut yield increased in the order of: T2 > T7 > T1 > T6 > T5 > T3 > T4. Analysis revealed there were significant differences in peanut yield among all seven treatments, with the yield of T4 being significantly lower than that of T2 and T7. The mean of the peanut yields were greater than 2.1t $h^{-1}$ for all treatments. The total N, K and phosphate of the pre-treatment analysis did not significantly differ from those of the post-treatment analysis. This study suggests that intercropping cultivation could provide a sustainable harvestable yield of peanut in the upland cropping system in Cambodia.

**Keywords** peanut, intercropping, upland cropping system, Cambodia

## INTRODUCTION

The challenges of farmers in improving upland farming systems in Cambodia were identified, in which soil fertility was one of the main challenges in agricultural production systems in Cambodia (Chan et al., 2009). Soil factors affecting crop suitability for upland crops in Cambodia have been documented (Seng et al., 2009). Previous studies revealed that upland areas are widespread throughout Cambodia, thus there was a considerable scope in developing upland crops and cropping technologies in Cambodia (Seng et al., 2011). The continuous mono-cropping particularly with cassava in upland areas

has led to a progressive decline in soil fertility. There is an urgent need to identify alternative agricultural production options capable of economically improving both the soils and production, while at the same time improve the incomes of rural households, which are almost 100% dependent on agriculture. Important upland crops in Cambodia are maize, rubber, soybean, mungbean, cassava, sesame, peanut and sugarcane (Bell et al. 2005). Inter-cropping is one of the options available for more sustainable agricultural production systems. Most farmers in the provinces of Prey Veng and Svay Rieng have tried to intensify agricultural production through mono-cropping of cassava, reflecting the high demand for this crop in commercial markets. However, this cropping intensification has been done with little knowledge of procedures or technologies for maintaining soil fertility.

Some farmers have reported that soil fertility shown a significant decline in areas with a history of cassava cropping because smallholder producers like them are unable to afford commercial fertilizers to replace the nutrients removed by successive cassava cultivation. In this study, a number of different 'systems of production' are being evaluated on the Prey Khmer soils in Prey Veng and Svay Rieng provinces. Crop growth and yield performance, together with issues of soil fertility sustainability, from different combinations of maize and cassava with selected legumes were investigated.

## OBJECTIVE

The objectives of the present study are to (1) examine growth and yield of peanut in intercropping cultivation in the upland cropping system of Cambodia and (2) investigate the changes in soil chemical and physical properties after intercropping cultivation.

## METHODOLOGY

This study was carried out in Prey Veng and Svay Rieng provinces which are located in the Southeastern Cambodia (Fig. 1). Prey Veng is located on the east bank of the Mekong River and is one of the largest rice producing regions in Cambodia and other crops while Svay Rieng is located on Cambodia's South-Eastern border with Vietnam, 125km from Phnom Penh capital.

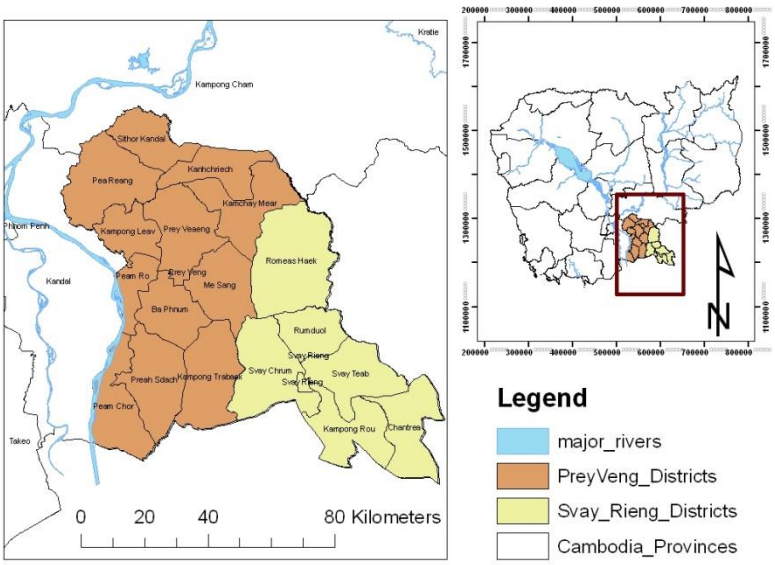


**Fig. 1 Map of the study areas**

Field trials of intercropping cultivation of peanut were conducted in eight basic production systems (7m × 10m) of farmers in the study areas of Prey Veng (n = 4) and Svay Rieng (n = 4) provinces. The detailed design of field trials is presented in Table 1. The plant height (cm), weight per hill (g), number of fruit per hill, grain weight per 100 seeds (g), peanut yield per hectare (t $h^{-1}$) were determined. Concurrently, soil samples were collected before and after each treatment, to determine soil properties and the changes in total C, organic C, N, $P_2O_5$, Ca, Mg, Na, K and exchangeable acidity ($pH_{KCl}$) and actual acidity ($pH_{H2O}$).

**Table 1 Summary of intercropping of peanut cultivation in the upland cropping system in Prey Veng and Svay Rieng provinces**

| Treatment | 2014 | | 2015 | |
|---|---|---|---|---|
| | EWS | LWS | EWS | LWS |
| T1 | CS+MB+F | – | PN+F | – |
| T2 | CS+PN+F | – | PN+F | – |
| T3 | CS+F | – | PN+F | – |
| T4 | CS-F | – | PN+F | – |
| T5 | MB+F | CS+MB-F | PN+F | – |
| T6 | PN+F | CS+PN-F | PN+F | – |
| T7 | Stylo+F | CS-F | PN+F | – |

*EWS, early wet season; LWS, late wet season; MZ, maize; SB, soybean; MB, mung bean; CS, cassava; PN, peanut; +F, fertilizer application; -F, No fertilizer application*

All statistical data analyses were employed using SPSS for Windows (Version 16.0). One-way ANOVA test was applied to verify the differences in plant height, weight per hill, number of fruit per hill, peanut yield among all treatments. Paired samples *t* testing was performed to certify the differences in soil pH, total C, organic C, total N, $P_2O_5$, K, Ca, Mg and Na between pre-treatment and post-treatment of each treatment. Significance is considered in a circumstance where $p < 0.05$.

## RESULTS AND DISCUSSION

### Peanut Yield

A summary of growth and yield of intercropping cultivation of peanut are presented in Table 2. The comparisons revealed that there were no significant difference in plant height at flowering and harvesting stages among all treatments (One-way ANOVA, $p > 0.05$). However, there were significant differences in weight per hill of peanut among all treatment (One-way ANOVA, $p < 0.05$). The weight per hill of T2 was significantly higher than that of T3, T4, T5 and T6 using post hoc Tukey HSD test ($p < 0.05$). Likewise, the number of fruit per hill significantly differed among all treatments (One-way ANOVA, $p < 0.05$). The post hoc Tukey HSD test revealed that number of fruit per hill of T2 was significantly greater than that of T3, T4, T5 and T6 ($p < 0.05$). Grain weights per 100 seeds were significantly different among all treatment (One-way ANOVA, $p < 0.05$). A previous study on field crop productivity in relation to soil properties revealed that peanut was the most reliable crop with successful establishment in the early wet season and harvestable yield at 80% of sites (Seng et al., 2011). The present study showed that peanut yield increased in an order of T2 > T7 > T1 > T6 > T5 > T3 > T4. A comparison revealed that there were significant differences in peanut yield among all treatments (One-way ANOVA, $F(6, 49) = 3.18$, $p = 0.01$). Post hoc Tukey HSD test indicated that peanut yield of T4 was significantly lower than that of T2 and T7 ($p < 0.05$). According to Seng et al (2011), peanut yield was between 2.1 to 3.4t $h^{-1}$ on Kampong Siem soils. Peanut yield of the present

study (Table 2) was comparable to that of Kampong Siem soil. Peanut yield varied with site and season in which about 43% of peanut crops yielded 1.5t $h^{-1}$ or less (Seng et al., 2011). The mean of peanut yield in all treatments in the present study were greater than 2.1t $h^{-1}$. These data suggested that intercropping cultivation could provide a harvestable yield of peanut in the upland cropping system of Cambodia.

Soil chemical and physical properties before and after intercropping are presented in Table 3. The soil texture that applied to soil sample was determined using the triangle (Brady and Weil, 2007). Soil particle analysis revealed that field soils were sandy loam. A comparison revealed that there were no significant differences between total C of pre-treatment and post-treatment in all treatment; however, the total C of post-treatment was significant lower than that of pre-treatment of T6 (Paired samples *t* test, $p < 0.05$). Likewise, organic C of pre-treatment and post-treatment of all treatments, except T6 ($p = 0.013$), are not significantly different (Paired samples *t* test, $p > 0.05$). There were not significant differences in total N and phosphate between pre-treatment and post-treatment in all treatments (Paired samples t test, $p > 0.05$).

**Table 2 Plant growth and crop yield after intercropping in the upland cropping systems of Prey Veng and Svay Rieng provinces**

| Treatment | Statistics | Plant height at flowering (cm) | Plant height at harvesting (cm) | Weight/Hill (g) | Number of fruit/Hill | Weight/ 100 seeds (g) | Yield ($th^{-1}$) |
|---|---|---|---|---|---|---|---|
| T1 | Mean | 13.01 | 40.40 | 48.90 | 46.48 | 171.85 | 2.47 |
| | SD | 2.35 | 8.58 | 5.95 | 2.83 | 5.97 | 0.33 |
| T2 | Mean | 13.88 | 39.40 | 52.80 | 50.20 | 177.88 | 2.72 |
| | SD | 2.68 | 7.06 | 6.58 | 3.50 | 3.76 | 0.38 |
| T3 | Mean | 13.65 | 40.88 | 42.68 | 42.23 | 165.43 | 2.31 |
| | SD | 2.97 | 6.97 | 4.52 | 3.51 | 5.03 | 0.41 |
| T4 | Mean | 11.69 | 38.08 | 40.93 | 40.53 | 161.86 | 2.12 |
| | SD | 1.72 | 8.49 | 4.88 | 4.20 | 9.74 | 0.38 |
| T5 | Mean | 11.17 | 37.48 | 43.50 | 42.73 | 170.80 | 2.39 |
| | SD | 0.96 | 9.09 | 5.44 | 3.92 | 6.11 | 0.20 |
| T6 | Mean | 12.18 | 35.68 | 44.15 | 43.85 | 171.75 | 2.44 |
| | SD | 2.40 | 10.41 | 5.06 | 4.63 | 7.40 | 0.29 |
| T7 | Mean | 11.61 | 38.15 | 50.65 | 48.08 | 177.58 | 2.69 |
| | SD | 3.30 | 8.76 | 5.32 | 2.23 | 6.33 | 0.30 |

*S.D, standard deviation*

Further analysis revealed that soil Ca levels of pre-treatment did not significantly differ from that of the post-treatment in all treatments (Paired samples t test, $p > 0.05$). However, soil Mg and Na levels of post-treatment of T5, T6 and T7 was significantly lower than those of pre-treatment (Paired samples t test, $p < 0.05$). A comparison indicated that there were no significant differences in soil K levels of pre-treatment and post-treatment in all treatment (Paired samples *t* test, $p > 0.05$). Concurrently, the exchangeable pH and actual pH of soil in the pre-treatment did not significantly differ from those the post-treatment (Paired samples *t* test, $p > 0.05$).

**Table 3 Mean values of the chemical and physical properties of soils before (n = 8) and after (n = 8) intercropping**

| Treatment | C | Org C | N | $P_2O_5$ | Ca | Mg | Na | K | pH |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Pre-treatment* | | | | | |
| T1 | 10.32 | 1.77 | 1.18 | 144.25 | 3.40 | 1.40 | 0.12 | 0.16 | 4.73 |
| T2 | 10.32 | 1.77 | 1.18 | 144.25 | 3.40 | 1.40 | 0.12 | 0.16 | 4.73 |
| T3 | 10.32 | 1.77 | 1.18 | 144.25 | 3.40 | 1.40 | 0.12 | 0.16 | 4.73 |
| T4 | 10.32 | 1.77 | 1.18 | 144.25 | 3.40 | 1.40 | 0.12 | 0.16 | 4.73 |
| T5 | 10.32 | 1.77 | 1.18 | 144.25 | 3.40 | 1.40 | 0.12 | 0.16 | 4.73 |
| T6 | 10.32 | 1.77 | 1.18 | 144.25 | 3.40 | 1.40 | 0.12 | 0.16 | 4.73 |
| T7 | 10.32 | 1.77 | 1.18 | 144.25 | 3.40 | 1.40 | 0.12 | 0.16 | 4.73 |
| | | | | Post-treatment | | | | | |
| T1 | 9.04 | 1.55 | 0.93 | 145.88 | 4.06 | 1.49 | 0.11 | 0.18 | 4.78 |
| T2 | 9.04 | 1.55 | 0.95 | 142.63 | 2.71 | 1.24 | 0.11 | 0.17 | 4.70 |
| T3 | 8.92 | 1.51 | 0.94 | 156.63 | 2.69 | 1.24 | 0.11 | 0.17 | 4.49 |
| T4 | 9.49 | 1.63 | 0.95 | 146.13 | 2.70 | 1.20 | 0.12 | 0.16 | 4.55 |
| T5 | 9.62 | 1.65 | 0.94 | 143.13 | 2.79 | 1.11 | 0.09 | 0.17 | 4.59 |
| T6 | 7.78 | 1.33 | 0.88 | 150.63 | 2.74 | 1.15 | 0.08 | 0.17 | 4.58 |
| T7 | 9.53 | 1.63 | 1.09 | 139.75 | 3.08 | 1.22 | 0.11 | 0.16 | 4.76 |

*C, Org C, N, P2O5, Ca, Mg, Na, K in mg kg$^{-1}$*

## CONCLUSION

Intercropping of peanut cultivation has been successfully implemented in the upland cropping system of Prey Veng and Svay Rieng provinces. Field data revealed that there were not significant differences in peanut height at flowering and harvesting stages among all treatments. However, weight per hill, number of fruit per hill and 100 grain weight significantly differed among the treatments. Peanut yield increased in the order of T2 > T7 > T1 > T6 > T5 > T3 > T4. The mean of peanut yield were greater than 2.1t h$^{-1}$ in all treatments. There were no significant differences in total N, phosphate, and K before and after intercropping cultivation. This study suggests that intercropping could provide a harvestable sustainable yield of peanut in the upland cropping systems of southeast Cambodia.

## ACKNOWLEDGEMENTS

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Research article

# Systems Analysis and Modelling of Pollution Loading for Management of Calumpang River in Batangas City, Philippines

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**Abstract** The whole stretch of Calumpang River in Batangas province, Philippines is being considered for ecotourism development by the Batangas City government. Water quality of this river, however, falls under the Philippine Department of Environment and Natural Resources' (DENR's) classification as Class D – suitable only for agricultural and industrial purposes. Restoration to Class B is needed for the river to qualify for Recreational Water Use. This is resource management concern needs to be addressed by the involved local government units (LGUs). Using systems analysis and modeling, study on pollution loading of Calumpang River is conducted to generate information that will aid policymakers in crafting management options for the restoration. Factors, relationships and processes involving people, land uses and management practices that lead to its current polluted state are identified and analyzed using the conceptual framework of a river system. Pollution contributions are identified and quantified. Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) are used in determining who should be responsible and accountable in the restoration and management of this water resource. Results showed that agricultural activities are the major contributor in the degradation of water quality in Calumpang River, swine production in particular, loading as much as 16,990 kg of solid waste daily. Using the physico-chemical and socio-economic characteristics and their pollution loading contribution as basis in determining the degree of accountability, results showed that Batangas and Lipa cities have the highest level of accountability with an AHP value of 0.24, followed by Rosario (0.15), Ibaan (0.14), and San Jose (0.10). Establishment of a governing body as a management option can be recommended using the results of the study as basis in determining the financial contribution of the accountable municipalities and the number of their representatives in the governing body.

**Keywords** systems analysis, Calumpang, watershed, swine, water degradation

## INTRODUCTION

The Batangas City Government acknowledges the vital role of ecosystem services provided by the Calumpang Watershed and the need for rehabilitation, protection and conservation of the river to push forth its ecological tourism plan. This recognition led to the formulation of the Calumpang Watershed Rehabilitation and Conservation Strategic Development Program for 2013-2023 which is now in its third phase of implementation. Phase-1 focuses on socio-environmental preparations, education, information, communication (EIC), institutional mobilization and strengthening multi-stakeholder collaboration. Phase-2 focuses on watershed rehabilitation, resources and technological investments. Phase-3 covers the feasibility analysis of river restoration and ecotourism hotspot development. This Phase requires cooperation and collaboration of all municipalities located within the watershed for though the Calumpang River is located within Batangas City, its tributaries covers six municipalities (Cuenca, Padre Garcia, Rosario, San Jose and Taysan) and two cities (Batangas City and Lipa City) (Fig. 1).

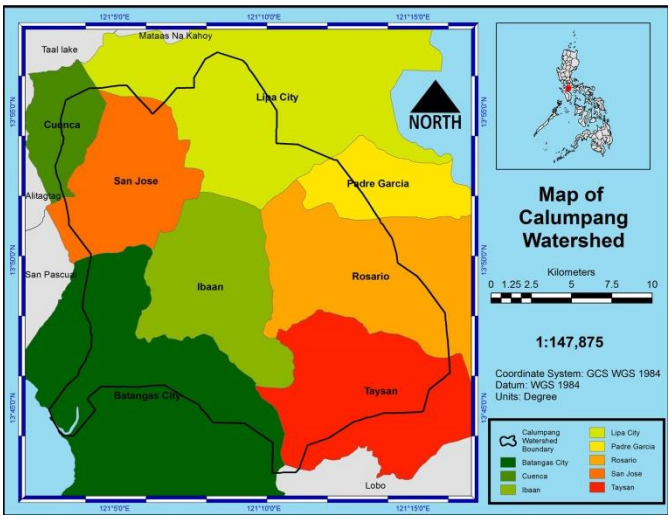


**Fig. 1 Calumpang Watershed Map**

One major constraint in the proposed development is its water quality. In 2013, the group of Arboleda found the river to have high fecal coliform content (2 000- 130 000 MPN/100 mL), high level of Biological Oxygen Demand (BOD) (9-23 mg/L), and low level of Dissolved Oxygen (DO) (0.53-4.71 mg/L). In 2014, Cinco reported that Calumpang River was classified as Class D by the Philippine Department of Environment and Natural Resource (DENR), indicating that the water is not fit for any recreational activities and only fit for agricultural and industrial use. Identified potential cause of pollutants includes inflow of untreated domestic sewage and animal wastes from poultries and piggeries in the Watershed. According to the Office of Provincial Planning and Development Coordinator, in 2010 there are approximately 870,000 people residing in the watershed, and only about (13.14%) are residing in Batangas City. Swine population is about 325,344 heads at any given time, mostly found in Lipa City (28.72%).

River rehabilitation and water quality restoration from Class D to Class B is a challenge that the local government has to face as they pursue their plans for development. Batangas City can modify the polluting factors within their jurisdiction using physical, economic, and/or political approaches. However, since the watershed encompasses several municipalities and cities, baseline information as basis for cooperative and collaborative river restoration is needed.

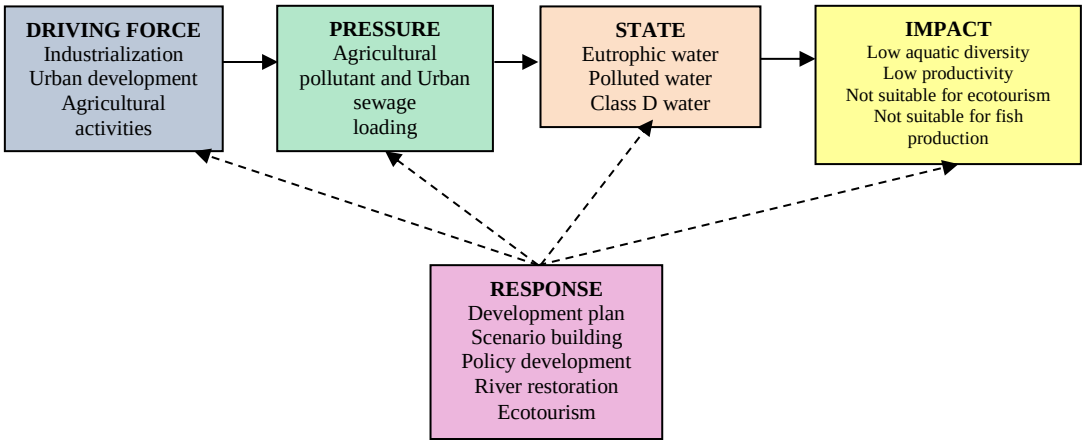


**Fig. 2 DPSIR Framework of Calumpang Watershed**

Coming up uses Systems Analysis to study the Watershed and to pinpoint the heaviest contributor of pollution. This study can be used to justify that even though Calumpang River falls within the territorial jurisdiction of Batangas City, the restoration and management of the River can be made as a combined effort of all municipalities and cities in the Watershed. Fig. 2 summarizes the abovementioned discussion.

