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Tel/Fax: +66-2957-8064
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Tel/Fax: +81-42736-8972
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Contents

Research article

Interactions among Soil Physical, Chemical and Biological Properties under Different Farming Systems

MARISOL TERASHIMA
Graduate School of Agriculture, Tokyo University of Agriculture, Japan
Email: chamiter@hotmail.com

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

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Abstract The definition of soil quality has always been changing over time within the soil science community. At first, the study focused more on chemical and physical properties and less importance on a sustainable environment. Therefore, the definition of soil quality has changed in the last decade. The importance of biodiversity that exists both on the surface and within the soil began to be understood. These organisms have essential functions such as nutrient cycling, provision of plant nutrients, and modification of physical soil structure, water regimes, and suppression of undesirable organisms on cropland. It has defined soil quality as the function it has within the environment, sustaining productivity, maintaining environmental quality, and promoting health in plants and animals. However, the interaction between some microorganisms is still unknown, or how it could affect the different parameters in the biodiversity of an agro ecosystem. Furthermore, it is unknown what parameters are important in determining soil quality. Therefore, this study analyzed the biological, physical, and chemical properties of the soil of two farms whose practices is different. Water retention capacity, aggregate distribution, organic matter, total nitrogen, NO_3, NH_4, and biomass of microorganisms were measured. Soils were air dried and sieved to 2mm. They were analyzed after drying in an oven at 105° C for 24 h. The biomass of microorganisms was measured by the direct extraction method. The results indicated that there was a significant difference between the microorganisms but could not be found with physical and chemical properties. This result could indicate the importance of biological properties over other parameters to discuss soil quality. In addition, the differences observed could be explained by the different practices carried out on each farm.

Keywords soil quality, soil health, biomass of microorganisms, aggregates, total nitrogen

INTRODUCTION

Soil health is associated with soil biological parameters, such as biodiversity and its stability in the environment. When there are outbreaks of plant diseases, they are indicators of ecosystem instability and poor health. Thus, healthy soil has the ability of the biological community to suppress plant pathogens, the population of plant pathogens in the soil, and control the incidence and severity of diseases (Bruggen van and Grunwald, 1996). Accordingly, Cruz (2004) defines soil quality as dynamic, changing over time within the soil science community. At first, it was focused more on fertility, the yield of crops, and less importance on a sustainable environment. In other words, science has defined soil quality in chemical and physical parameters, such as the quantity or concentration of nutrients, organic matter, and water retention.

In the last few decades significant efforts have been made to increase agricultural productivity through increased fertilization and pesticide application, improved irrigation, soil management regimes and crops, and massive land conversions (Tilman et al., 2002). There is increasing concern, however, that agricultural intensification is placing tremendous pressure on the soil's capacity to

maintain its other functions leading to largescale ecosystem degradation and loss of productivity in the long term (Tilman et al., 2001; Foley et al., 2005; Vitousek et al., 2009). Since microorganisms are involved in many soil processes, they may also give an integrated measure of soil health, an aspect that cannot be obtained with physical/chemical measures alone (Nielsen et al., 2002; Kibblewhite et al., 2008; Mueller et al., 2010; Sharma et al., 2011).

There have been a few reports that have indicated that organic farming practices have positive effects on soil microbial populations, processes and activities (Clark et al., 1998; Doran et al., 1996; Drinkwater et al., 1995). Applications of insecticides may promote changes in population biodiversity and dynamics by inhibiting or killing components of the soil microbial community. Fungicide application can cause significant changes to the relative sizes of the bacterial and fungal communities in soil (Sall et al., 2006; Sigler and Turco, 2002). Although most of the research has shown increased microbial diversity in soils from organic farming systems compared to conventional farming systems, some studies have found different results. Shannon et al. (2002) studied microbial communities in soils managed under organic and conventional regimes, and found conflicting evidence that the size, composition and activity of the soil microbial biomass were attributed to management practice. They found that differences in microbial communities in soils under different management practices were subtle rather than dramatic (Liu et al., 2007). Therefore this study focus on analyzing some physical, chemical, and biological (the microorganism communities) properties as indicator of soil quality / soil health of two agro ecosystem which have different practices. In addition, the discussion about what parameters could be important to determine soil health.