## OBJECTIVES

This study aims to describe the effect of swine production and human population within the watershed to the pollution of Calumpang River; and to roughly quantify the extent of contribution of each municipality or city to serve as basis for restoration and rehabilitation accountability.

## METHODOLOGY

This study was conducted from July to December 2014 as part of a commissioned project by the Local Government of Batangas City to the School of Environmental Science and Management. Primary and secondary data gathering was conducted in the area (Fig. 1) using the DPSIR framework shown in Fig. 2 as a guide for data requirement. System analysis approach was applied in the analysis of the state of Calumpang River system, the contributing factors to its current state, its impact to the people and environment, and the government responses to address the identified problems. Analysis was conducted using tools such as Geographic Information Systems (GIS), systems modelling and Analytical Hierarchy Process (AHP). GIS was used to generate information on loading process based on the amount of pollutants at source and proximity of pollutant sources to the river. The absence of data on the rate of flow of the tributaries is offset by estimating the amount and flow of water as affected by the soil, slope and elevation. This method was used to estimate the flow of pollutants from the source and the amount that reached the water. Lastly, a decision criterion, employing AHP, is set up to determine which municipality(ies) is/are are accountable in the current state of the river and their level of participation that is crucial in the management and restoration of Calumpang River.

## RESULTS AND DISCUSSION

### System Analysis of Calumpang Watershed

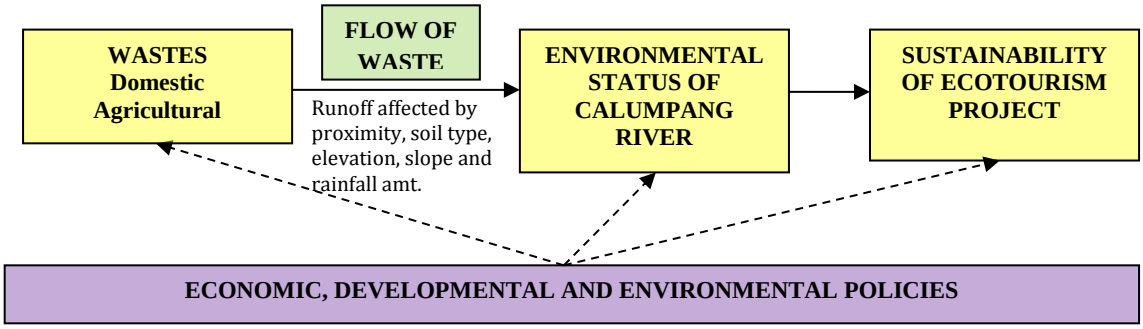


**Fig. 3 Framework of Calumpang Watershed**

Analysis of the Calumpang river system based from observations and data gathered in the area showed that though households typically have a septic tanks or sanitation facilities, there are piggeries with no water treatment facilities and a few households with no septic tanks. The combined wastes of the residents and pigs from all municipalities will be received by a catchment point in Batangas City. The flow of water is not constant from each municipality; rate of flow is usually affected by elevation, slope, soil type, proximity to the area, and rainfall. The state of the water in the River will determine how successful the proposed ecotourism project will be. Initial analysis of the Calumpang river system shows that sustainability of ecotourism project is dependent on the environmental status of Calumpang River. The river is polluted due to the waste coming from the different municipalities and cities within the watershed which are using the tributaries as sink of domestic and agricultural waste (Fig. 3). To achieve a Class B, restoration of the River must be done. This can be done by introducing policies either at the waste source, such as reduction in number of pigs per farm; or at the River by dredging of the River; etc.

### Computation of Total Wastes Received by Calumpang River

Using the above framework as a conceptual model of the Calumpang river system, quantification of the relationship was done which can be used by policy makers as aid in crafting policies for the restoration and management of Calumpang River.

**Table 1 Summary of parameters that affect the flow of water to Calumpang River**

| | Batangas City | Ibaan | Lipa City | Cuenca | Taysan | San jose | Rosario | Padre Garcia |
|---|---|---|---|---|---|---|---|---|
| Proximity (m) | 0 | 5,851 | 16,511 | 12,745 | 10,965 | 9,051 | 12,099 | 18,187 |
| Elevation (m) | 1-100 | 21-500 | 101-500 | 201-975 | 51-500 | 101-500 | 51-200 | 101-200 |
| Slope* | Flat to steep | Very steep | Flat to hilly | Domi-nantly hilly | Flat to hilly | Rolling to hilly | Flat to rolly | Flat to hilly |
| Soil Type | Hydrosol, Taal Sandy Loam, Calumpang Clay, Ibaan Loam, Ibaan Clay Loam | Ibaan Loam (Gravelly Phase), Ibaan Clay Loam, Guadalupe Clay Loam | Ibaan Loam, Ibaan Clay Loam, Lipa Loam | Ibaan Loam, Ibaan Loam (Gravelly Phase) | Ibaan Loam (Gravelly Phase), Guadalupe Clay Loam, Ibaan Clay Loam | Ibaan Loam, Ibaan Loam (Gravelly Phase) | Ibaan Clay Loam, Guadalupe Clay Loam | Lipa Loam, Guadalupe Clay Loam, Ibaan Clay Loam |

**Flat= 0-3%, Rolling= 3-6%, Hilly= 6-15%, Steep= 15-30%, Very Steep= >30% measured near the river*

For the quantification, this study uses the value derived by Agbisit et. al. on swine daily waste generation which is at 0.26 kg, and the average daily human solid waste generation which is about 0.5 kg. Daily waste generation of each municipality and city were computed and the amounts of wastes that will end up in the Calumpang River were estimated. Due to lack of data on amount of rainfall received per municipality or city, it is assumed that each municipality or city receives the same amount of rainfall per month or year and only wastes produced by the residents and swine are included in the analysis since they are the highest waste generator. Table 1 summarizes the parameters that affect the flow of waste to Calumpang River, while the summary of human and swine population can be found in Table 2.

Figure 4 shows the pollution loading of each municipality within the watershed of Calumpang River. Results showed that Batangas City (7951.95 kg) is the greatest polluter of Calumpang River, followed by Ibaan (2707.74 kg), Lipa City (2204.94 kg) and San Jose (1583.25 kg). This result is expected since Batangas City is the nearest municipality to the catchment area, and the municipality that has the highest number of residents and second in number of swine. For the case of Lipa City, though this area is one of the farthest from the catchment point, its elevation, its high number of residents and swine causes it to contribute more to the pollution. However, for Ibaan and San Jose, despite the low number of residents in the municipality, its proximity to the area and the high number of swine causes the high amount in waste contribution. Meanwhile, Cuenca (1165.68 kg), Taysan (908.01 kg), Rosario (391.13 kg) and Padre Garcia (79.03 kg) are the least polluter of Calumpang River.

Calumpang River receives approximately 16,991 kg of wastes daily. If no intervention will be introduced in the area, the water will continued to be polluted: this may result to poor water quality in the region, which can then result to loss of biodiversity, loss of livelihood (fishery), illness such as diarrhea and other related diseases, the failure of the proposed ecotourism project, etc. This situation, if not solved, will make Batangas City's efforts to develop Calumpang River into an ecotourism site futile.

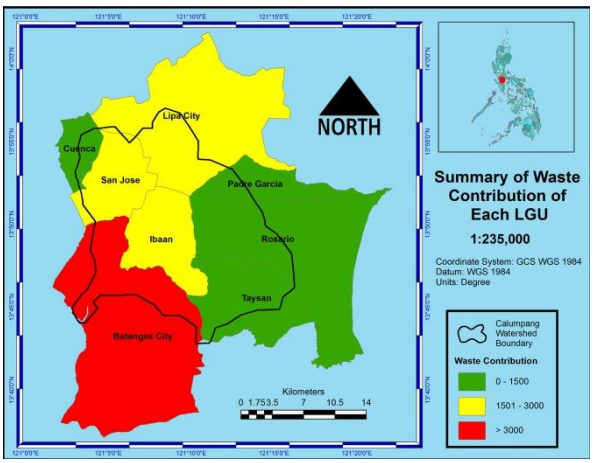


**Fig 4. Summary of Pollution Loading of Municipalities or Cities in Calumpang Watershed**

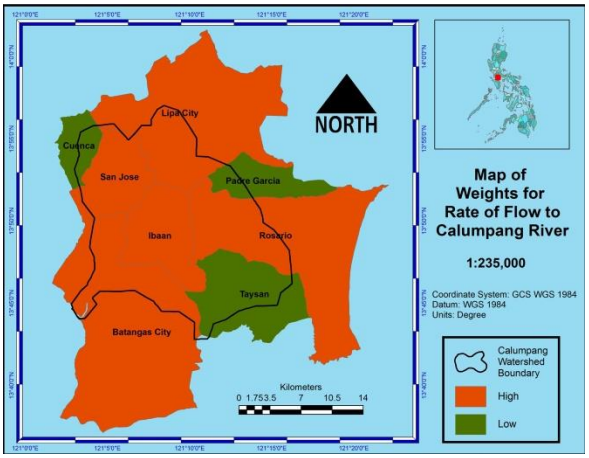


**Fig 5. Summary of Weights Computed**

**Decision Criterion on Selection of Participants to Restoration and Management Project**

Given that the river has many sources of pollutant which could exacerbate the declining water quality, the proposed ecotourism would not be successful. However, the problem is that Batangas City cannot be expected to clean up all wastes contributed by other municipalities and cities. If a governing body

will be established to craft policies and implement restoration and rehabilitation program based on their contribution and accountability in the water pollution, a basis for decision making is needed. For this purpose, AHP was used to determine which among the municipalities surrounding the river is more accountable and should be responsible for the restoration and management of the River.

Land area, population of residents, population of swine, and the area's contribution to pollution has been chosen as the criteria for joining this governing body. Land area is chosen since the larger the land area occupied, the higher its use of the watershed. Population of residents and total swine animal units are chosen since the higher the number of these two factors will result to higher amount of taxes paid to the municipality or the city, which will result to the municipality or the city having more money to fund the project. Lastly, pollution loading is chosen since the higher this is, the higher the responsibility of the area to the pollution of the River.

Data used for these criteria is based on the study by Morales (2011). Table 2 summarizes the criteria together with the corresponding value per municipality. Note that the population of residents is taken in 2007, while the population of the swine is taken in 2011. Comparison of municipality or city is done pair-wise and the one that presents the higher value is given the higher point.

It has been found that Batangas City (0.24), Rosario (0.15), Ibaan (0.14), Lipa City (0.24), and San Jose (0.10) present the highest weights. Expectedly, these five municipalities are the ones with the largest land areas in the Watershed, the largest population, the most number of swine, and the greatest polluter of Calumpang Watershed. On the other hand, Padre Garcia (0.06), Taysan (0.09), and Cuenca (0.07) present the lowest weights.

**Table 2 Criteria for joining the restoration and management project**

| | BATANGAS CITY | IBAAN | LIPA CITY | CUENCA | TAYSAN | SAN JOSE | ROSARIO | PADRE GARCIA |
|---|---|---|---|---|---|---|---|---|
| LAND AREA (ha) | 6546 | 6881 | 5024 | 956 | 4971 | 5510 | 6550 | 893 |
| RESIDENTS | 295231 | 45649 | 260568 | 28581 | 33454 | 61307 | 95785 | 42942 |
| SWINE | 65498 | 34961 | 93452 | 2720 | 17722 | 28600 | 74410 | 7981 |
| POLLUTION LOADING (kg) | 7951 | 2708 | 2205 | 1165 | 908 | 1583 | 391 | 79 |

## CONCLUSION

Calumpang River is predicted to be polluted, and the results show that every municipality contributes to it in different extents. Restoration and management program should be done to realize the proposed ecotourism project in Calumpang River. However, Batangas City government will need help from other municipalities and cities since each of them contributed in the pollution and also because of jurisdiction issues, Batangas City's restoration program cannot go beyond their administrative boundaries. Quantification of each municipalities contribution can be used as basis for determining the extent of accountability and responsibility of each municipality in the restoration and management program that will be introduced. Option to ensure rehabilitation and restoration of Calumpang River, could be a creation of consortium or a governing body composed of municipalities contributing to river pollution members are proportionate to its contribution based on the results of this study. In terms of financial contribution or otherwise, further study should be conducted to determine its feasibility.

## ACKNOWLEDGEMENTS

This study was conducted by the ENS 211 class of 1st Semester, AY 2014-2015 contributing to the project commissioned by the Local Government Unit (LGU) of Batangas City to the University of the

Philippines Los Banos School of Environmental Science and Management (UPLB-SESAM). Maps were generated using the licensed version of ArcMap 9.2 of the SESAM.

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Research article

# Differences in Benthic Cover and Fish Assemblage Inside and Outside Marine Protected Areas

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**Abstract** Marine protected areas (MPAs) are being used increasingly to manage and protect marine resources. Most studies of MPAs have only focused on either benthic cover or fish assemblage. In this study, the influence of MPA protection on both parameters in two areas at Bohol (Badiang, Anda and Baybayon, Mabini) was investigated. At each MPA, three 50-m transect lines at 10 m interval were permanently established inside and outside at 5-8 m depth. The systematic point intercept method was used in determining the benthic cover and fish visual census method for fish assemblage. In Badiang, the protected area had significantly higher live hard coral cover than the general use area. Dead coral with algae covered the general use area in both Badiang and Baybayon. Fish species richness were significantly different in Baybayon with moderate condition in protected area and poor condition in the general use area. Fish density inside the protected area and general use area were not significantly different but were in moderate condition. The high levels of hard coral cover and fish species richness in the protected areas may be a result of their protection status.

**Keywords** coral, coral nursery unit, fish assemblage, restoration, management

## INTRODUCTION

A part of the world's population lives along the coastal plain comprising the coasts, seas, oceans, rivers and estuaries. Humans deal with the coastal and aquatic ecosystems as food resources and a large proportion of the people in most countries are dependent on aquatic resources to provide their daily needs. Unfortunately, many of these natural ecosystems have been indiscriminately harvested or even devastated due to over fishing, physical and chemical destructions arising from industrial activities, untreated sewage of nearby cities and factories, oil and gas contamination from refineries and passing vessels and oil rigs. All these factors have caused the destruction and/or degradation of marine ecosystems, especially decrease in the population of many kinds of aquatic biota (Azhdari et al., 2012).

One of the solutions being used to address the threats plaguing marine resources is the establishment of marine protected areas (MPAs). They are "clearly defined geographical spaces, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (IUCN definition by Dudley, 2008). This is one of the most achievable modes of protection particularly in the Philippines in relation to Coastal Resource Management (CRM) (White et al., 2002). In the Philippines, MPAs can be categorized into two governance levels: nationally established and locally established MPAs. In general, they take four forms: 1) Marine sanctuary or no take marine reserve, where all forms of

extractive activities are prohibited; 2) Marine reserve, where extractive and non-extractive activities are regulated; 3) Marine parks, where uses are designated into zones; and 4) Protected landscape and seascape, where protection may include non-marine resources (Miclat and Ingles, 2004, White et al., 2014). The most common objectives of MPAs establishment are biodiversity conservation, fisheries sustainability, and tourism and recreation, among others.

In a recent review of 112 independent empirical measurements of 80 different reserves, it was found that average values of all biological measures were strikingly higher inside marine reserves compared to the general use areas (Halpern, 2003). Relative to general use sites, population densities were 91% higher, biomass was 192% higher, and average organism size and diversity were 20–30% higher in reserves. Furthermore, these values were independent of reserve size, indicating that even small reserves can produce high values.

There are only a few reports that determine the biological response of the reserve protection in Bohol (Pollnac et al., 2001). Thus, this study investigated the benthic characteristics condition of the general use and protected area as well as reef fish status based on the diversity and density of fishes. In addition, we tried to determine if there is a significant difference between these parameters in the general use and protected areas.

## METHODOLOGY

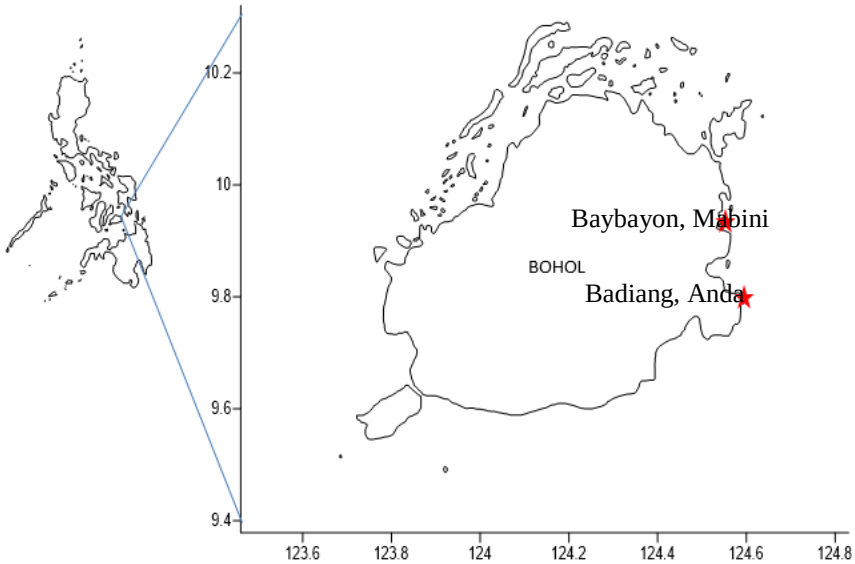


**Fig. 1 Map showing the locations of the two MPAs in Bohol as survey sites**

### Site Selection

This study was conducted in the MPAs at Badiang, Anda, and Baybayon, Mabini, located in the eastern part of Bohol (Fig 1). Badiang, Anda MPA known as Badiang Fish Sanctuary was established in 2003 with a total area of 0.701 $km^2$ while Baybayon, Mabini known as Lumayag Islet Marine Park was established in 1995 with a total area of 0.265 $km^2$.The river water quality was monitored at 37 sampling points located on the main stream (nos. 1-17) and each tributary (A-T) of the Tokachi River basin in June, either August or September and October from 2007 to 2011 under base flow conditions. Water samples were analysed for pH, BOD, SS and EC.

### Benthic Survey Technique

The benthic cover at each location along three randomly established transect lines at 5 m depth (during highest high tide) were assessed using the systematic point intercept method. Each transect was 50 m in length. Photographs were taken using an underwater camera at .25 m intervals and at a height of .50 m above the substrate of each transect. To examine the condition of the coral reef, we grouped the coral cover into 16 categories: branching, table, digitate, encrusting, foliose, mushroom, massive, sub-massive, soft, macroalgae, seagrass, other fauna, dead coral, rubble, hard rock, and sand. Coral reef status were categorized using the criteria of Gomez et al. (1994).

### Fish Species Richness and Density

Divers recorded the density and diversity of fish in 250 $m^2$ area demarcated by a 50 m transect line (laid during the benthic survey) an hour after the benthic survey. The number of individuals per species was noted. The families surveyed are those that are diurnal only. Reef fish status was determined based on fish density (individuals/1,000 $m^2$) and diversity (mean number of fish species/250 $m^2$), using the categories by Hilomen et al. (2000).

### Statistical Analysis

The data were arcsine transformed to pass the assumptions. T-tests were used to determine if there is a significant different between each biological component measured in the general use and protected areas.

## RESULTS AND DISCUSSION

Living structures excluding dead corals covered an average of 51% and 33% of the substrate in the protected areas of Badiang and Baybayon, respectively, and 10% and 29% in the general use areas (Fig. 2). Live hard coral, rubble, and sand and silt were among the benthic categories which have high percentage cover in both protected areas of the study sites. Dead coral with algae, sand and silt, and rubble were among those which have high percentage in the general use areas. Soft corals, sponges, and fleshy algae combine contributed less than 3% to total benthic cover in both protected and general use. In Badiang, the protected area had significantly higher live hard coral cover compared to the general use area ($p < 0.05$). Its live hard coral, which had the highest coral percentage cover observed, was classified as ‘good’. The general use in Badiang was ‘poor’ while the coral status in Baybayon in both general and protected areas was ‘fair’.

The 1950’s were typically regarded as the start of the demise with the introduction of dynamite fishing during the Second World War and other illegal practices in the subsequent decades, such as cyanide fishing and trawling (Marcus et al., 2007). Green et al. (2002) conducted a survey on illegal fishing in Bohol Province and they found out that out of 11 out-lawed fishing gears and activities, dynamite was the most widely used. Though the areas examined in this study are not listed as dynamite and cyanide hotspots in Bohol by Green et al. (2002), we suggest that the use of cyanide, and local plant poisons such as *tubli* and *lagtang* were the most likely reason for the high percentage cover of dead coral with algae in the general use areas since this kind of destructive fishing practices do not directly result in physical breakage of hard corals (McManus et al., 1997). The presence of rubble in the protected and general areas also indicates incidence of dynamite fishing.