MATERIAL AND METHODS

Soils from 2 farms in Kanto Area, Japan, with a history of natural and conventional crop production were sampled. These were sampled at a depth of the upper 5 cm of the soil. Soils were air dried and sieved to 2mm. The dry weight of the soil was determined after drying in an oven at 105°C for 24 h.

The biomass of microorganism was measure by direct extraction method. Ten subsamples of 5.00 g of each soil were weighed separately into 50 ml centrifuge tubes and 20 ml of 0.5 M K_2SO_4 was added to each. To three subsamples, 0.5 ml of ethanol-free chloroform was added. Both the chloroform-exposed and the non-fumigated samples were capped and shaken simultaneously for 1 h. After shaking, the suspensions could settle for 10 min and the supernatants were filtered through Whatman No. 42 filter. For the sub-samples with chloroform, only the top 15 ml of the supernatant was filtered to reduce the amount chloroform in the filtrate. Filtrates from soils with and without chloroform were immediately bubbled with air for 30 min to remove any residual chloroform. Blanks were treated in the same manner. Dissolved organic carbon in all filtrates was determined after dichromate digestion by titrating with 0.033 M acidified ferrous ammonium sulphate (Anderson, et al. 1993). Chloroform labile C was calculated as the difference between the C extracted from the chloroform fumigated and the non-fumigated sample. All results are expressed on an oven-dry basis. No conversion factor (kEC) was used to convert chloroform labile C to microbial biomass C because the range of kEC values (0.41 - 0.58) is used in the literature and it has not been tested which is best suited for the soils used here (Setia et al., 2012).

In addition, number of culturable bacteria and fungus were quantified. The plate count methodology by plating is a widely used methodology (Hoben and So-masegaran, 1982), which consists of making 1:10 serial dilutions and spreading 100 µl of each dilution on a plate; plates are incubated until colonies are countable.

The chemical and physical properties were measured as aggregate size, water retention capacity, organic matter, total nitrogen, total phosphorus, nitrates, and ammonia. Soil samples analyzed the aggregate's stability and distribution to observe the resistance in the water. Stability is influenced by the physical and chemical properties of soils. In addition, the soil samples were evaluated for their relationship with the organic matter.

For NO_3 it was measured by nitration of salicylic acid (Cataldo et al., 1975) and for NH_4 with indophenol blue method described by Searle (1984). Statistical analysis with ANOVA was done for all the treatments.

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties

In Fig. 1 it shows us the distribution of soil aggregates. Soil aggregates play an essential role in the formation of soil structure and soil health. In agriculture, the stability of the aggregates is important for the functioning of the agroecosystem. The pore spaces influence the storage of air and water and the gas exchange. They create a habitat for soil microorganisms and allow the development and penetration of plant roots. They also help in nutrient cycling and transportation.

It indicates that there are bigger aggregates in the conventional than in the natural one. Although, no significant difference was found between the different agroecosystems. Thus, both the Conventional and Natural ones mostly had aggregates greater than 0.5 mm.

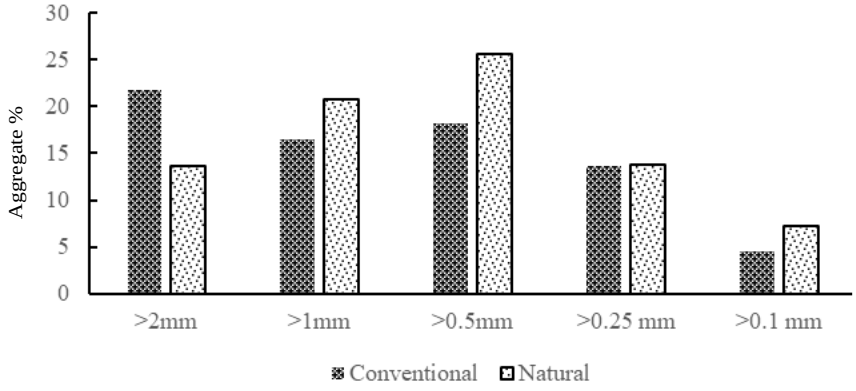

Fig. 1 Aggregates (%) in both agroecosystems

Table 1 Soil organic matter (SOM) and water holding capacity in both agroecosystem

Agroecosystem	SOM (%)	Water holding capacity (%)
Conventional	11.82	76.67
Natural	6.18	61.5

No significance difference

The amount of organic matter in the soil depends on many factors, such as its rate of chemical and biological oxidation, the rate of decomposition of organic matter already existing in the soil, soil texture, aeration, humidity and climatic factors. Crop management practices can also influence this parameter, since, for example, the use of mineral fertilizers accelerates the decomposition of the organic matter in the soil. The water holding capacity depends on its texture, its structure, and the depth of the roots. That is why the results relate to the fact that there is more organic matter, larger aggregates, and better retention in the conventional agroecosystem (Table 1).

These results may be related to conventional agricultural management. They use synthetic fertilizers, fungicides, and pesticides, but they also make crop rotations and incorporate animal manure as an organic amendment. On the other hand, in Natural Farm for many years, no amendments have been incorporated, only making crop rotations.

Table 2, total nitrogen analysis measures N in all organic and inorganic forms. Nitrate nitrogen (NO_3-N) is important because it is the primary form of nitrogen available to trees and, therefore, an indicator of nitrogen soil fertility. However, soil concentrations of NO_3-N depend upon the biological activity and may fluctuate with changes in soil temperature, soil moisture, and

other conditions. Nitrate is also easily leached with rainfall or irrigation. Most ammonia is produced by bacteria in water and soil as a product of plant and animal waste decomposition. It is found in relatively low nontoxic concentrations in soil and provides a source of nitrogen for plants. Ammonium rarely accumulates in soil because bacteria will rapidly convert the ammonium that is not taken up by plant roots into nitrates (nitrification).

Table 2 Chemicals properties in both agro ecosystem

Agroecosystem	TN (mg/kg)	TP (mg/kg)	NO_3 (mg/kg)	NH_3 (mg/kg)
Conventional	2343.33	267.14	0.15	6.86
Natural	1563.33	370.00	0.13	5.57

No significance difference

Even the results are no significance difference, indicate that there was a higher level of nitrogen in the Conventional Farm than in the Natural ones, but, in the total phosphorus, the case was the opposite. P deficiency being common in weathered and tropical soils throughout the world, by rising costs of P fertilizer, and because efficiency of P use by plants from soil and fertilizer sources is often poor despite containing a relatively large amount of total P that is sparingly available to plants. Soil P exists predominantly in inorganic fractions that adsorb to mineral soil surfaces or appear as poorly available precipitates and in organic forms that adsorb, incorporate into biomass, or associate with soil organic matter (Richardson and Simpson, 2011). Although no significant difference was found, the value of TP in the Natural Farm is higher, which can indicate related to the microbial biomass. Thus, it can also be related to the organic content, which was higher in Conventional Farm. Other parameters need to be analyzed to be able to discuss them further.

Soil Biological Properties

Soil microorganisms affect attributes like aggregate formation and water movement. In addition to fertility, soil microorganisms also play essential roles in the nutrient cycles that are fundamentally important to life on the planet. The microorganisms that live in the soil and interact with the other components, varies greatly depending upon conditions and it is highly complex and dynamic. The most numerous microbes in soil are the bacteria, followed in decreasing numerical order by the actinomycetes, the fungi, soil algae and soil protozoa. Soil microorganisms are both components and producers of soil organic carbon, a substance that locks carbon into the soil for long periods. Abundant soil organic carbon improves soil fertility and water-retaining capacity.