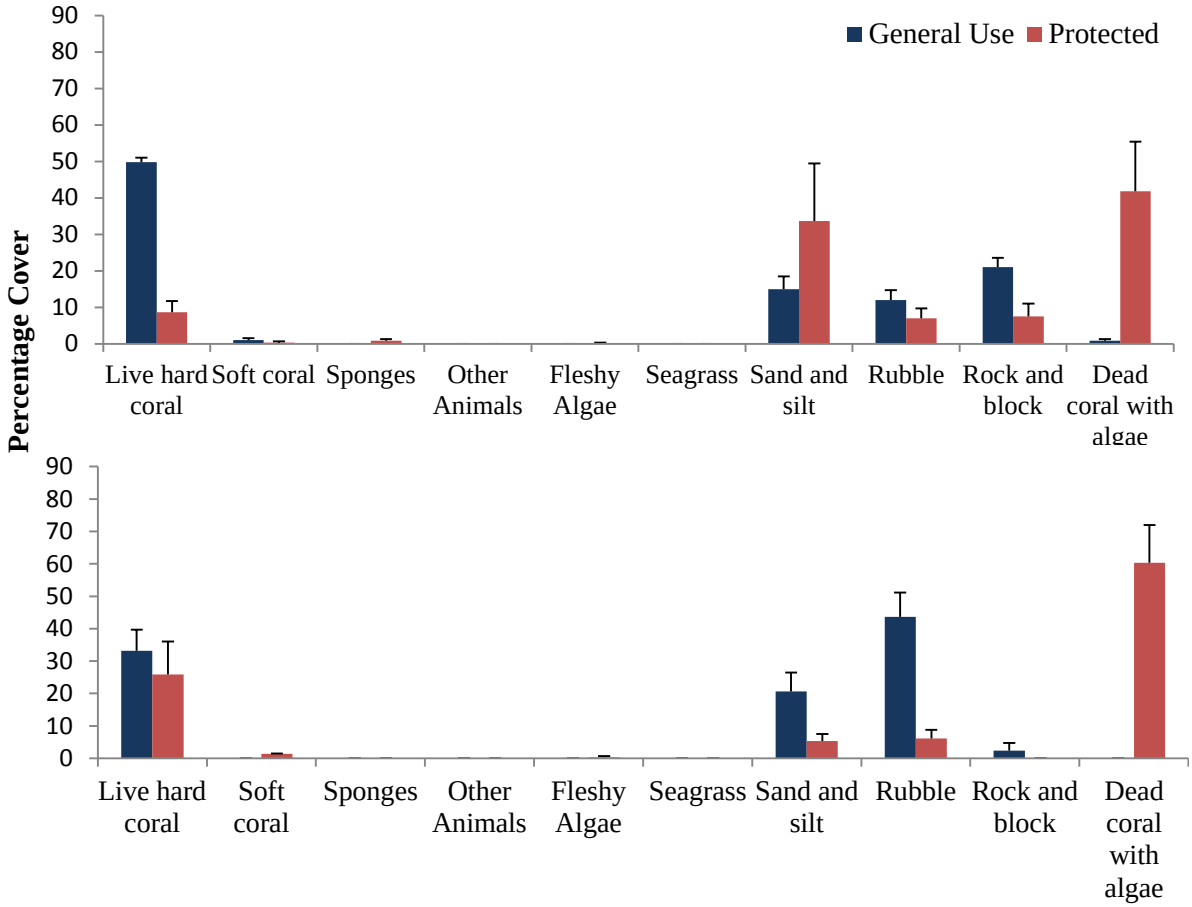


**Fig. 2 Benthic composition in the general and protected areas at Badiang and Baybayon**

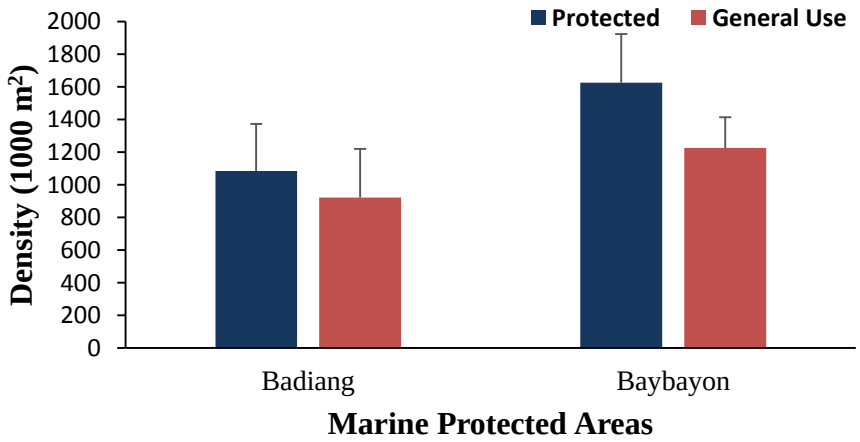


**Fig. 3 Fish density in the two marine protected areas**

Fish diversity were significantly different in Baybayon with a moderate condition in protected area and poor condition in the general use area (Table 1). However, fish density in the protected and general use areas of both Badiang and Baybayon showed no significant difference (Fig. 3). This is an indication that they were under more or less of the same condition. Based on the classification of

Hilomen (2000), the density of fishes in all study areas were in moderate condition. The most dominant families in both Badiang and Baybayon came from Pomacentridae and Pomacanthidae. Higher density of these species was probably due to the lack of top predators which declined following intense fishing pressure (Corrales et al., 2015).

**Table 1 Species richness in the marine protected areas at Badiang and Baybayon**

| Family | Badiang | | Baybayon | |
|---|---|---|---|---|
| | Protected | General Use | Protected | General Use |
| Acanthuridae | x | x | x | x |
| Apogonidae | x | x | x | x |
| Balistidae | x | x | x | |
| Caesionidae | | | x | |
| Chaetodontidae | x | x | x | x |
| Centriscidae | | x | x | |
| Haemulidae | x | x | | |
| Holocentridae | x | | x | |
| Labridae | x | x | x | x |
| Lethrinidae | | | | |
| Lutjanidae | x | x | x | x |
| Monacanthidae | | x | x | |
| Mullidae | x | x | x | x |
| Ostracidae | | | x | |
| Ogcocephalidae | | | x | |
| Nemipteridae | x | | x | x |
| Pempheridae | x | x | | |
| Plotosidae | x | x | x | x |
| Pomacanthidae | x | x | x | x |
| Pomacentridae | x | x | x | |
| Scaridae | x | x | x | x |
| Scorpaenidae | | | x | |
| Serranidae | x | x | x | x |
| Siganidae | x | | x | x |
| Synodontidae | | x | x | |
| Tetraodontidae | x | | x | |
| Zanclidae | x | x | x | |
| Total | 19 | 18 | 24 | 12 |

## CONCLUSION

The MPAs the study sites have played an important role in fishery conservation and this is evident in the higher levels of hard coral cover and fish species richness within the areas. However, they still need long-term protection and good management to improve fish population.

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Research article

# Influence of Meteorological Variable Combinations on Reference Evapotranspiration Estimated by the FAO56 Penman-Monteith Method

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**Abstract** An estimate of potential evapotranspiration (PET) is typically required for rainfall runoff modeling, and such as estimate of PET is often determined from use of the Penman-Monteith (PM) method using air temperature, humidity, wind speed, solar radiation and sunshine hours data. This method is recommended by the FAO and used widely across the world. The estimated PET is known to vary depending on the combination of meteorological data used in the PM equation. For example, PET can be estimated by using wind speed and air temperature data only, or by using all five meteorological data. There have been no cases that were examined regarding how combinations of the five data influence estimated PET for the Asian Monsoon region. Air temperature, wind speed, solar radiation, sunshine hours and humidity were measured and recorded at ten-minute intervals for three years at a weather station in the Minami-Soma City, Fukushima Prefecture, Japan. The daily PET was estimated for the 13 combinations of the five data. It was found that PET is overestimated when the solar radiation is not included in the combination. The above results show that data on the solar radiation are indispensable for PET estimation that uses the PM equation in the Asian Monsoon region.

**Keywords** hydrological model, potential evapotranspiration, FAO, Penman-Monteith method

## INTRODUCTION

In recent years, there have been hydrological hazards such as floods and landslides due to heavy precipitation and metrological hazards such as storms and extreme temperature that have occurred in many areas of the world. Particularly in the Asia-pacific region including the Asian monsoon region, hydrological and metrological hazards were the most frequent disasters in 2014. Furthermore, economic losses due to those disasters were estimated in more than 50 billion USD (ESCAP, 2014). Therefore, river development and watershed management for mitigating flood damage have been called for. In planning projects for river development and watershed management for natural disaster mitigation, it is necessary to simulate the effectiveness of the project by using a rainfall runoff model, with which it is possible to predict the changes in the river discharge in relation to the rainfall in the watershed scale.

For such a rainfall runoff model to be used, data on potential evapotranspiration (PET) is required. Measured PET data is not generally used for the model. The PET data is determined from the five meteorological data of air temperature, intensity of solar radiation, humidity, wind velocity and sunshine hours and by using a FAO-56 Penman-Montieth (PM) method, which was described in the FAO Irrigation and Drainage Paper No 56 “Crop Evapo- transpiration” in 1998 by the Food and

Agriculture Organization (FAO) of the United Nations, to revise guidelines for computing crop water requirements (Allen et al., 1998). The most common equation for estimating PET, which is recommended by the FAO and is used widely in the world, is the Penman-Montieth (PM) equation.

## OBJECTIVE

The estimated PET is known to vary depending on the combination of meteorological data used in the PM equation (Todorovic et al, 2013; Pereiraa et al. 2015). For example, PET can be estimated by using wind velocity and air temperature data only, or by using all five meteorological data. There have been no cases that were examined regarding how combinations of the five data influence estimated PET for the Asian Monsoon region. In this study, comparisons between measured and estimated values were performed for atmospheric pressure, vapor pressure, and solar radiation by using the root mean squared error (RMSE), and the accuracy of the estimation method recommended for use in the PM method was examined. The influence of the estimation accuracy of these three items on the estimated PET was clarified.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} PET_i - \widehat{PET_i}} \quad (1)$$

Where N is number of calculation data, $PET_i$ is computing value by using all five meteorological data, $\widehat{PET_i}$ is computing value by using 2 to 4 meteorological variables.

## METHODOLOGY

Meteorological observation was done for the 22 months from November 2011 to September 2013. A weather station was installed at a location 2km inland from the sea coast of Minami-Soma City, Fukushima Prefecture (Fig.1 and Photo.1), during those 22 months. The observation items were precipitation (P), wind direction (WD), wind speed (WS), temperature (T), relative humidity (RH), solar radiation ($R_S$), and actual hours of sunshine (AH). These were measured at 10-minute intervals. The daily average, daily lowest, and daily highest values for these seven items were determined. Atmospheric pressure (P) could not be measured at the observation site. Instead, the atmospheric pressure observed by the Japan Meteorological Agency at Sendai City, 60 km from the observation station, was used.

In calculating the daily potential evapotranspiration (PET), the Penman-Monteith (PM) method, which is recommended by the FAO, was used. The equation used for the PM method is shown below.

$$ET_0 = \frac{0.408\Delta(R_n - \mathrm{G}) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (2)$$

Where $ET_o$ is the reference evapotranspiration (= PET) (mm/d), $R_n$ is the net radiation at the crop surface (MJ $m^{-2}$ $d^{-1}$), $T$ is the air temperature at 2 m height ($^{O}C$), $u_2$ is the wind speed at 2 m height (m $s^{-1}$) $e_s$ is the saturation vapour pressure (kPa), $e_a$ is the actual vapour pressure (kPa), $\Delta$ is the slope vapour pressure curve (kPa $^{O}C^{-1}$), $\gamma$ is the psychrometric constant (kPa $^{O}C^{-1}$) $G$ is the soil heat flux density (MJ $m^{-2}$ $d^{-1}$). For day and ten-day periods, as the magnitude of the day or ten-day soil heat flux beneath the grass reference surface is relatively small, it was ignored.

In using the PM method to determine the PET, it is necessary to obtain several variables: $R_n$, $T$, $u_2$, $e_s$, $e_a$, $\Delta$, $\gamma$, and $G$. The meteorological data, including T, RH, $R_s$ or AH, and P are used to determine the variables. The PET can be determined even without data such as $R_s$ (or AH), RH, or P. The flows of

calculation for the items relevant to the PM method are shown in Fig. 2. The P can be estimated from the elevation. To determine the vapor pressure $e_a$, RH and T are used; however, when the RH data are unavailable, it is possible to estimate $e_a$ by using the T data. When the $R_s$ data are not available, $R_s$ can be estimated from the AH.

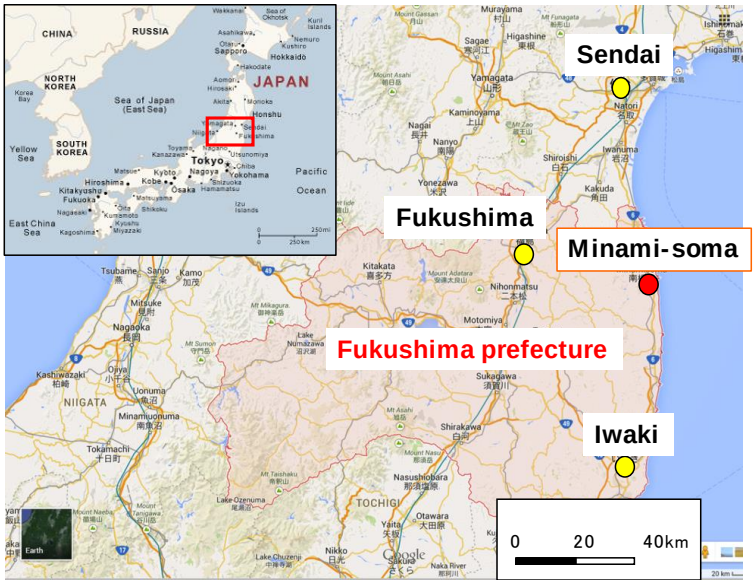


**Fig. 1 Investigation site (Red point)**

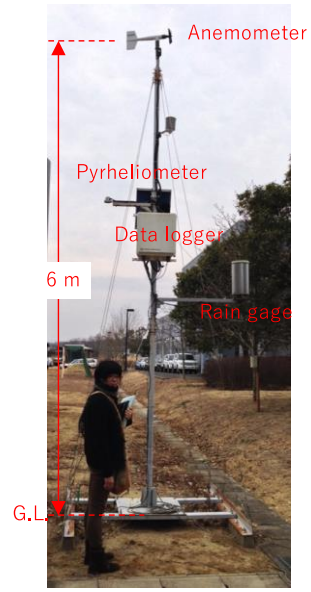


**Photo. 1 Weather station**

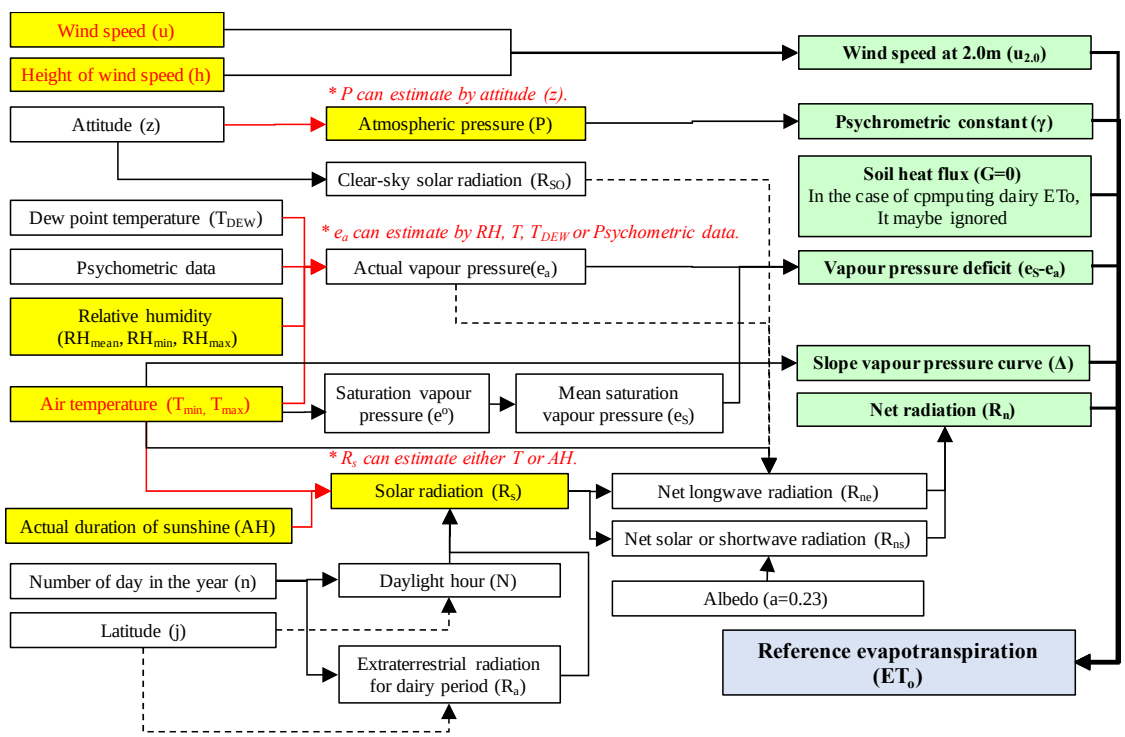


**Fig. 2 Flow diagram of potential evapotranspiration calculation by the PM method**

As shown in Table 1, when determining the PET by using the meteorological data such as T, RH, Rs (or AH), and P as variables, there are 13 combinations of data items, here designated A to M (Table 1). The estimated PET differs according to what combinations of meteorological data items are used. However, no previous reports have investigated how combinations of the meteorological data influence estimation of the PET for the Asian monsoon region.

**Table 1 Thirteen patterns of meteorological data set for calculating PET by the PM method**

| | Air temperature | Wind speed | Atmospheric pressure | Relative humidity | Actual hours of sunshine | Solar radiation | Reference |
|---|---|---|---|---|---|---|---|
| | T | WS | P | RH | AH | $R_S$ | |
| A | □ | □ | □ | □ | □ | | |
| B | □ | □ | □ | □ | | | |
| C | □ | □ | □ | | □ | | |
| D | □ | □ | | □ | □ | | |
| E | □ | □ | | □ | | | |
| F | □ | □ | | | □ | | |
| G | □ | □ | □ | | | | |
| H | □ | □ | | | | | |
| I | □ | - | - | - | - | - | Hargraves equation |
| J | □ | □ | □ | □ | | □ | Basic data set |
| K | □ | □ | □ | | | □ | |
| L | □ | □ | | □ | | □ | |
| M | □ | □ | | | | □ | |

□ □Observation data

## RESULTS AND DISCUSSION

### Weather Characteristics of Minami-Soma City

The meteorological data obtained during the 22 months is shown in Fig. 3. The daily data for the 22 months are shown in the graphs for the monthly data. The daily average temperature was the highest in August and the lowest in February. The annual temperature difference was 25°C. The humidity was high in summer (July), at 70% or greater, and low in winter (Jan., Feb., March), at 60%. The wind speed ranged between 1.0 and 1.5m/s. The wind speed in this area was extremely low throughout the year. The variation in atmospheric pressure was small; it ranged between 1000 and 1010 hPa. The solar radiation and sunshine hours were the greatest in June and the smallest in December. These changed with an annual cycle. The precipitation was great in spring (April, May) and fall (September, October). This area has little snowfall. There is no snow cover during winter.

When P data were unavailable, P was estimated by using the elevation in the PM method. Here, the measured and estimated P are compared and the estimation accuracy is examined. Fig. 4 shows the relationship between the measured and estimated daily data for P during the 22 months. As there was only one elevation reference location, the P estimated from that elevation was 100kPa. The estimated values varied between 97kPa and 103 kPa. The RMSE was an extremely small value of 0.71kPa. The above result clarified that the P could be accurately estimated from the elevation, even when the P data were unavailable.

The actual vapor pressure ($e_a$) is determined as a function of the daily average RH and daily highest and lowest T. The value of $e_a$ can be determined from the daily lowest T even when the RH data are unavailable. Here, $e_a$ determined by using the RH and T data was compared to that determined by using only the T data. The estimated values determined in the two methods were compared (Fig. 6). The comparison revealed a high correlation between the two values. The RMSE was an extremely small value of 0.16kPa. Based on the above, it was thought that $e_a$ can be accurately estimated irrespective of the use of the RH data.

When the $R_s$ (net radiation) data were unavailable, the $R_s$ was estimated from the AH or T. Here, the observed solar radiation is compared with the values estimated from the AH and the values

estimated from the T (Fig. 7). The values estimated from the AH and the values estimated from the T show a positive correlation with the observed values. However, the RMSE is the great value of 6 MJ $m^2$ $d^{-1}$ for both types of estimated values. The Fig. 7 shows that the difference between the observed and estimated values is small in the areas near the highest and lowest observed values. The estimated values were 20, 25 and 25 MJ $m^2$ $d^{-1}$, while the observed values were 5, 10, 15 and 20 MJ $m^2$ $d^{-1}$. The estimated values overestimated the observed values by a factor of 4, 2.5 and 1.25, respectively. This comparison found that $R_s$ is unable to be accurately estimated from the AH or T.

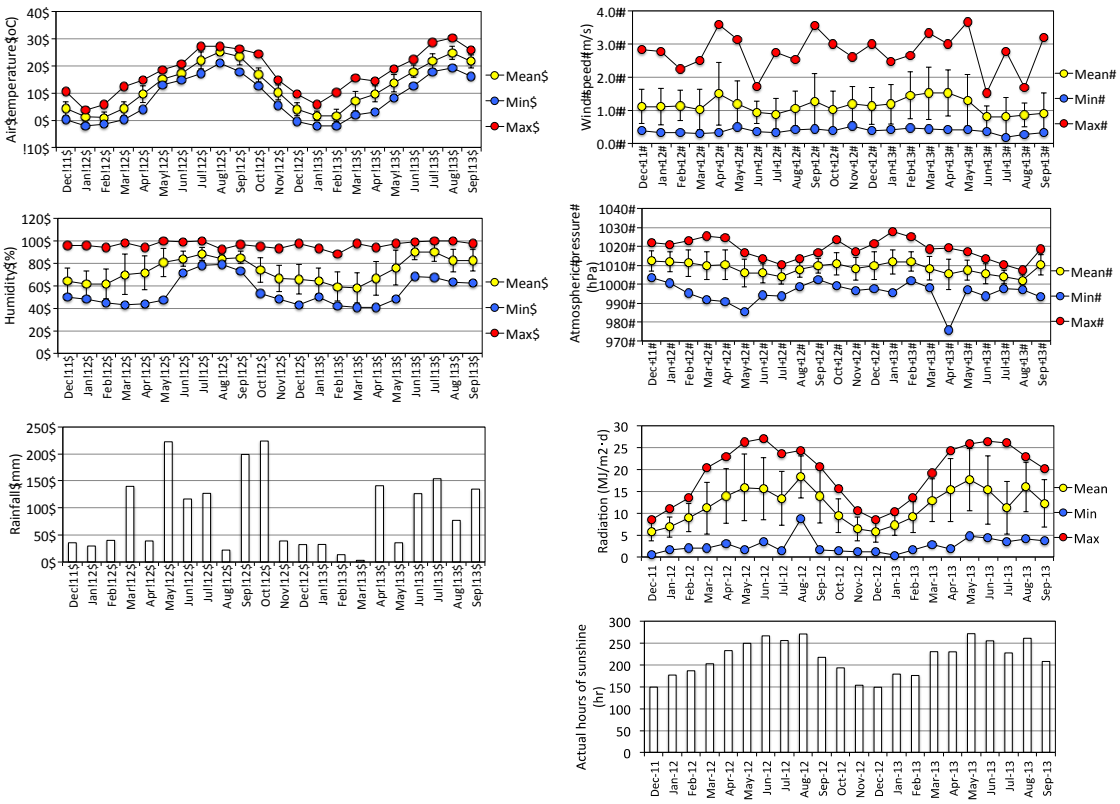


**Fig. 3 Meteorological data obtained during the 22 months**

**Estimation Accuracy of Atmospheric Pressure, Vapor Pressure and Solar Radiation**

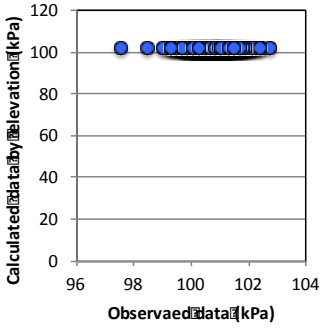


**Fig. 4 Relationship between the observed and the calculated daily data for P**

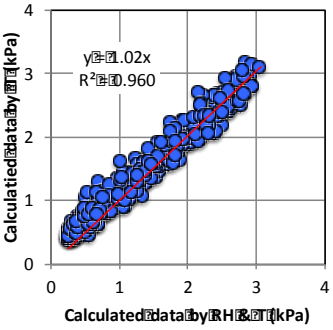


**Fig. 5 Relationship between the calculated data by RH & T and the calculated data by T**

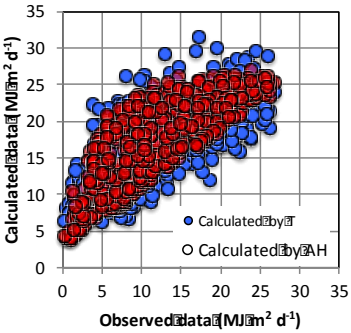


**Fig. 6 Relationship between the observed and the calculated daily data for $R_s$**

### The Influence of Combinations of Meteorological Data Items on the Estimation of the PET

Figure 7 shows the daily average of the PET determined from the data obtained during the 22 months. The error bar indicates the standard deviation. The graph shows the 13 patterns of combinations of meteorological data items. J shows the PET (2.07mm/d) that was determined by the estimation calculation using T, WS, RH, $R_s$, and P, which is recommended in the PM method. The discussion will be done using the J value as the standard. For the combinations of meteorological data items A to I, in which $R_s$ was not used, the PET values (2.51 - 2.27) are overestimated and are higher than those of J (1.21 - 1.10). For the combinations of meteorological data items K to M, in which the $R_s$ was used but one or more data were not used, the PET was between 1.98 and 2.07, which are small values equal to or 0.96 times that of J. From the above, it was clarified that the PET can be accurately estimated by using the PM method when $R_s$ data are available, even when the RH or P data are unavailable. It was also clarified that when the PM method is used in the Asian monsoon region, $R_s$ is an important variable in addition to WS and T.

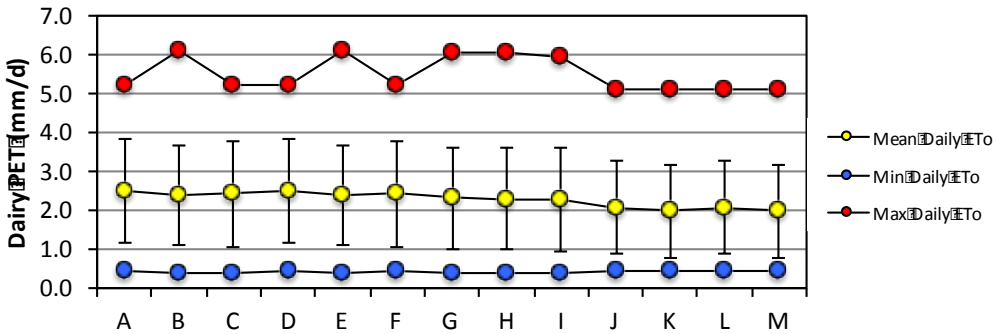


**Fig. 7 Daily average of the PET determined from the data obtained during the 22 months**

## CONCLUSION

In this study, examination was done on the use of the PM method for estimating the PET of the relatively warm regions with small precipitation. As the results, the potential evapotranspiration can be accurately estimated by using the Penman-Monteith method when solar radiation data are available, even when the relative humidity or atmospheric pressure data are unavailable. It was also clarified that when the Penman-Monteith method is used in the Asian monsoon region, solar radiation is an important variable in addition to wind speed and air temperature.

However, the climatic divisions are varied even in the Asian monsoon region. It is necessary to conduct an examination that is similar to the one done in this study in areas with heavy rain and in cold areas. It is also necessary to conduct an examination in which the year is divided into quarters so that the accuracy of PET estimation in seasons with small or great solar radiation can be examined.

## ACKNOWLEDGEMENTS

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Research article

# Determining C Factor of Universal Soil Loss Equation (USLE) Based on Remote Sensing

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**Abstract** Soil erosion is a serious environmental problem which causes degradation of soil and water environment. Thus, soil conservation is necessary for the areas where accelerated erosion occurs. At early stages of soil conservation, certain strategies should be implemented based on predicted soil erosion rate of the area. Soil erosion rate has been calculated using erosion models, such as Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE), Water Erosion Prediction Project (WEPP), etc. However, the most common model is either Universal Soil Loss Equation (USLE) or Revised Universal Soil Loss Equation (RUSLE), as they are easy in handling by users. Attention has been paid to Cropping Management, factor C of USLE or RUSLE, since it is challenging to determine. The factor depends on the type of crop and the growing stage, however growing conditions would change locally and harvesting time are unpredictable. Also, vegetation could be changed unpredictably due to weather or farming conditions. Approaches based on remote sensing technology which has less temporal and spatial restrictions on detection of vegetation were applied to determine C factor using vegetation indices. However, it is not always successful in field application. Therefore, the objective of the study is to improve determination of C factor using vegetation indices. For clarification, experiments for identifying the relationship between C factor and vegetation indices such as Normalized Difference Vegetation Index (NDVI) and Soil-Adjusted Vegetation Index (SAVI) were carried out under several types of soil. Furthermore, the accuracy of determination of C factor using vegetation indices was discussed through an erosion model experiment. The results showed SAVI is more strongly correlated with C factor than NDVI. Estimation of C factor based on NDVI and SAVI have 30% and 36% of relative error in field application. Therefore, it was concluded that vegetation indices have high potential to determine C factor of USLE or RUSLE. Also, estimation of field C factor based on SAVI is more recommendable for determination of C factor in the field where there are several types of soil.

**Keywords** soil erosion, soil conservation, USLE, C factor, remote sensing, NDVI, SAVI

## INTRODUCTION

It is well known that accelerated erosion results in serious form of soil degradation, and pollutes the water environment with component of nitrogen and phosphorous. Thus, soil conservation is necessary for protecting soil and water areas, where accelerated soil erosion happens. At the early stage of soil

conservation planning, soil erosion predicting model is employed for evaluating condition of local soil erosion rate, before and after soil conservation strategies are applied. Many models have been developed for predicting water-induced soil erosion rate. Especially, Universal Soil Loss Equation (USLE) and Revised Universal Soil Loss Equation (RUSLE) have been used to calculate annual soil erosion rate (Wischmeier and Smith, 1978; Renard, 1997). USLE is empirical model, originally developed to predict soil erosion rate, mainly in agricultural land. RUSLE is an advanced version with less limitation on application area. However, more details about field are required. Both USLE and RUSLE have the same mathematic structure which can be written as follows:

$$A = RKLSCP \quad (1)$$

Where A is soil erosion rate (ton/ha yr.), R is rainfall and runoff erosivity factor (MJ mm/ha h yr.), K is soil erodibility factor (t ha h/ha MJ mm), LS is topographic factor comprised of slope length and slope gradient-slope steepness, C is Cropping Management factor, P is soil conservation practice factor. (Revised) Universal Soil Loss Equation is most common model for soil conservation planning. Determining LS factor and C factor is always challenging when applying (Revised) Universal Soil Loss Equation in field. Complicated topographic feature causes difficulties in initial field data collection for computing LS factor. Several proposed ideas indicate remote sensing has high potential in estimating LS factor, in terms of high speed of execution and computing in topographic complex (Desmet, et al., 1996; Winchell, et al., 2008). Efforts linking LS factor and remote sensing have been successfully carried out by processing topographic function in Geographic Information system (GIS) with raster database of Digital Elevation Model (DEM). However, determining C factor still remains a challenge. C factor is defined as relative impact of vegetation reducing on soil erosion rate. Determining C factor requires one to know about vegetation which is difficult to identify manually. Remote sensing technology which has less temporal and spatial restrictions on detection of vegetation were widely applied to determine field C factor using vegetation indices such as Normalize Difference Vegetation Index (NDVI) (Van der Knijfff et al., 2000; Lin et al., 2002). However, it is not always successful in field application (Alejandro, et al., 2007).

## OBJECTIVE

Accordingly, the objective of the study is to improve determination of C factor using vegetation indices.

## METHODOLOGY

### Estimation of C Factor Based on Vegetation Indices

Required materials such as experimental plots, soil samples, canopies, portable spectroradiometer (MS-720E), and white panel were prepared. Soil physical properties were analyzed and classified based on IUSS method (Table 1). For each plot, same amount of soil samples was used and were randomly planted canopies with coverage approximately ranging from 0% to 70%. In total, there were three different kinds of treatments; (a) *Andosol* (1) + *Ophiopogon japonicus* (b) *Ultisol* + *Ophiopogon japonicus* (c) *Andosol* (2) + *Lolium perenne*. At the beginning, white panel was used for calibrating effect of shadow and spectra reflectance of red light and near-infrared red were measured in each plot by spectroradiometer outdoor (Fig.1). After reflectance spectra data of each plot was acquired, vegetation index was calculated as in Eq. (2) proposed by Deer (1978).

$$NDVI = (NIR - Red) / (NIR + Red) \quad (2)$$

Where NDVI is Normalized Difference Vegetation Index calculated with function of reflectance differences between red and near infrared red (NIR), Red is reflectance of red light (630 nm - 690 nm) and NIR is reflectance of near-infrared red (775 nm - 900 nm). Secondly, experiment of soil erosion was conducted under artificial rainfall simulator for evaluating C factor (Fig. 2). Plots were placed on slope of 8 degree under rainfall simulator. At each trial of rainfall simulation, rainfall intensity was varied from 36 to 120 mm/hr. for 30 minutes. Soil loss was collected after rainfall-simulation and measured by oven-drying for 24 hours. The weight of soil loss was used for computing C factor based on the ratio of soil loss between the plots with bare soil and vegetation cover. Finally, the graph of the relationship between C factor and vegetation index was drawn. Besides, equation of C factor based on vegetation index was established by statistical regression analysis.

**Table 1 Soil physical properties**

| Soil | Specific gravity | Pacticle size distribution (%) | | | | | Ignition loss (%) | Soil texture |
|---|---|---|---|---|---|---|---|---|
| | | Gravel | Coarse sand | Fine sand | Silt | Clay | | |
| a. Andosol (1) | 2.64 | 1.2 | 17.9 | 16.7 | 31.8 | 32.4 | 15 | Sandy Clay Loam |
| b. Ultisol | 2.73 | 0.1 | 0.9 | 15.5 | 49.6 | 34.0 | 8 | Clay Loam |
| c. Andosol (2) | 1.53 | 2.4 | 4.2 | 9.9 | 27.0 | 56.5 | 64 | Clay |

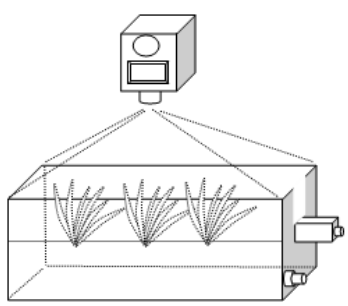

**Fig. 1 Experiment for evaluating vegetation index**

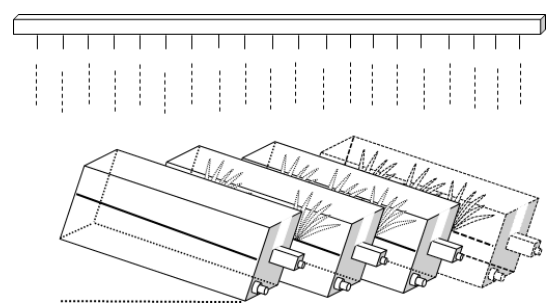

**Fig. 2 Slope model experiment for evaluating C factor**

**Field Measured C Factor**

In this procedure, field C factor was measured in study area. Study area is located in Linkou distinct, north part of Taiwan. It lies in 25°3′ to 25°9′ N latitude 121°17′ to 121°25′ E longitude (Fig. 3). Total area of study is 54.15 $km^2$. Forest and agriculture are main dominant land use pattern in Linkou distinct. Annual average rainfall is about 2500 mm. Degree of soil erosion is influenced by changes of vegetation and land use pattern. Main species of canopy in the field is *Eremochloa ophiuroides* (*Munro*).

To determine field C factor , parameters such as amount of annual soil erosion (A), rainfall and runoff erosivity factor (R), soil erodibility factor (K), topographic factor (LS), Soil conservation practice factor (P) were measured in the field. In addition, field measured C factor are computed based on Eq. (3).

$$C = A/RKLSP \quad (3)$$

As the arrangement for measuring annual soil erosion (A) was illustrated in Fig.4, two poles were inserted into ground surface tightly and deeply in the field. Initial difference of height for both sides of

the pole was 17.5 cm. Both side of the pole was connected with a baseline of 14.9 m long and was given a mark at every 10 cm interval. After equipment was installed in the field, the height from baseline to the ground was measured and recorded at interval of 10 cm. Experiment was conducted from 13 September, 2014 to 5 September, 2015. Changes of soil surface and dried density of soil was measured to calculate total amount of soil erosion (A) in the field. Data of hourly rainfall from 2004 to 2013 was collected from local weather station for calculating rainfall and runoff erosivity factor (R). Soil erodibility factor (K) and topographic factor (LS) was computed based on field measurements and experimental analysis. Soil conservation practice factor (P) was assumed as 1.

**Fig. 3 Study area**

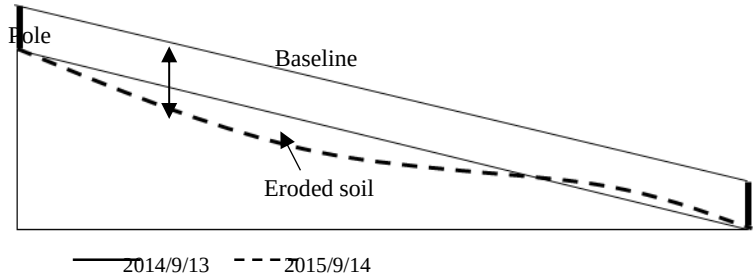


**Fig. 4 Observation of soil erosion in the field**

## Validation of Determination of C Factor Using Vegetation Indices

By comparing with field measured C factor, estimated C factor based on vegetation indices could be validated. Estimated C factor was derived by substituting monthly field vegetation index into C factor equation based on NDVI. Moreover, monthly vegetation index was calculated as in equation (2) with data of satellite-image of Landsat 7 from 2014 to 2015. The satellite-image was first downloaded from website of NASA and calibration of atmospheric effect was done by following instruction of Landsat 7 Handbook.

## RESULTS AND DISCUSSION

## Estimation of C Factor Based on Vegetation Indices

The estimation of C factor of USLE or RUSLE becomes challenging as land use pattern and vegetation change (Alejandro, et al., 2007). It was thought that determining C factor using vegetation indices is promising technology for responding to fast land use and vegetation changes. Lin (2002) stated that there is linear correlation between C factor and NDVI. Moreover, Van der Knijfff (2000) presented exponential C factor equation based on NDVI, which is applicable for environmental condition in Europe. As results of experiments shown in figure 5, it shows linear correlation ($R^2 = 0.69$) between C factor and NDVI. The result is similar to approach of Lin (2002). Nevertheless, it was observed that NDVI is highly variable as C factor equals to 1. It would decrease accuracy of estimation of C factor. Therefore, Soil-Adjusted Vegetation Index (SAVI) presented by Huete (1988) was applied to improve estimation of C factor. Equation of Soil-Adjusted Vegetation Index (SAVI) can be expressed as follows.

$$SAVI= (NIR-Red)\ (1+L)/\ (NIR+ Red+ L) \quad (4)$$

Where L is an adjustment length and it was assumed as 0.5. In Fig. 6, the relationship between SAVI and C factor was shown. The results indicated SAVI is more strongly correlated with C factor than NDVI. Correlation $R^2$ increases from 0.69 to 0.73. Huete (1988) indicated estimation of vegetation based on SAVI is less affected by soil background. It means estimation of C factor based on SAVI is more accurate than NDVI in the field where there are several types of soil. Besides, it was observed that there is less variation in SAVI than NDVI under bare soil (Table 2). Moreover, it was observed that equation established by statistical regression analysis (Figs. 5 and 6) has similar mathematic structure which could be defined as follows:

$$C= -a\ VI + 1;\ VI <0,\ C=0 \quad (5)$$

Where C is cropping management factor, VI is vegetation indices which represents vegetation signal response of canopy, and *a* is defined as efficiency of vegetation in reducing soil erosion rate. The *a* is equal to 0.82 when VI is NDVI, and *a* is equal to 1.18 when VI is SAVI. It was considered that the value of *a* may decrease as height of vegetation increases because higher vegetation has lower efficiency in reducing soil erosion rate (Wischmeier and Smith, 1978; Renard, 1997). In the case of study, heights of vegetation were about 5 cm to 15 cm.