Table 3 indicates that in the number of colonies formed in both fungi and bacteria there were more in the Natural agroecosystem. In addition, soil microbial biomass also it was found more in Natural agroecosystem than Conventional agroecosystem. Although with these results its richness and abundance of species cannot be determined, it could be thought that microorganisms are essential to maintain a healthy soil. This is because in the Natural Farm, for more than 20 years no type of amendments has been incorporated. It is that its maintenance of functioning in the soil depends 100 percent on the internal activity that exists between microorganisms, plants and organisms that live in the environment and soil. They could not be correlated with the chemical and physical properties, but this can be thought to be related to the management that the Conventional agroecosystem had. The Conventional agroecosystem, add manure, synthetic fertilization, pesticides and fungicides. Pesticides and fungicides are known to affect the microbial population rapidly, which may be the reason why there is less in the results obtained. In addition, another practice that they carry out is weeding. In Natural Farm, they only weed in the first growth stage of the crop. On the other hand, in the Conventional Farm, they try to keep the soil without weeds. This practice could be affecting microorganisms. According to Massenssini et al. (2014), the soil microbial community structure might change depending on the crop species. Studies have shown that the relationships of weeds and crops with the soil microbiota may be different. Weeds seem to

show higher dependence on interactions with soil microorganisms. The structure of the soil microbial community is responsive to competition between plants. In general, the competition promotes changes in the soil microbial community structure, making it different from that found when plants are grown in monoculture. Furthermore, weeds tend to have positive feedback interactions with soil microorganisms, while crops may present neutral or negative feedback interactions.

Table 3 Biological properties in both agro ecosystem

Agroecosystem	Number of colony forming units/g dry soil		Total microbial biomass (μg/g)
	Total culturable fungi	Total culturable bacteria	
Conventional	6.92×10^{1a}	3.15×10^{3A}	0.16^{α}
Natural	1.71×10^{3b}	1.10×10^{4B}	0.22^{β}

a, A, α significance difference p> 0.05

CONCLUSION

The difference between both farms is by using fertilizers and pesticides. The Natural Farm is not adding any amendments for 20 years. Furthermore, Conventional Farm use more manure than chemical fertilizers. Pesticides affect the survival of soil microorganisms more severely than other practices carried out by the farm. The diversity of plant roots helps to maintain soil microorganism diversity and abundance.

Interdisciplinary soil research is necessary to better understand the biological properties of soil. To maintain the sustainability of the production it is necessary to maintain the population of soil microorganisms. Further research is needed to understand the correlation with chemical and physical properties. As well as to begin to understand the function that each group of bacteria and fungi has, its relationship with other living organism in the soil.

The production system influences the diversity of arthropods and microorganisms in an agricultural ecosystem. Therefore, if a system cannot conserve or increase agricultural land biodiversity, it will be more unstable and poor health of the soil ecosystem.

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Research article

Farmers' Organic and Inorganic Fertilizers Application and its Effects on Rice Productivity in Prey Chhor District, Kampong Cham Province

MUY LEANG KIM
Graduate School of Agriculture, Tokyo University of Agriculture, Japan
Email: muyleangkim70@gmail.com

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan /
Institute of Environmental Rehabilitation and Conservation, Tokyo, Japan
Email: m-mihara@nodai.ac.jp

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Abstract Kampong Cham Province is located in plain region of Cambodia. The major activity of people in the province is agriculture, mainly cultivating rice and vegetables. More than 60% of farmers in Kampong Cham Province applied chemical fertilizers inappropriately without understanding on its impacts. The use of high rates of chemical fertilizers continuously for several years, often lead to unsustainability in production and post harmful to the environment. Recent years, with the support from the government and non-governmental organization (NGOs), many farmers realized and look for a better agricultural practice which could harmonize with natural environment and human health. Several practices were carried to promote the use of organic fertilizers such as green manures, compost, and bio-liquid fertilizer in Kampong Cham Province. The use of organic fertilizers it can reduce the input of chemical fertilizer, improve soil, water, and environment quality. Therefore, the objectives of this study are to describe farmers' practices on fertilization and discuss the effect of fertilization practices on productivity in Samraong and Baray Communes. Ones hundred farmers were selected for interview with questionnaire surveys on agricultural practices in Samraong and Baray Communes. The results from the questionnaire surveys showed that more than 70% to 80% of farmers in Samroang and Baray Communes applied organic in combination with inorgnaic fertilizers and less than 20% use only inorganic fertilizers and 10% only organic fertilizer. The amount of rice production in each fertilization practices was different, the rice production in organic fertilizer practices was high compared to other fertilization practices in Baray Commune, however, in Samraong Commune the rice production was high in chemical fertilization practices. As farmers in Samraong Commune used more chemical that is why the production was high compared to other fertilization practices.