**Table 2 Comparison of NDVI and SAVI under bare soil**

| | NDVI | | | SAVI | | |
|---|---|---|---|---|---|---|
| Bare | Max. | Min. | Sd. | Max. | Min. | Sd. |
| soil | 0.30 | 0.06 | 0.07 | 0.16 | 0.03 | 0.03 |

*Sd. is standard deviation*

## Field Measured C Factor

About 72 ton/ha/yr. of soil loss (A) was observed in the field (Fig. 8). Moreover, field measured C is equal to 0.56 which is calculated by following parameters summarized in Table 3.

## Validation of Determination of C Factor Using Vegetation Indices

The results of monthly NDVI and SAVI (Fig. 7) are shown. Moreover, estimated C factor based on different approaches were summurized in table 4. It was observed that estimated C factor based on both

NDVI and SAVI are higher than field C factor. Moreover, although SAVI is more strongly correlated with C factor than NDVI (Figs. 5 and 6), estimation of C factor based on NDVI is most accurate with 30 % of relative error. It was considered that estimation of C factor based on SAVI becomes accurate as different types of soil is existed in the field. However, only single type of soil (Ultisol) was found in the field. Furthermore, it was observed that both estimated C factor based on NDVI and SAVI are more accurate than appoach of Lin (2002).

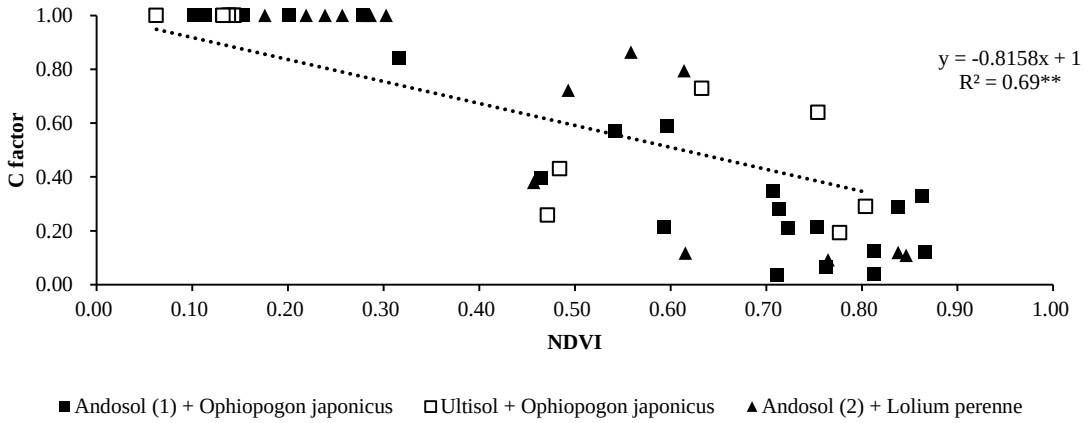


**Fig. 5 Relationship between C factor and NDVI**

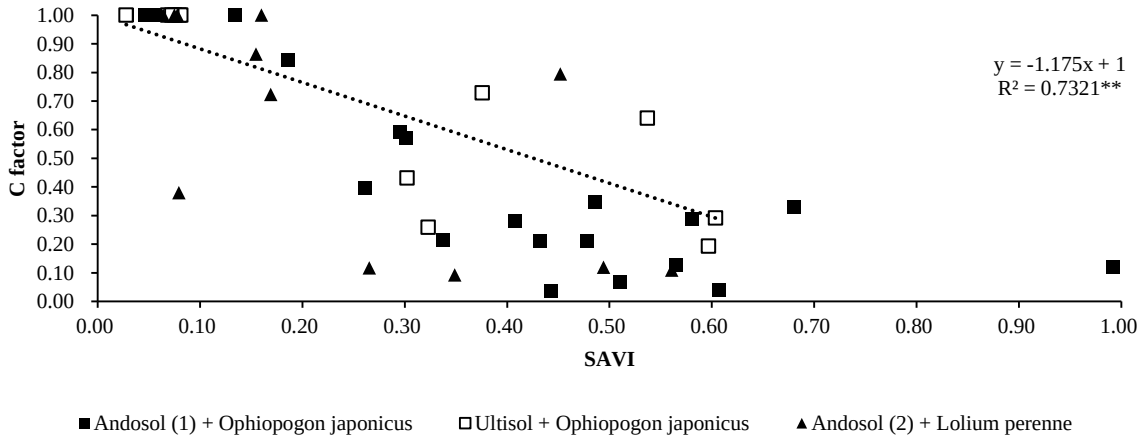


**Fig. 6 Relationship between C factor and SAVI**

**Table 3 Parameters for calculating C factor in the field**

| A | R | K | L | S | P | Field measured C factor |
|---|---|---|---|---|---|---|
| 72 | 8135 | 0.02 | 0.82 | 0.96 | 1 | 0.56 |

**Table 4 Comparison of field C factor with different C factor approaches**

| C factor (Field) | C factor (NDVI) | Relative error % | C factor (SAVI) | Relative error % | C factor (Lin, 2001) | Relative error % |
|---|---|---|---|---|---|---|
| 0.56 | 0.73 | 30% | 0.76 | 36% | 0.33 | 45% |

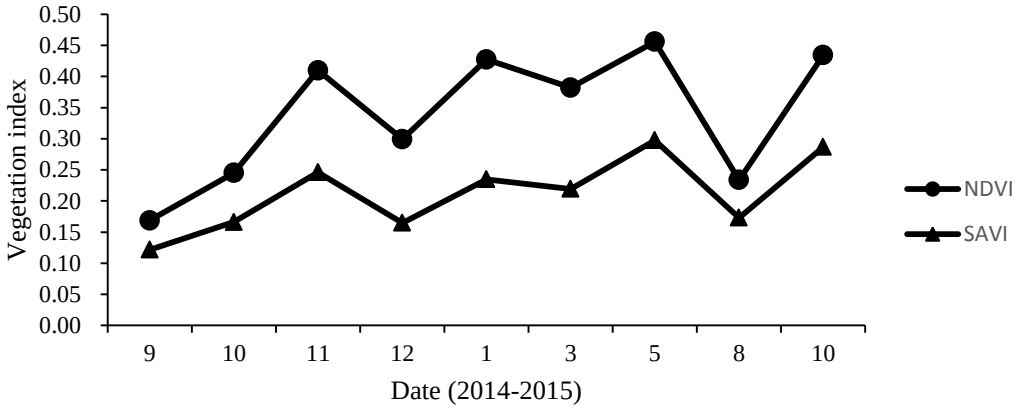


**Fig. 7 Variation of vegetation indices from 2014 to 2015**

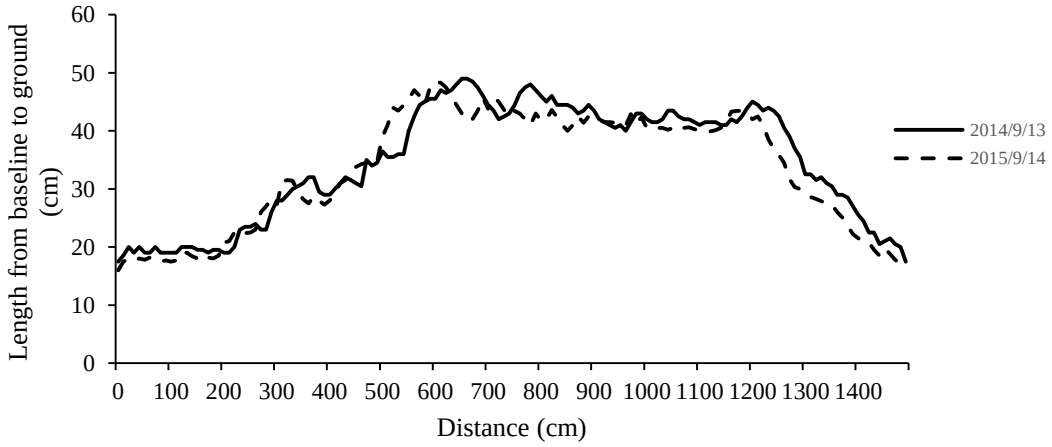


**Fig. 8 Changes in heights from baseline for evaluating annual soil loss in the field**

## CONCLUSION

Therefore, it was concluded that (1) vegetation indices have high potential to determine C factor of USLE or RUSLE, (2) estimation of field C factor based on SAVI is more recommendable for determination of C factor in the field where there are several types of soil. For the future research plan, the experiment for evaluating the relationship between C factor and vegetation indices will be conducted in other different kinds of vegetation and soil. Also, more field erosion model experiments will be conducted for validating determination of C factor using vegetation indices.

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Research article

# Factors Affecting Householders' Acceptance to Adopt Reduce, Reuse and Recycle - 3Rs Program in Domestic Waste Management in Mekong Delta, Vietnam

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**Abstract** Reduce, reuse and recycle (3Rs) is one of the elements contributing to the success of launching the integrated solid waste management recommended by the United Nations Environment Program. A survey of 360 urban and suburban household respondents was conducted in the Mekong Delta, Vietnam to understand how domestic solid waste managed at household level, to experience respondents' knowledge, awareness and their acceptance participating 3Rs program if it is introduced in the Mekong Delta. Results show that 78% respondents sold recyclable waste and listed activities meaning reducing, reusing and recycling solid domestic waste. More than 70% respondents supported this program when it is launched. The results of the logit model reveal the significant difference in factors affecting urban and suburban respondents' acceptance this program. Age, gender and educational attainment of respondents, household income, respondents' knowledge on reduce, reuse and recycle their solid domestic waste and community participation are factors affecting household acceptance involving in 3Rs. They also propose how to organize successful 3Rs program, namely the collaboration between household and local community in organizing this program, upgrading households' awareness on environmental protection and the support in propaganda of local authorities and social media.

**Keywords** domestic solid waste, 3Rs, reduce, reuse, recycle, Mekong Delta

## INTRODUCTION

Domestic solid waste has increased rapidly in Vietnam and other Southeast Asian countries (Rathi, 2006; Visvanathan and Tränkler, 2003; Bai and Sutanto, 2002). However, it has not been managed properly, especially in Vietnam (Trang, 2012; Hoang and Viet, 2011 and Thanh et al., 2010). In the Mekong Delta, Vietnam, solid waste increases about 10 - 16% annually and about 5,3 million tons of domestic solid waste is generated per day in the Mekong Delta (about 0.3 kg per capita per day) (Hoang and Viet, 2011 cited from MONRE, 2010). However, only 65 -72% of them is collected that most of them are dumped at the landfill.

Reduce, reuse and recycle – 3Rs is one of the suggested solutions for the integrated solid waste management recommended by the United Nations Environment Program (Bernstad, 2014; Tai et al., 2011; Uyen and Hans, 2009). The purpose of 3Rs is to minimize waste generation or disposal and it is a waste hierarchy, the first step, in managing domestic solid waste at source. However, 3Rs has not been widely propagandized and practiced in the Mekong Delta, Vietnam. Thus, this case study was conducted in the Mekong Delta, Vietnam to understand how domestic solid waste is managed at a

household level to experience respondents' knowledge, awareness and their acceptance participating 3Rs program if it is introduced in the Mekong Delta, Vietnam.

## METHODOLOGY

### Study Sites and Methods of Data Collection

A survey of 360 respondents was conducted in six urban and suburban wards/town in four provinces and cities in the Mekong Delta, Vietnam (Fig 1). Domestic solid waste in those urban sites have been collected for many years while solid waste collection service has just been provided in three suburban areas recent 2-3 years. The respondents are the persons in the households that fully understand how their domestic waste generation and management. Purposive sampling technique was applied with the guide of the head of each ward/town to avoid bias.

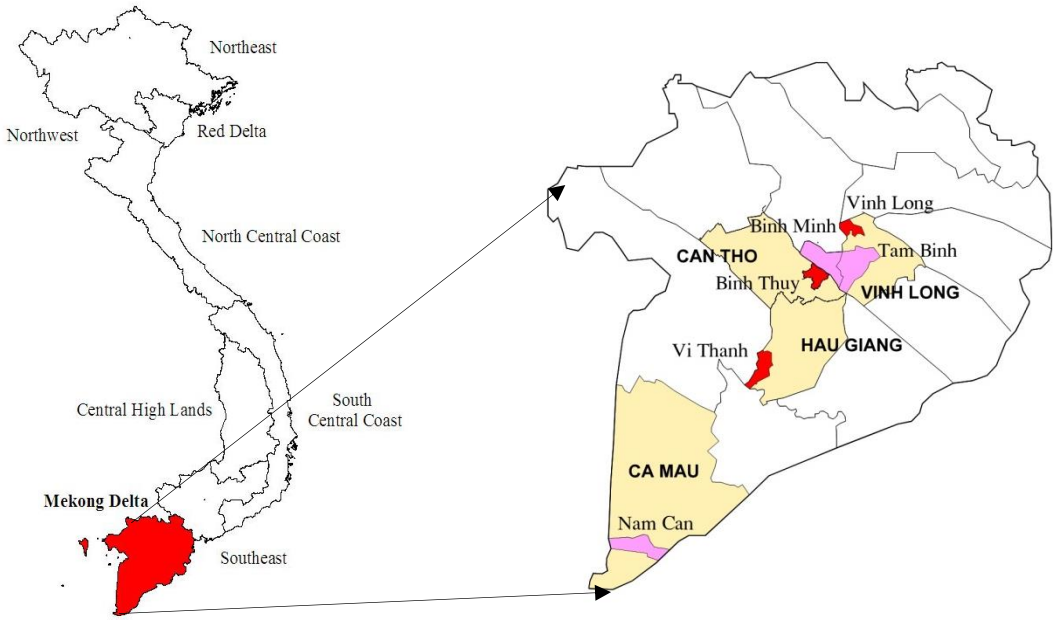


**Fig. 1 Map of study sites in Mekong Delta, Vietnam**

*Note: Red is urban sites and pink is suburban sites*

### Data Analysis

The surveyed data were analyzed descriptively using frequency, descriptive and cross tabulation, T-test and chi-square to describe the socio-demographic characteristics of respondents and households, households' solid waste generation and management, respondents' awareness and acceptance 3Rs in the urban and suburban areas in the Mekong Delta, Vietnam.

### Model to Identify Factors Affecting Respondents' Acceptance 3Rs Program

An assumption was created that 3Rs program will be launched to those six urban and suburban sites in the Mekong Delta. Full introduction about the meaning and examples how householders practice 3Rs at home were carefully explained to respondents. Then, they were asked whether would they accept to

adopt this program when would be launched. The follow-up questions were the reasons why they accepted or not to adopt this program and how to organize successfully this program.

The binary logistic regression model was applied to find out the factors affecting respondents' acceptance to practice 3Rs program. The model is as follows.

$$Yi = \ln \frac{(Pi)}{(1-Pi)} = \beta i Xi + \alpha$$

Where $Y_i$ is respondents' acceptance to apply 3Rs program when it is introduced to their sites. $Y_i$ = 1: accepted and $Y_i$ = 0: not accepted). i =1 is represented for 360 respondents i= 2 and 3 are urban and suburban sites respectively (180 respondents). βi are the coefficient of the explanatory variables (Xi). The explanatory variables are defined in Table 1. The explanatory variables were based on households' socio-demographic characteristics, respondents' knowledge and awareness how to practice 3Rs at household solid waste management are major factors influencing 3Rs practices (Bernstad, 2014; Miafodzyeva and Brandt, 2014; Singhirunnusorn et al., 2012; Banga, 2011; Farley, 2011; MoEF, 2010; Uyen and Hans, 2009; Shafeeqa et al., 2009; Gamba and Oskamp, 1994).

**Table 1 Description of variable in the logit model**

| Var. | Description | Expected signs | Characteristics |
|---|---|---|---|
| $X_1$ | Area of survey, $X_1$ = 1: urban area, otherwise, $X_1$ = 0: rural area | +/- | 50% urban area |
| $X_2$ | Age of respondents (years) | + | 45.2±11.9 years |
| $X_3$ | Gender of respondents, $X_2$ = 1: male, otherwise $X_2$ = 0: female | +/- | 40% male respondents |
| $X_4$ | Educational attainment of respondents, $X_4$ = 1: attended high school (grade 10) or higher, otherwise $X_4$ = 0 | +/- | 64% respondents' educational attainment equal or higher high school (grade 10) |
| $X_5$ | Gross household income (VND/month) | +/- | 10±8 million VND/month ~ 450±374 USD/month |
| $X_6$ | Aware using friendly products means reducing waste, $X_7$=1: yes, otherwise $X_7$=0 | + | 44% respondent's awareness of reduce |
| $X_7$ | Reuse carton boxes means reuse waste, $X_8$=1: yes, otherwise $X_8$=0 | + | 58% respondent's awareness of reuse |
| $X_8$ | Household selling recycle waste, $X_6$ = 1: yes, otherwise $X_6$ = 0 | | 78 % household selling recycle waste |
| $X_9$ | The participation of the local community and government contribute to the success of 3Rs program, $X_{10}$ = 1 yes, otherwise $X_{10}$ = 0 | + | 49% respondents reveal that collaboration between local community and government will contribute to the success of 3Rs program |

## RESULTS AND DISCUSSION

### Respondents and Households' Characteristics in the Mekong Delta, Vietnam

Among 360 respondents, 50% of them is from urban areas and 40% of them is male (Table 1). The average age is 45.2 ± 11.9 years and 64% reach high school or higher. There are 4.2 ± 1.4 members in a household with 2-3 members are in the working age. The average gross household income is about 10 million VND per month (~ 450 USD/month).

### Management of Households' Domestic Waste in the Mekong Delta, Vietnam

The waste quantity is generated about 1.9 ± 1.0 kg per household per day and more waste is disposed in the urban than in the suburban areas (Table 2). The persons who dispose their household waste to the common trash bin or waste truck are more female (61%) than male (16%) and 23% both male and female in the household takes turn to dispose their waste. Plastic bags and trash bins are the most used for waste containers. Each household has 1-3 trash bins and place them in the kitchen or back-yard. About 78.3% household sell recycle waste. The most recycle waste is used bottles or jars, carton boxes, cans and books or newspapers. They earn about 79,000 ± 83,000 VND per quarter (~3.6 ±3.7 USD).

**Table 2 Current situation and management of domestic waste of household in Mekong Delta**

| Characteristics | Urban | Suburban | Total | |
|---|---|---|---|---|
| Waste generation (kg/day/household) | n=180 | n=180 | n=360 | |
| | 2.0± 1.1 | 1.7± 0.9 | 1.9±1.0 | *** |
| % of HH selling recycle waste | 79.4 | 77.2 | 78.3 | |
| Recycle trash (%) | n=139 | n=143 | n=282 | |
| Used bottles or jars | 73.4 | 90.2 | 81.9 | *** |
| Used carton boxes | 59.7 | 56.6 | 58.2 | * |
| Beer cans | 58.3 | 45.5 | 51.8 | ** |
| Used books or newspapers | 45.3 | 29.4 | 37.2 | *** |
| Others | 39.6 | 18.9 | 29.1 | *** |
| Return from selling recycle trash (thousand VND/quarter) | 89± 90 | 105± 90 | 79±83 | *** |

*Note: ***, ** and * mean significant different at 1%, 5% and 10%, respectively*

## Respondents' Awareness on Reuse, Reduce and Recycle (3Rs) in Domestic Waste Management in the Mekong Delta, Vietnam

Most of respondents listed activities meaning to reduce, reuse and recycle waste (Table 3). Even their understanding is simple, it would contribute to the success of introducing this 3Rs program to the public. The presence of plastic bags and containers are the main causes of increasing waste generation.

**Table 3 Respondents' awareness on 3Rs in domestic waste management in the Mekong Delta, Vietnam**

| Respondents' awareness on 3Rs | Urban (n=180) | Suburban (n=180) | Total (n=360) |
|---|---|---|---|
| How to reduce waste generation (%) | | | |
| Only buy necessary goods | 71.7 | 96.1 | 83.9 |
| Buy endurable products | 75.0 | 89.4 | 82.2 |
| Buying in bulk rather than individuals | 57.2 | 60.0 | 58.6 |
| Use environmental friendly products | 43.3 | 45.6 | 44.4 |
| Bring reusable bags when shopping | 42.2 | 44.4 | 43.3 |
| Use reusable food containers | 36.1 | 25.6 | 30.8 |
| Use glasses or bottles for buying drinks | 27.8 | 27.8 | 27.8 |
| How to reuse waste (%) | | | |
| Reuse used plastic bags | 71.7 | 86.1 | 78.9 |
| Reuse used bottles | 62.2 | 77.2 | 69.7 |
| Reuse used rubber and plastic bands | 66.7 | 61.1 | 63.9 |
| Donate used clothes, shoes or notebooks | 71.1 | 49.4 | 60.3 |
| Rese carton box to keep things | 53.3 | 61.7 | 57.5 |
| Others | 31.7 | 5.0 | 18.3 |
| How to recycle waste (%) | | | |
| Recycle is selling recycle trash | 56.7 | 75.6 | 66.1 |
| Recycle is to recreate useful things from trash | 51.7 | 64.4 | 58.1 |
| Residents cannot do recycling by themselves | 34.4 | 40.6 | 37.5 |

*Note: Percentage of the same (one, two and three) letter is not significantly different at 1%, 5% and 10%, respectively.*

People do not bring containers or reusable bag when go shopping or buy food and drink. The convenience of small containers also causes more waste. Providing plastic bags to buyers is perceived politeness and care by sellers as results from our study.

The results indicate that respondents often reuse plastic bags, bottles, rubber bands, clothes, notebooks, shoes and carton boxes (Table 3). More people in suburban reuse those things than in the urban areas. The reuse practice is not only mean saving, but it is also a habit of care users. The convenience and household wealth restrict people to reuse things. That is important point that needs to upgrade residents' behavior in reuse things to reduce waste generation and environmental protection.

The same with the first two Rs – reduce and reuse, recycle is more popular for poor people. Respondents often sell recycle waste and recreate useful things from trash (Table 3). More residents in the suburban sell recycle waste than in the urban areas. Price of recycle waste and household wealth also restrict recycle behavior. Due to the goods cost is low and mostly is not included cost of the waste disposal, their price is lower and thus it leads people lazy to sell recycle waste. Residents recycle waste due to the economic benefit rather than to reduce waste generation or environmental protection.

**Factors Affecting Respondents' Acceptance to adopt 3Rs program in the Mekong Delta, Vietnam**

After receiving information about the proposed 3Rs program, 72% of the respondents accept to practice this program. More suburban residents (79%) prefer this program than urban residents (66%). The result of the logit models is presented in Table 4.

**Table 4 Factors affecting respondents' acceptance to adopt the 3Rs program in the Mekong Delta, Vietnam**

| | Variables | Total | Urban | Suburban |
|---|---|---|---|---|
| $X_1$ | Regions | -0.1179*** | | |
| $X_2$ | Ages of respondents | -0.031** | -0.024 | -0.056** |
| $X_3$ | Genders of respondents | -0.349 | -1.114 | -1.165** |
| $X_4$ | Educational attainment of respondents | 0.727** | 1.226*** | -0.066 |
| $X_5$ | Gross household income per month | 0.000* | 0.000 | 0.000 |
| $X_6$ | Aware on reduce waste generation | 0.262 | 0.428 | -0.146 |
| $X_7$ | Aware on reuse waste generation | 0.396 | 0.675*** | 0.675*** |
| $X_8$ | Practice selling recycle waste | 0.547 | 0.587 | 0.587 |
| $X_9$ | Community | 0.020*** | 0.011 | 0.011 |
| | Constant | 0.406 | -0.596 | -0.596 |
| | No. of observation | 360 | 180 | 180 |
| | Percentage of acceptance (%) | 72 | 66 | 79 |
| | Log likelihood | -303.033 | -195.057 | -94.714 |
| | $R^2$ | 0.279 | 0.251 | 0.247 |

*Note: Number in the table is the coefficient of the logit model*
****, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively*

There are differences in the results in three logit models. More suburban respondents accepting this program if it is introduced. The significant factors of these models confirm the characteristics of respondents and households (age, gender, educational attainment of respondents and household income) affecting the acceptance of this program (Banga, 2014; Miafodzyeva and Brandt, 2013). Besides, the awareness of reduce and reuse waste generation also affect their acceptance (Banga, 2014; Miafodzyeva and Brandt, 2013; Farley, 2011; Uyen and Hans, 2009; Shafeeqa et al, 2009). Lastly, the collaboration between the local residents and the government is the factor affecting for the success of the 3Rs program (Challcharoenwattana and Pharino, 2015; Miafodzyeva and Brandt, 2013; MoEF, 2010).

Besides, respondents recommend that the collaboration between the local residents and government, residents 'awareness on environmental protection and preserve the environment for the future as well as the propaganda for the program are factors contributing to the success when 3Rs program is launched. The most effective modes of communication for this 3Rs program are television, local propaganda, radio/radio station. Besides, local information exchange, newspapers, internet and providing 3Rs information through the basic schools.

## CONCLUSION

3Rs program should be introduced and propagandized widely in the Mekong Delta as well as the whole Vietnam. It will be the start hierarchy to improve domestic solid waste management in the Mekong Delta through minimizing waste generation and make use of waste before disposal and dumping. The 3Rs program should incorporate the linkage of individual – community performance and social media to upgrading households' awareness on environmental protection and successfully launch this program in the Mekong Delta and Vietnam.

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Research article

# Earthworm Communities and Activities in Rice Ecosystem under Different Soil Salinity Levels in Northeast Thailand

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**Abstract** Soil salinity is one of the most serious agricultural problems. This problem generates low soil productivity and soil ecosystem. Earthworms are one of the most important soil organisms in soil ecosystem (maintaining soil structure and the fertility of soil). Soil salinity has become one of the major determinants of crop productivity in Northeast Thailand. The aim of present study was size and composition of earthworm communities on related soil properties and rice growth under different soil salinity; 2 levels 1) low soil salinity (EC 2-4 dS/m) and 2) moderate soil salinity (EC 4-8 dS/m). Soil and earthworm cast were collected to analyze for soil chemical properties. The results showed that there was significant difference between density and size of different species of earthworms in different level of soil salinity. In rice ecosystem in moderate salt-affected area the earthworm species *Drawida beddardi* was the only one found at 95 days after rice sowing, while in low salt affected area the earthworm species, *Glyphidrilus chiensis* and *Drawida beddardi* were the most common species found at 45 days after rice sowing. Earthworms improve soil properties and rice growth rate. *Oryza sativa L*. (Khao Dawk Mali 105 and RD6) growth decreased with increasing levels of soil salinity.

**Keywords** earthworm, rice ecosystem, salt-affected area

## INTRODUCTION

Increasing soil salinity is a serious land degradation issue worldwide. Thailand salinization is amongst the major degradation processes endangering the potential use of Northeast Thailand soils. Despite of the naturally occurring salinization, deicers for removal from salt-bearing rocks (Land Development Department, 1991) in the Nakhon Ratchasima, Khon Kaen, Roi-Et and Mahasarakham provinces (Department of Mineral Resources, 1982). Salts have negative effects on ecosystem and environments have appeared increasingly. Sodium chloride (NaCl) from salt-bearing rocks is responsible for the increased salinity of soil surface and ground waters. Chloride accumulation can compromise soil structure and increase soil erosion, reduce soil fertility, and have an effect on soil chemistry. Salts negatively affect environmental ecosystems crop yield (Grewal, 2010; Li et al. 2010; Zhang et al. 2010), soil microorganisms (Yuan et al., 2007; Ibekwe et al., 2010), plants (Gadallah and Ramadan, 1997; Joutti et al., 2003; Ruhland and Krna, 2010), and soil organisms (Owojori et al., 2008). There has been a growing concern of the environmental effects resulting from deicing.

Earthworms are soil engineers, they have potential to improve soil properties, physical, chemical, and biological (Jouquet et al., 2009). Earthworm cast is usually chemical and physically protected and stabilizes aggregate and SOM in soil and (Bossuyt et al., 2005; Jouquet et al., 2008a; Chutima et al., 2010). There is also the positive influence of earthworms on soil structure (Mackay and Kladivko, 1985; Ketterings et al., 1997) and plant growth and yield (Scheu, 2003; Eisenhauer et al., 2009). Although, most of the published works which reported earthworm aerobic ecosystems, very few studies were carried out in partially or totally flooded environments, such as paddy fields. Flooding events are considered as adverse periods limiting the activity of macrofauna such as earthworms (Schütz et al., 2008; Chutima et al., 2010).

## OBJECTIVE

The aim of this paper was to monitor the diversity and size of earthworm species in rice ecosystem and influences of earthworm on soil properties and rice growing in salt-affected area.

## METHODOLOGY

### Study Site

Studied in paddy field salinity area Phai district, Khon Kaen province during rainy season 2014, were selected area from map of the distribution of saline soil Land Development Department 5 Khon Kaen, two levels salinity, 1) low soil salinity (EC 2-4 dS/m) and 2) moderate soil salinity (EC 2-4 dS/m). These are areas sowing jasmine rice 105 and sticky rice RD 6, samples of soil rice growing and earthworms in three replicates.

### Statistical Analyses

The data collected were statistically analyzed using analysis of variance techniques. Statistical analysis was 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

### Distribution of Earthworm

Distribution of earthworm population is highest on low salinity area (EC 2-4 dS/m$^{-1}$) about 280 (Juvenile and Adult) earthworm number per m$^2$ (Table 1), found earthworm activities *Glyphidrilus chiensis* and *Drawida beddardi* species (Fig. 1) at 45 days after rice sowing. Moderate soil salinity (EC 2-4 dS/m) *D. beddardi* is found only specie in this area about 20 (Adult) earthworms per m$^2$, they had activity at 95 days after rice sowing. Chanaban et al. (2013) have discovered a new earthworm species in the genus Glyphidrilus in paddy fields Northeast of Thailand. Earthworm species is most commonly found in paddy soil. Ivask and et al. (2007) study of earthworm's community in coastal areas and grasslands, flooded areas has lower earthworm's species. Thibaud et al (2003) reported factors that have influence on earthworm diversity environmental conditions, physical and chemical properties of soil, topography, climate and humans (agriculture and pollution).

**Table 1 Diversity of earthworms in rice ecosystem under different soil salinity levels in Banpai district, Khon Kaen province**

| Rice ecosystem under different soil salinity levels | Species | Stage of earthworm | |
|---|---|---|---|
| | | Juvenile | Adult |
| | | (Number/ $m^2$) | |
| Low soil salinity | | | |
| - found earthworm activities at 45 days after rice sowing | *Glyphidrilus chiensis* | 196 ±13.2 | 28 ±3.1 |
| | *Drawida beddardi* | 48 ± 4.4 | 8 ±2.1 |
| Moderate soil salinity | | | |
| - found earthworm activities at 95 days after rice sowing | *Glyphidrilus chiensis* | - | - |
| | *Drawida beddardi* | - | 20 ±2.1 |

*Mean (n=3)*


**Fig. 1 Earthworm species *Glyphidrilus chiensis* and *Drawida beddardi* in rice ecosystem under different soil salinity levels**

## Earthworm Activities on Soil Properties

The results of earthworm activities on soil chemical properties showed OM, pH, total N, available P and K in cast were increased. Earthworm activities have decreased soil EC (Table 2). Soil salinity reduces soil fertility, to have an effect on soil chemistry. Salts negatively affect environmental ecosystems crop yield (Grewal, 2010; Li et al. 2010; Zhang et al. 2010), soil microorganisms (Yuan et al., 2007; Ibekwe et al., 2010), plants (Gadallah and Ramadan, 1997; Joutti et al., 2003; Ruhland and Krna, 2010) and soil organisms (Owojori et al., 2008). Earthworms decompose organic matter and release plant nutrients into the soil such as ammonium nitrate, exchangeable potassium etc. and plant growth hormones and vitamins.

**Table 2 Earthworm cast properties in rice ecosystem under different soil salinity levels in Banpai district, Khon Kaen province**

| Rice ecosystem under different soil salinity levels | | OM | pH | EC | Total N | Avai P | K |
|---|---|---|---|---|---|---|---|
| | | % | (1:5) | (dS/m) | % | ppm | ppm |
| low soil salinity | soil | 0.84 | 6.6 | 0.29 | 0.1 | 5.39 | 42.83 |
| (EC = 2-4 dS/m) | cast | 2.08 | 7.5 | 0.11 | 0.4 | 11.58 | 139.68 |
| moderate soil salinity | soil | 0.78 | 6.4 | 0.65 | 0.1 | 2.62 | 31.17 |
| (EC = 4-8 dS/m) | cast | 1.88 | 7.1 | 0.46 | 0.4 | 5.12 | 100.37 |

*Mean (n=3)*

## Earthworm activities on rice growth under different soil salinity levels

Statistical analyses showed that the influence of earthworm activity with earthworm cast and salinity levels on rice number per $m^2$ and height of rice (Table 3) Jouquet et al. (2008b) showed that casts

produced by *Glyphidrilus* sp. can be considered as patches of nutrients in paddy fields in Northeast Thailand. In Africa, Owa et al. (2003) also observed faster rice development and greater productivity when earthworm casts were associated to rice plants.

**Table 3 The growth of rice ((*Oryza sativa* L.) KhaoDawk Mali 105 and RD6) under different soil salinity levels**

| Rice ecosystem under different soil salinity levels | Number of plant ($m^2$) | Height of plant flowering stage (cm) |
|---|---|---|
| Low soil salinity growing KhaoDawk Mali 105 | 35.32 | 92.13 abc |
| Low soil salinity growing RD6 | 30.00 | 103.07 a |
| Moderate soil salinity growing KhaoDawk Mali 105 | 19.00 | 81.63 c |
| Moderate soil salinity growing RD6 | 24.64 | 97.20 ab |
| F-test | ns | * |
| C.V. (%) | 48.11 | 8.11 |

*Remark: Mean (n = 3) in the same column followed by the same lower case letters are not significantly different at $|p| \leq 0.05$ (LSD)*

## CONCLUSION

Within the rice ecosystem in low salt affected area (EC 2-4 dS/m), the earthworm species, *Glyphidrilus chiensis* and *Drawida beddardi* were the most common species found at 45 days after rice sowing (280 earthworms per $m^2$), while in moderate salt-affected area (EC 4-8 dS/m) the earthworm species *G. chiensisis* was the only specie found at 95 days after rice sowing (20 number of earthworm per $m^2$). *Oryza sativa* L. (Khao Dawk Mali 105 and RD6) growth decreased with increasing levels of soil salinity. Soil salinity influences the distribution of earthworm and rice growth. In salt-affected area earthworms play a main role on maintaining soil fertility, soil chemical properties, soil microbial communities and soil physical properties.

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Research article

# Spatial Analysis of Ecosystem Disservice via Disamenity of Mosquitoes – a case study in Nagoya City, Japan

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**Abstract** Nature provides many benefits to human society, known as ecosystem services (ESs), and also has negative impacts on human society, known as ecosystem disservices (EDSs). Mosquitoes contribute to EDSs, such as the risk of disease, the disamenity of mosquito bites. The purpose of this study was to understand the factors of EDSs caused by mosquitoes, employing a case study in Nagoya City, Japan. Mosquitoes were collected by CDC (Center for Disease Control) $CO_2$-baited traps. Also a questionnaire survey of Nagoya citizens was conducted to assess the disamenity level of mosquitoes. Many variables, such as land use type, were developed by geographical information system (GIS). Statistical analyses were conducted to identify the main factors of mosquito abundance and disamenity. Important factors were identified for both mosquito abundance and its disamenity. Further studies, including multi-point trap surveys and more detailed spatial studies, are required to elucidate these aspects.

**Keywords** ecosystem service, ecosystem disservice, mosquito, biodiversity, GIS

## INTRODUCTION

Nature provides many benefits to human society, known as ecosystem services (ESs), which include carbon absorption, water regulation, timber supply, and water cycling, among others (Millennium Ecosystem Assessment, 2005). Nature also has negative impacts on human society, known as ecosystem disservices (EDSs), which include agricultural pests and vectors of diseases, etc. (Lyytimäki and Sipilä, 2009; Escobedo et al., 2011). The use of the concept of EDSs is relatively limited (Ango et al., 2014). Mosquitoes (MQs) are considered an EDS because they are disease vectors and also because of their disamenity effect. Numerous studies have already been conducted on MQs as a public health issue (Eshita and Kurihara, 1978; Kobayashi et al., 2002; Tsuda et al., 2006; Tsuda 2011, 2013). According to Tsuda (2011), the main purpose of MQ studies in Japan was to establish the distribution status of MQ species to assess the risk of diseases caused by them, as opposed to developing counter measures for potential diseases. Kamimura (1968) reported that *Aedes albopictus* (Skuse) was one of main MQ species appearing in residential areas in Japan. In Nagoya City, the third largest city in Japan, the most abundant MQ species were *Culex pipiens* group and *Ae. albopictus* (Sugiyama, 2007; Yokoi, et al., 2014; Nagoya City, 2015). To date, many studies, especially from a public health perspective, have been conducted on *Ae. albopictus* (Takagi et al., 1995; Tsuda et al., 2003; Tsuda and Kim, 2012). With the technological advancement in the geographical information system (GIS) and remote sensing, studies on the relationship between land use and MQ distribution is an emerging area of research

(Johnson et al., 2008; Yonejima et al., 2011; Landau and van Leeuwen, 2012). However, there are limited studies on the EDSs of MQs, e.g., the level of disamenity, because disamenity depends on the citizens' subjective assessment. The GIS studies and factor analyses of MQ's EDSs, especially *Ae. albopictus* have been limited to urban areas in Japan.

## OBJECTIVE

The aim of this study was to understand the main factors of EDSs, focusing on the disamenity of MQs (especially for, *Aedes albopictus* (Skuse)), using MQ traps and a questionnaire survey of the subjective assessment by citizens in Nagoya City, Japan.

## METHODOLOGY

Nagoya City (the city hall: 35.181°N, 136.906°E) is located in the central part of Japan (Fig.1 (a)). The average annual temperature in 2014 was 16.1°C, and the average precipitation was 1506 mm (Japan Meteorological Agency, 2015: http://www.data.jma.go.jp/obd/stats/etrn/index.php). The city has an area of about 326 km$^2$ and a population of 2.3 million as of April 1, 2014 (Nagoya City, 2015: http://www.city.nagoya.jp/shisei/category/67-5-0-0-0-0-0-0-0-0.html). The study area for the trap survey was the east part of the city, including an urban residential area, universities, and a forest park (Fig.1 (b)).

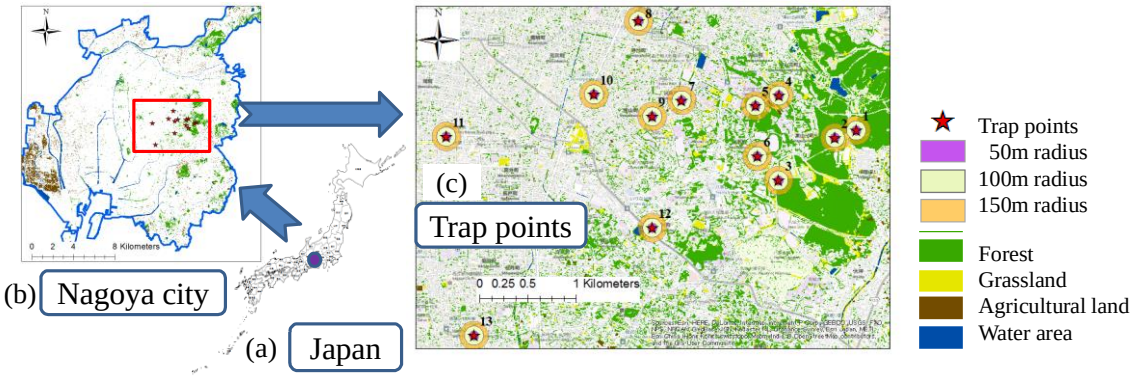


**Fig. 1 Maps of the study area: (a) Japan with Nagoya City circled, (b) Nagoya City outlined in blue, with trap points indicated by star symbols, (c) trap points in east-Nagoya**

A two-step approach was employed to assess the disamenity of MQs in the urban area. In the first step, MQs were collected by CDC (Center for Disease Control) $CO_2$-baited traps (Inokuchi-Tekko, Nagasaki, Japan) in Nagoya City, Japan. The traps were set at approximately 1.5 m height under tree branches or equivalent height of structures. The traps were equipped with a small, battery-driven fan, and 1 kg of dry ice wrapped with newspaper in a styrofoam cooling box, was set at approximately 10–15 cm above the fan. In total, 13 traps were set within an area of approximately 9 km$^2$. Traps were set in a relatively large secondary forest located on the east hill of the city, on the edges of forests, and in residential areas in flat locations for five nights from July to September of 2013 (Fig. 1 (c)). The candidate trap points were decided after conducting a pre-survey in 2012. These sites were selected to study the relationship between land use type and MQ abundance. The elevations of the sites were between around 15 m and 70 m. The traps were set between 12:15PM and 16:40PM on the first day of period1, and collected between around 9:00 AM and the afternoon on the next day (Table 3). In the other days, the traps were set between 11:00AM to 15:00PM, mostly. At that time most cakes of dry ice

had already melted. After collecting the traps, the samples were stored in a refrigerator. Several data points were missing in this survey due to technical issues of sample collection (Table 3) and the average number of trapped MQs was determined for each of the points. Species identification was conducted, focusing on *Ae. albopictus* and *Cx. pipiens* group by several research assistants as well as two of the authors.

**Table 1 Variable development and selected variables (#) for the trap statistical analysis**

| Variables | Description | |
|---|---|---|
| Hitosuji_T | Trapped number of *Ae. albopictus* in average in each point | (1) |
| Hitosuji_ln (Dependent variable) | ln(Hitosuji_T+0.5) | |
| Land use potential variables | | |
| Forest50, Forest100, Forest150 | % of forest within 50m, 100m and 150m radii from each trap | (2) |
| Grass50, Grass100, Grass150 | % of grassland within 50m, 100m and 150m radii | |
| Agri_land50, Agri_land100#, Agri_land150 | % of agricultural land within 50m, 100m and 150m radii | |
| Water50, Water100#, Water150 | % of water area within 50m, 100m and 150m radii | |
| Urban50, Urban100, Urban150 | % of urban area within 50m, 100m and 150m radii | |
| RoadW2_50# | Each way not less than two lanes within 50m from each trap | (3) |
| Slope potential variables | | |
| Slope1 | Slope situation1 (1: in a middle of slope, 0: other) | (3) |
| Slope2# | Slope situation2 (1: edge of slope with flat area, 0: other) | |

Source: (1) by the trap survey, (2) developed by ArcGIS based on Nagoya City(2010), (3)author's assessment on site

Next, the identification of explanatory variables was performed using a GIS and data collected on site (Table 1). By analyzing the Green coverage GIS data (Nagoya City, 2010), the percentage of five land use types (forest, grassland, agricultural land, water area, and urban area) were calculated in 50 m, 100 m and 150 m radii. According to Tsuda (2013), the individual range of *Ae. albopictus* was within several hundred meters. Using this as a reference, the three ranges of radii were employed. The other variables are listed in Table 1. The "Hitosuji_ln" was used as the dependent variable, calculated from "Hitosuji_T". The correlations among the potential explanatory variables were checked by Pearson correlation coefficients and to avoid multi-collinearity by checking the variance inflation factor (VIF). The high correlated variables were excluded. Finally the variables ("#" in Table 1) were selected for multiple regression analysis (MR). Each variable was selected for the proxy of land use types including road, and slope. Because several studies have included land use parameters for the analysis of the distribution status of MQ species (Johnson et al., 2008; Yonejima et al., 2011; Landau and van Leeuwen, 2012). Also the slope variable was selected as a still water parameter which could be used for nursery ground for MQ larva based on Tsuda (2013).

Lyytimäki and Sipila (2009) indicated that the same ESs can be understood to be positive or negative, depending on the person questioned. Therefore, subjective assessment of the people was conducted as a secondary step. An internet-based questionnaire survey was conducted from September to the beginning of October in 2013 for Nagoya citizens by Rakuten Research Inc. The survey requests were sent out to the monitor registrants of the company. The respondents could get small amount of rakuten points after the answer. At the first screening stage, 39,340 requests were sent out to the monitors and received 5,272 responses which could be used as a stock of the subsequent survey. Then requests were sent to each monitor from the stock. Before sending the requests, the targets of collected number of samples in each gender and age range were decided based on population data as of July 2013 (Nagoya City: http://www.city.nagoya.jp/shisei/category/67-5-5-0-0-0-0-0-0-0.html). Once a target was fulfilled, the collection of relevant samples was stopped by each gender and age range category. However after collecting the samples, we noticed sampling errors. After the examination of this issue, finally we decided to conduct additional requests to complement 171 samples in the middle of October to the same monitor pool by the same company. Finally in total 1,400 samples were

collected. Among them, a total of 565 samples were weightedly collected close to the trap points: the Chikusa, Showa, Meito and Tenpaku wards of the city. The samples took into consideration gender and age range balances for each ward, as much as possible, and the remaining 835 samples covered the other 12 wards, which were treated as one region from the perspective of gender and age ranges.

**Table 2 Questionnaire contents and selected variables (#) for the EDS statistical analysis**

| Questions/ variables | Detailed |
|---|---|
| Disamenity of MQs(mosquitoes) | 1.no; 2.a bit; 3. either; 4.a bit; 5.very strong disamenity. This was converted to two□ scale. New "1" means old "1" to "3", and new "2" means old "4" and "5". |
| Individual attributes and subjective assessment by questionnaire survey | |
| Forest_preference# | 1.do not prefer □3.rather prefer □5.very prefer: in 5-level |
| Nature_vs._development | Priority on 1.nature; 2.rather nature; 3.either; 4.rather development; 5. development |
| Number of MQs near home# | 1.few; 2.not many; 3.normal; 4.a bit large number; 5.large number |
| Source of MQs near home# | 1.trees, garden#; 2.gutter, drain#; 3.forest, park, cemetery; 4.river, pond, water area; 5.other |
| Most noxious things(two choices) | 1.MQs; 2.insects; 3.birds; 4.fallen leaves and branches; 5.others: 1st & 2nd choices |
| Gender | 1.male; 2.female |
| Age range | 20s, 30s, 40s, 50s, 60s, 70years ≦ |
| Under junior high school children# | Are there any children in the family? 1: Yes, 2: No |
| Others: Distance and visiting frequency of important forest or frequent visit forest, Appearance_of_MQs, Distance from source of MQs, Occupation, Education, Family number, Income, Zip code, etc. | |
| Land use potential variables developed by ArcGIS | |
| Pond_zip#, River_zip#, Agri_zip#, Forest_zip | % of each land use type area in each zip code area (1) |
| Build_zip | % of building area in each zip code area (2), |
| Road_zip# | % of road area (width ≧10m) in each zip code area (3) |
| Slope potential variables developed by ArcGIS | |
| Difference_DEM# | Difference between max and minimum elevation values in each zip code area (4) |

Source: (1): Nagoya City (2010), (2): Nagoya City (2011), (3): digital map by MLIT, (4): DEM by GIA-J

The questionnaire contents, including zip codes to roughly identify the geographical location of each sample, were summarized in Table 2. Two types of data sets were developed. One aimed to understand the general tendency of the city average; therefore, randomly adjusted resampling (1,080 samples) was conducted to reflect a total population balance (gender and age ranges) of the city, except "women 70years ≦" samples which was compensated from "women 60s", because in 1,400 samples there were some shortages of the number of samples in some slots of age ranges and the five ward samples were collected weightedly.

The other set focused on *Ae. albopictus*, targeting the surveys with the answer "MQs appearing frequently during the day", for further analysis (141 samples). Because the most frequently trapped MQs in the city were *Ae. albopictus* which is common during the day, and *Cx. pipiens* group (Sugiyama, 2007; Yokoi, et al., 2014; Nagoya City, 2015). Parameters related to land use type including road, slope, and building shade were also developed using a GIS. Variables in Table 2 were used to check the Pearson and Spearman correlation coefficients to avoid multi-collinearity. As small scale MQ source information, "source of MQs near home" parameters were considered based on the questionnaire survey even if these were subjectively assessed. Also EDS might have a relation with personal way of thinking so the subjective assessment of nature (such as, "forest_preference"), and individual attributes including, age range, gender, education, income, children, etc. were examined. The selected variables ("#" in Table 2) were chosen for the binary logistic regression (BLR) analysis.

Statistical analyses were conducted using SPSS statistics ver.22 (IBM). ArcGIS10.2.2 (ESRI Japan) was used for GIS analysis.

## RESULTS AND DISCUSSION

In Table 3, the basic results of the trap survey were presented. The NO4 which was located at the edge of forest near agriculture land was the highest in the number of *Ae. Albopictus*. On the other, forest (NO1, 2 and 5) and urban area near a big road (NO10, 11 and 12) were relatively low in the number of trapped MQs. Next the MR results were summarized in Table 4. As for land use variables, agriculture and urban related variables, namely, Agri_land100 and RoadW2_50, were the significant variables ($p$ < .10). Agri_land50 was also significant ($p$ < .10) instead of Agri_land100 in the Model 1.

**Table 3 Trap points and collected number of MQs**

| Site | Site description | Average number of trapped MQs | | |
|---|---|---|---|---|
| | | *Ae. albopictus* | *Cx. pipiens* group | Other |
| NO1 | Forest | 3.6 | 0.2 | 1.2 |
| NO2 | Forest | 4.8 | 1.2 | 0.2 |
| NO3 | Edge of forest* | 18.8 | 2.5 | 0.0 |
| NO4 | Forest edge near agriculture land | 58.4 | 6.4 | 0.4 |
| NO5 | Forest** | 5.6 | 1.8 | 0.2 |
| NO6 | Edge of forest** | 12.0 | 16.4 | 0.2 |
| NO7 | Edge of forest** | 12.8 | 24.8 | 0.0 |
| NO8 | Urban residential area** | 12.8 | 9.4 | 0.0 |
| NO9 | Urban residential area | 1.2 | 1.6 | 0.2 |
| NO10 | Urban area near a big road | 1.0 | 0.4 | 0.0 |
| NO11 | Urban area near a big road | 1.4 | 2.0 | 0.0 |
| NO12 | Urban area near a big road*** | 0.3 | 1.8 | 0.0 |
| NO13 | Urban residential area**** | 7.6 | 41.4 | 0.0 |

Note1: period1: July 31to Aug. 1, period2: Aug. 7-8, period3: Aug. 20-21, period4: Sep. 11-12, period5: Sep. 25-26 in 2013. The cakes of dry ice in NO1, 2 and 3 only were stored in steal small cages requested by the government for security reason.
Note2: The time difference between the first and the last settings of the traps in each day were 4h25m, 3h15m, 2h3m, 2h14m and 1h17m, for period 1 to 5, respectively, except NO13. The traps of NO13 were set at 15:00PM except period5 at 16:00PM.
*: Data missing in period2, and as for period4 the trap NO3 was set again on Sep.13-14 instead of Sep. 11-12 by technical issues; **: in a university campus; ***: Data missing in period3 by technical issues, in a temple; ****: in a different university

According to Tsuda (2013), *Ae. albopictus* normally does not breed from paddy field. One explanation for agriculture factor was as follows. Agricultural site near the traps was limited, namely, NO4. The paddy field near NO4 was located in a university campus with a small water reservoir tank for the paddy field and many artificial small containers, such as, bowls and planters, for university research purposes, which could be used for the container habitats by *Ae. Albopictus*. Also there was small wetland close to NO4.

Forest was not recognized as a significant factor, which was similar to the results of Tsuda (2013). Water100, also same with Water150 instead of Water100 in the Model 1, and Slope2 were not significant in this study. Thus further studies are required with increasing the number of traps to study spatial structure of abundance of MQs.

There were several issues remaining. One was that the setting time of each trap was different. Most traps were set around noon to 14:00. But some were set around 15:00-16:00 even if the trap settings were conducted by three separate teams with the effort to minimize the setting time differences. In the future it is better to set all traps almost same time because *Ae. Albopictus* is mostly appearing in the day time. Also at the trap setting, the effect of wind should be considered in detailed, such as, daily monitor of wind. And the sky openness factor should also be considered and treated as one parameter of the analysis.

Regarding the questionnaire survey in Table 5, MQs were recognized as the “most noxious things” compared to other environmental pests claimed by nearly 76.9% in the 1,080 sample survey. Also the majority of citizens felt that the “disamenity of MQs” was high, concentrating on level 4 and 5. The “5.very strong disamanety” reached to 46.9%. These showed that, especially in urban areas like Nagoya, the disamenity of MQs could be identified as one of the most important targets for EDS analysis. Also the “source of MQs near home” was high in “1.trees, garden (34.6%)” and “2.gutter, drain (38.7%)”. Then the public assessment on “number of MQs near home”, which might be related to MQ abundance by the trap survey, was the highest at level 3 (41.3%).

Focusing on *Ae. albopictus*, the citizen’s subjective assessment of MQs was studied in Table 6 (N = 141). The number of MQs near home was negatively correlated with Road_zip by the Spearman's rank correlation coefficient, which was similar result with the Model 1 for the trap survey. Then road

variables were identified as one of the important factors of MQ abundance for both the trap and questionnaire surveys. Also the source of MQs near home was significantly correlated with the number of MQs near home. The source of MQs variable represented small scale land situation including tree and green distributions even if these were subjectively assessed by the citizens. The number of MQs might be impacted by small scale land usage.

Next, to analyze the main factors of the disamenity of MQs, the BLR was conducted for 141 samples, focusing on *Ae. albopictus*. After checking the correlation coefficients, the selected variables ("#" listed in Table 2) were used for the analysis. Finally, two types of models were developed in Table 7. As a full model, Model 2 included all potentially related variables: land use, slope, the number of MQs near home, the source of MQs, the subjective assessment of nature, and individual attributes, referring to the trap survey results and above mentioned correlation. Model 3 was developed by a variable reduction step wise method by Wald ($p \leqq .20$ (in), $p \geqq .25$ (out) ) from Model 2.

The $R^2$ values for both were relatively low; however, three significant variables were identified in both models (Table 7). The citizen's subjective assessment on MQs, such as, the number of MQs near home ($p < .01$) and the source of MQs near home (trees, garden and gutter, drain) ($p < .05$) were significant variables.

However, all land use variables developed by GIS were not recognized as significant variables. One reason for that was that these GIS based land use variables were the percentage of each land use type within each zip code area so the assessment scale of the variables were relatively large compared with land use parameters impacted on MQ appearance which might be much smaller scale such as trees, garden, gutter and drain existences. In this study each questionnaire sample location was roughly identified by the coordinates of the center of gravity for each zip code. Concrete coordinate point data are required for detailed analyses reflecting the specific land use situation in the future.

Regarding individual subjective assessment on nature and its attributes, all the variables tested in this study were not identified as significant variables. As mentioned above, MQs were recognized as the most noxious pests so the most of citizen feel MQ's disammenity might be high.

**Table 4 MR result for the trap survey: Model 1 (N=13)**

| Variables | Unstandardized Coefficients | | Standardized Coefficients | t | *p* | VIF |
|---|---|---|---|---|---|---|
| | *B* | Std. Error | | | | |
| (Constant) | 1.827 | .264 | | 6.906 | .000 | |
| Agri_land100 | .199 | .090 | .407 | 2.199 | .059 | 1.273 |
| Water100 | -.842 | .889 | -.183 | -.948 | .371 | 1.385 |
| RoadW2_50 | -1.311 | .556 | -.472 | -2.360 | .046 | 1.490 |
| Slope2 | .540 | .527 | .194 | 1.024 | .336 | 1.341 |

Note1: Dependent Variable: Hitosuji_ln,

Note2: $R^2$ = .785, adjusted $R^2$ = .677 (model evaluation test: $p$ < .009)

**Table 5 Basic results of questionnaire survey (%)**

| Questions | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Most noxious things | 76.9 | 7.5 | 13.2 | 0.5 | 1.9 |
| Number of MQs near home | 4.4 | 16.4 | 41.3 | 20.9 | 17.0 |
| Disamenity of MQs | 1.6 | 8.1 | 13.5 | 29.9 | 46.9 |
| Source of MQs near home* | 34.6 | 38.7 | 14.5 | 15.6 | 1.7 |

Note: each choice of 5-level(1 to 5) is presented in Table 2

*: multiple answer questions. In addition, "do not know" answer was 23.6%. (N=1,080)

**Table 6 Correlations with Number of MQs near home**

| Spearman's rank correlation coefficient | | (N=141) | |
|---|---|---|---|
| | | RD | S_TG |
| Number of MQs near home | correlation | -.235 | .346 |
| | sig. | .005 | .000 |
| Road_zip(RD) | correlation | | -.147 |
| | sig. | | .082 |

S_TG: Source of MQs near home (trees and garden)

**Table 7 BLR models for disamenity of MQs (N=141)**

Model 2 (full model) and Model 3(variable reduction step wise (Wald): $p \leqq .20$ (in), $p \geqq .25$ (out))

| Model | *B* | Std. Error | Wald | *p* | Exp(*B*) | 95% C.I.for EXP(B) | | *B* | Std. Erro | Wald | *p* | Exp(*B*) | 95% C.I.for EXP(B) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model 2 | | | | | | | Model 3 | | | | | | |
| Agri_zip | 5.096 | 8.749 | .339 | .560 | 163.370 | .000 | 4.577E+09 | | | | | | | |
| Pond_zip and River_zip | 7.834 | 12.368 | .401 | .526 | 2.525E+03 | .000 | 8.504E+13 | | | | | | | |
| Road_zip | 3.530 | 4.649 | .577 | .448 | 34.131 | .004 | 3.093E+05 | | | | | | | |
| DifferenceDEM | .025 | .020 | 1.596 | .206 | 1.025 | .986 | 1.065 | .024 | .019 | 1.620 | .203 | 1.025 | .987 | 1.064 |
| Number_of_MQs_near_home | 1.008 | .287 | 12.307 | .000 | 2.740 | 1.560 | 4.812 | .983 | .284 | 12.015 | .001 | 2.673 | 1.533 | 4.661 |
| Source of MQs near home(trees, garden, etc.) | 1.634 | .592 | 7.605 | .006 | 5.124 | 1.604 | 16.366 | 1.547 | .573 | 7.276 | .007 | 4.697 | 1.526 | 14.452 |
| Source of MQs near home(gutter, drain, etc.) | 1.157 | .511 | 5.129 | .024 | 3.179 | 1.168 | 8.650 | 1.111 | .479 | 5.384 | .020 | 3.038 | 1.188 | 7.768 |
| Forest_preference | -.037 | .198 | .036 | .850 | .963 | .654 | 1.419 | | | | | | | |
| Under junior high school children | .297 | .525 | .320 | .572 | 1.346 | .481 | 3.770 | | | | | | | |
| Constant | -3.519 | 1.268 | 7.703 | .006 | .030 | | | -3.152 | .949 | 11.033 | .001 | .043 | | |

Note 1: Dependent variables: Disamenity of MQs (1, 2, 3 level →0, 4, 5 level →1)

Note 2 for model 2: -2 Log likelihood=135.44, Cox&Snell $R^2$ = .227, Nagelkerke $R^2$ = .322, model evaluation test $p < .000$, Hosmer & Lemeshow test $p = .434$

Note 3 for model 3: -2 Log likelihood=137.17, Cox&Snell $R^2$ = .217, Nagelkerke $R^2$ = .309, model evaluation test $p < .000$, Hosmer & Lemeshow test $p = .586$, VIF for DifferenceDEM(1.021), Number_of_MQs_near_home (1.166), Source of MQs near home(trees, garden, etc.) (1.151), Source of MQs near home(gutter, drain, etc.) (1.017)

## CONCLUSION

The EDSs, focusing on the disamenity of mosquitoes and its abundance, was studied based on data from trap survey as well as the questionnaire survey. According to the trap survey, agricultural and road parameters were identified as significant factors. One possibility for the agricultural factor was that the paddy field near a trap was located in a university with a small water reservoir tank and many small containers which could be used for container habitats by *Ae. Albopictus.* However, the number of traps was limited, therefore an increase in the number of traps should be considered to further study on the relation between mosquito abundance and land use. As for the disamenity, subjective assessment of mosquito numbers, and source of mosquitos might be important factors. Land use parameters impacted on mosquito appearance might be much smaller scale such as trees, garden, gutter and drain existences than those developed by GIS. Concrete coordinate point analysis is required for detailed analyses reflecting small scale land use situation in a future study.

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Research article

# Socio-Economic and Spatial Evaluation of Ecosystem Services in Nagoya, Japan

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**Abstract** In recent years, the value of urban green spaces and parks in Japan has begun to be reevaluated. In particular, attention is being paid to easily accessible and routinely available urban green spaces and parks, where many people benefit from cultural services such as recreation and relaxation. However, these spaces are facing the threat of destruction by urban development. Thus, to assess the recreation function of the small- to medium-scale urban parks and green spaces routinely used by many people, this study aimed to evaluate their economic value using the travel cost method (TCM). To expand the results from the TCM, suggestions were made with regard to prioritizing ecosystems in urban areas for conservation. The potential supply of ecosystem services was estimated using five categorized proxy variables and weighted by the TCM results. This assessment can be applied to any city whose social and natural statistics are not well-managed.

**Keywords** conservation priorities, land use, travel cost method, urban green space

## INTRODUCTION

The Millennium Ecosystem Assessment (MEA) performed the organization of the concept of ecosystem services. These refer to a variety of services, from concrete services that human society receives from ecosystems (carbon storage, soil formation) to related subjective cultural services (landscape, leisure). However, integrated quantitative evaluation tools that would encompass all ecosystem service concepts are still at the research and development stage.

In addition, in recent years, urban green spaces and parks in Japan have been increasing in area, and many people can use such places to engage in recreation and relaxation. However, they are facing the threat of disappearing due to urban development. Therefore, it is important to economically assess their utility values and the values of their ecosystem services.

With regard to the literature on recreation function assessment, Kuriyama (2001) calculated the recreation values of Yakushima Island and Mt. Fuji in Japan by using the travel cost method (TCM) and the contingent valuation method. Maeda (2004) economically assessed the recreation value of Kushiro Marsh and then proposed new environmental conservation measures based on the economic assessment results. Hein et al. (2006) estimated the total economic value of a wetland's ecosystem services based on the assessment results using the TCM. Thus, there are many previous studies assessing recreation functions. However, these studies focused on nationally famous tourist sites and

facilities, and tended to deal less with assessing the economic value of the small- to medium-scale parks and urban green spaces that are used by citizens on a daily basis.

In addition, within a certain management scope, there is also demand to rank ecosystems in order to prioritize their conservation such that important ecosystem services are not lost. There are several conservation planning support softwares that use GIS to conserve certain specified species. Based on certain restrictive conditions (costs, etc.), they obtain the optimum spatial plan, which can be applied to determine conservation priorities in order to maximize ecosystem services.

## OBJECTIVE

The study is proposing a method for the integrative evaluation of the supply potential of the various ecosystem services that urban ecosystems provide. This study estimated ecosystem services and biodiversity conservation using the relatively simple method developed by Ooba et al. (2014, 2015), which assumes that land use transforms ecosystem services. The economic values of cultural services in small and medium urban green spaces in Nagoya were assessed through the TCM using an internet survey and estimating the economic value of each ecosystem service. Further, this web questionnaire also asked for the importance of each ecosystem service, and based on the results, weighted and performed integrated evaluations of the ecosystem services that were individually estimated. Finally, conservation software was used to calculate conservation priorities and determine where important urban ecosystems were located.

## METHODOLOGY

### Study Area

Aichi prefecture in Japan, the venue of the ordinary meeting of the Conference of the Parties (COP10) to the Convention on Biological Diversity in 2010 and a prefecture eager to preserve urban green spaces, was selected for study. The four selected small and medium urban parks and green spaces used on a daily basis by citizens in Aichi pref. are the Idaka green space (60.4 ha), Aioiyama park (84.9 ha), Chayagasaka park (6.18 ha), and Meitoku park (15.4 ha) (Fig. 1).

### Estimation of Ecosystem Services

**Outline of questionnaire survey**: To estimate the economic values of the recreation functions of the urban green spaces and parks, the TCM was adopted based on the travel costs and numbers of visitors for each green space and park obtained through the internet survey (Rakuten Research, Japan). In December of 2014, a screening survey was first conducted with a sample of 20,000 monitor members across Aichi pref. who intended to answer the questionnaire. Then, in consideration of the regional population, age distribution, and sex distribution in the pref., 2,800 samples were collected through pseudo-random sampling in January of 2015. The question items explored the following: whether respondents had visited the selected parks and green spaces within the past five years; the number of visitors in the past five years; the purposes of the visits (multiple choice from 21 items); modes of transportation employed; travel times for each mode of transportation; visit durations; and average number of visitors. Then, the ecosystem services of the general urban green spaces were explained so that respondents could rate the importance of cultural services on a five-point scale. Finally, questions about individual attributes (occupation, annual income, and educational background) were asked.

**Analysis by the TCM**: Generalized round-trip costs per capita (total cost) were calculated based on required costs such as transportation and facility usage costs (e.g., train fare, cost of gasoline, and admission fee) and the product was found by multiplying required time, i.e., the sum of travel time and

visit duration, by the time value. Following the method of Cesario (1976), the time value was set to 989 yen, which is equivalent to 33% of the average hourly income of 2,967 yen (data from the Ministry of Internal Affairs and Communications in 2012). In addition, demand curves were estimated through regression analyses of the annual average visit times and generalized costs. Then, recreation values were calculated by multiplying the consumer surpluses per visitor by the annual numbers of visitors (Eq. (1)). Finally, the annual recreation values were divided proportionally according to the importance levels of the ecosystem services to determine the economic value of each ecosystem service.

$$RV = (-AT/I) \times AV \quad (1)$$

Where $RV$ is the recreation value, $ID$ is the slope of the demand curve, and $AT$ is the annual average visiting number of a visitor, and $AV$ is annual numbers of visitors.

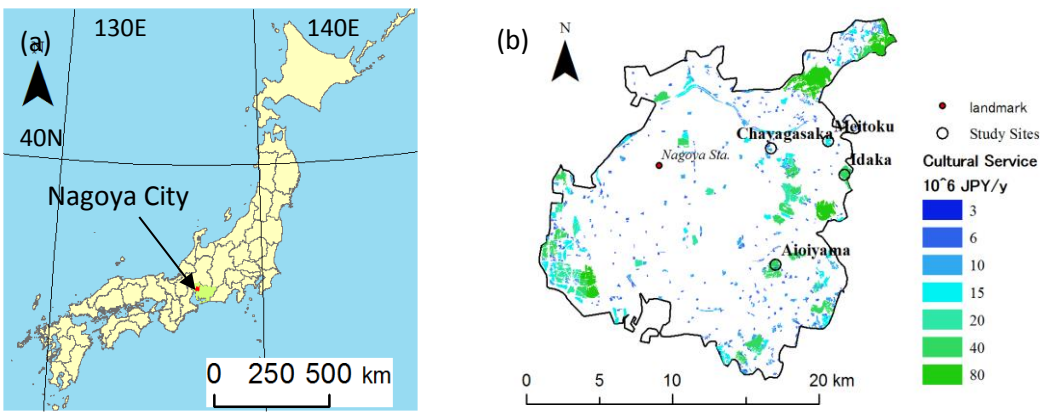


**Fig. 1 Location (a) and study sites (b) including economic evaluation for cultural service**

**Spatial evaluation of ecosystem services:** Based on the four MEA categories, ecosystem services were categorized. These services are conceptual, so the carbon storage rate quantified based on proxy variables, food supplies, prevention of soil erosion, recreation, etc., were estimated. Biodiversity was estimated based on habitat continuity (see also Ooba et al., 2015). Detailed Digital Information for Urban Landuse (Geospatial Information Authority and Japan Map Center) was used in relation to land use. The latest version of the product was provided for only map at 1997. Nagoya City has been developed well and then slight change between the current and 1997 was assumed at 1-km grid size. The 17 land use subdivisions were reclassified into five types: water area, cities, roads, agricultural land, and forestland. "Parks" and "green belts" were classified as forestland. This simplification of landuse is aimed to application for developing country where landuse map may be limited and methodology of estimating ecosystem services is also limited. For elevations and slopes, a Digital Elevation Model (DEM) was used provided by the Geospatial Information Authority. For this study, the national third mesh system (approximately 1 km meshes) was used to calculate the total supply of ecosystem services.

Carbon storage and food supply were estimated using agricultural statistics (Table 1). For soil erosion prevention, the USDA's Revised Universal Soil Loss Equation (RUSLE) was employed. The results of the TCM were used to estimate the economic values of cultural services. The economic value $V$ (1 million yen /ha y) per unit of area was estimated as follows.

$$V = aA^b \quad (2)$$

Where $A$ is area (ha) and $a$ and $b$ are parameters obtained by a regression calculation ($b < 1$). For a green space of 1 ha or greater, respective services were evaluated. With regard to habitat continuity, the continuity of green spaces with a radius approximating 2 km was calculated using GIS based on

previous research (Li, 2014). The estimated quantities of services are shown by different unit systems, so for inter-comparison purposes, values were compared after normalization based on the average values and standard differentials through logarithm conversion.

**Integrated evaluation of ecosystem services:** To perform the integrated evaluation of ecosystem services, Zonation, which calculates conservation priorities (Moilanen et al., 2012), was employed. Zonation divides the region of focus into meshes and identifies the mesh with the greatest overall loss when one mesh is removed (for example, if it is species diversity, then the diversity of species, or if it is ecosystem services, then the value of integrated ecosystem services). Conservation priority is determined by repeatedly removing the mesh that was identified and searching among the remaining meshes for the cell with the maximum loss.

As a calculation method, the Core Area Zonation that minimizes loss by assigning high rank to spatial continuous and high weight ecosystem services was used. This study used the average value of importance obtained through the web questionnaire. The costs were all assumed to equal one. The other Zonation parameters were set to the default values.

Because of technical restrictions on data entered into Zonation, the national 3rd mesh system of Japan was converted into 500 m meshes to calculate conservation priority.

**Table 1 Methods used to estimate ecosystem services (see also Ooba et al., 2015)**

| Service category | Proxy variable | Basic units, method details* | Unit | Reference |
|---|---|---|---|---|
| Support | Carbon sequestration | 3.09(F) | t/y ha | Ogawa et al.(2002) |
| Provision | Food supply | 2.98(A) | t/y ha | Aichi Pref.(2012) |
| Regulation | Inverse of soil erosion coefficient | $S = 65.41\sin^2\square + 4.56\sin\square + 0.065$<br>C = 1 (U), 0.33(A), 0.0085(F) | - | Renard et al. (1997) |
| Culture | Economic value of green space | Value per unit area as green belt area $A$(ha) $V = 3.0184A^{-0.437}$ | $10^6$ JPY/y | This study |
| Habitat | Continuity of green space | ArgGIS tool (Focal statistics) proximity as 2 km radius | - | Li (2014) |

** Land-use codes—U: Roads and urban areas, F: Forestland, A: Agricultural land*

## RESULTS AND DISCUSSION

Table 2 shows the purposes of visits to the four urban parks/green spaces. Representing about half of responses, the first and second purposes were seeing a landscape and enjoying a walk, respectively. Regarding the characteristics of each park and green space, Meitoku park has a campsite and people who visit this park to use the campsite accounted for 9% of respondents. The Idaka green space has a sports ground and visiting this facility accounted for 7% of responses, whereas seeing the *Hotaria parvula* (species of firefly) in the Aioiyama green space and represented 10% of responses.

**Table 2 Purposes of visits (%)**

| | Chyagasaka | Meitoku | Idaka | Aioiyama |
|---|---|---|---|---|
| Seeing a landscape | 44 | 26 | 30 | 37 |
| Enjoying a walk | 19 | 28 | 18 | 12 |
| Light exercise | 7 | 7 | 7 | 8 |
| Forest bathing | 8 | 7 | 13 | 7 |
| Enjoying playing tool* | 5 | 9 | 7 | 10 |
| Other | 17 | 21 | 25 | 26 |

**Firefly viewing only at Meitoku park*

Also shown is the importance of the four types of ecosystem services as estimated on a five-point scale (Table 3). The cultural services obtained high scores for many parks and green spaces, with value of 4.15 on the five-point scale. The supply services obtained low scores, with average value 3.59.

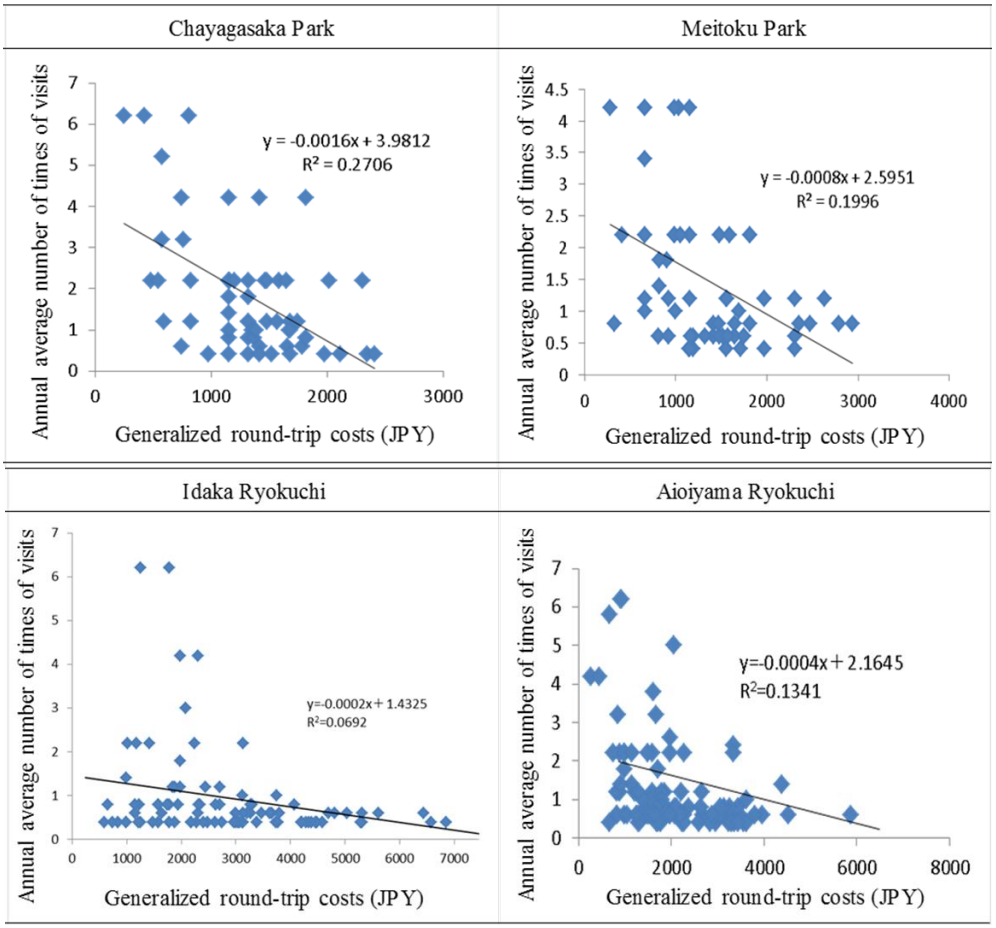


**Fig. 2 Estimated demand curves of the parks from TCM**

**Table 3 Importance level and economic value**

| | | Chyagasaka | Meitoku | Idaka | Aioiyama |
|---|---|---|---|---|---|
| Total number of visitor (1/y) | | 445,569 | 155,200 | 571,161 | 442,646 |
| Number of visit time (1/y) | | 1.14 | 0.95 | 1.05 | 0.97 |
| Importance level* | Regulating ES | 4.15 | 4.01 | 4.23 | 4.13 |
| | Providing ES | 3.61 | 3.51 | 3.63 | 3.60 |
| | Cultural ES | 4.15 | 3.97 | 4.30 | 4.17 |
| | Supporting ES | 3.95 | 3.89 | 4.05 | 4.07 |
| | Biodiversity | 4.09 | 3.88 | 4.19 | 4.16 |
| Economic value (Million JPY) | Regulating ES | 8.77 | 11.97 | 51.84 | 24.05 |
| | Providing ES | 7.63 | 10.48 | 44.49 | 20.96 |
| | Cultural ES | 8.77 | 11.85 | 52.70 | 24.28 |
| | Supporting ES | 8.35 | 11.61 | 49.63 | 23.70 |
| | Biodiversity | 8.64 | 11.58 | 51.35 | 24.22 |

**Five grade scale*

Figure 2 and Table 3 shows the estimated demand curves and their economic values. The annual average number of visits was about 1.0 for each park and green space, representing a low frequency. The correlation between the generalized costs and the numbers of visits was not very strong. The estimated recreation values correspond to the values of the cultural service, and the economic values vary significantly according to the annual numbers of visitors. In the analysis of importance, all four parks and green spaces exhibited the highest scores for cultural services and the lowest scores for supply services. The reason for this could be that citizens greatly enjoy cultural benefits such as playing and seeing beautiful landscapes but do not care as much about receiving supply services such as food.

**Spatial Evaluation of Ecosystem Services**

Cultural services were estimated based on the value of four parks by a power function such as Eq. (2), $a = 3.0184$, $b = -0.437$ ($R^2 = 0.63$). If the area increases, the value per unit area decreases, but because this is multiplied by the area, the area and value of the cultural services increases gradually. Figure 1b shows the part of the green space of 1 ha or greater used for this study and the value of the estimated cultural services. Like Itaka and Aioiyama, the values for the Higashiyama and the western part of Nagoya City were high.

The results of the total and converted estimated ecosystem services for each national 3rd mesh are shown in Figs. 3a to e.

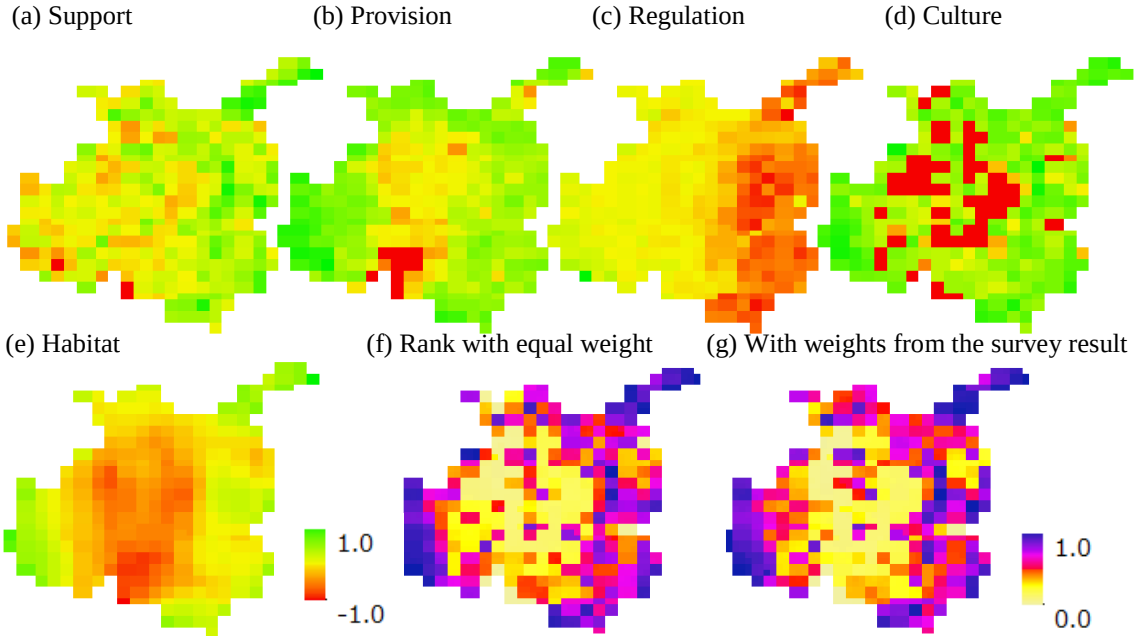


**Fig. 3 Distribution of Ecosystem Services (a-e) and Conservation Priority (f and g)**

This study performed estimations through a simple method related to land use, so places high in ecosystem service supply were arranged to be relatively easily identifiable. Carbon storage (Fig. 3a) was high in Eastern Nagoya City and Moriyama, where there are many woodland areas. Food production (Fig. 3b) was high in western Nagoya, where there are relatively large areas of paddy and farmland. Cultural services and habitat quality (Figs. 3d and e) tend to be low in the central area but higher in the surrounding areas.

Results that relatively display the conservation priority (where 1 is the top priority) are shown in Figs. 3f and g. Priority tends to be high in the surrounding areas, where individual ecosystem services were high, and in Higashiyama, Moriyama, and western Nagoya City. Atsuta, which is isolated inside the city, and green spaces in the Nagoya region also earned high priority.

The difference between Figs. 3f and g resulted from weighting: equal weights (every weight was assumed to be 1.0) and weighting based on the results of the questionnaire survey. The priority of the east side of Nagoya was lower in the weighted case (Fig. 3g) than the equal weights case (Fig. 3f) due to the low weight of provisioning services. It is assumed that this is because this area has few nearly natural ecosystems.

## CONCLUSION

The results show that among urban green spaces and parks, differences are observed in the purposes of use according to the availability of accompanying facilities such as playground equipment as well as urbanization around forest areas. Many visitors simply enjoy the scenery of green spaces, which shows that relaxing by seeing beautiful landscapes and walking in the woods is of great value. Regarding green spaces, the correlation between the generalized cost and the number of visits is not very high. However, the economic value of greenery-related recreation estimated in this survey is shown to be extremely high due to a very large number of visitors per year, despite the small and medium size of the evaluated green spaces and parks.

In the analysis of importance, all four parks and green spaces exhibited the highest scores for cultural services and the lowest scores for supply services. This could be because citizens greatly enjoy cultural services, such as playing in parks and green spaces and seeing beautiful landscapes, whereas they do not care as much about supply services, such as food. However, the respective ecosystem services are not independent, and it is likely that the economic value is overestimated. The authors are reviewing spatial estimation methods about cultural services, and in a future study more reliable methodology can be proposed.

Ecosystem services at the 1 km mesh level were estimated using a simple method related to land use and the survey results. In the area surrounding the city, relatively high services were exhibited due to the presence of agricultural land and green spaces including secondary forests. The conservation rankings also showed the same trend; however, the conservation priority of agricultural land is relatively lower than that of the other green spaces due to the low weight of provision services in the survey results.

The implementation that have been carried out in this study was limited (few landuse types and simple estimation methods). These limitation of landuse are resulted from the aim to application of our framework in developing country where usually data and estimation methods is limited. However these limitation may be easily replaced by more detailed landuse map and complicated methods.

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