Keywords organic farming, inorganic fertilizers, compost, sustainable agriculture, Kampong Cham

INTRODUCTION

Plant nutrients are essential for the growth and productivity of crops. Farmers supply nutrients in the form of organic and inorganic fertilizers. Recently, farmers in Asia have increased the use of inorganic fertilizers over organic fertilizers, however, integration of both organic and inorganic fertilizers helps to increase crop productivity, soil fertility and decreases the damage that can be introduced by inorganic fertilizers. Moreover, farmers in Kampong Cham Province still lake knowledge regarding the advantages and disadvantages of applying organic and inorganic fertilizers.

Kampong Cham Province is located on the plain region of Cambodia. The province consists of 9 districts and 1 municipality, 109 communes and 916 villages. The total population of this

province is about 1.6 million people in 2013 (JICA, 2013), which accounts for 12.5% of the total population of Cambodia. The population is comprised of 80% farmers, 1% craftsmen, 14% service providers and 5% engaged in other businesses. Agriculture activities of people in Kampong Cham Province are changing from subsistence to commercial monoculture with increased use of inorganic fertilizers.

Organic and inorganic fertilizers are important for achieving an increase in crop productivity (Tong, 2010), if there is enough supply of nutrients to the soils, crop will grow well and produce high yields. Application of organic fertilizers, compared to inorganic fertilizers, maintain soil quality by increasing soil organic matter as well as improve soil physical and chemical properties through decomposition of its substances (Mader et al., 2002). Additionally, Farmers in Baray Commune, Prey Chhor District of Kampong Cham Province has been applied organic fertilizers for more than 10 year which results in better soil properties with organic fertilizer application. Compared to that in Samraong Commune, farmers applied organic fertilizer for only 5 years in results there was not clearly shown the influence of organic fertilizer application on soil properties (Kim and Mihara, 2018). Therefore, the study focused on investigating farmers fertilization practices and the effect of fertilization practices on n productivity in Samraong and Baray Communes, Prey Chhor District, Kampong Cham Province.

OBJECTIVE

The objectives of this study are to investigate and describe farmers' fertilization practices and to discuss the effect of different fertilization practices on rice productivity in Samraong and Baray Communes.

METHODOLOGY

Study Site

The study is focused in Samraong and Baray Communes in Prey Chhor District, Kampong Cham Province (Fig.1).

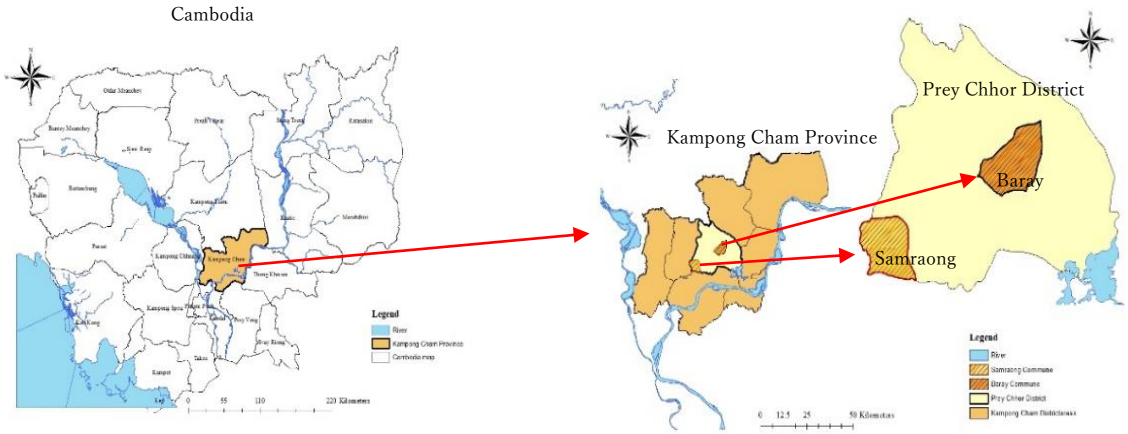

Fig. 1 Maps of the study areas and location of Samraong and Baray Communes, Prey Chhor District, Kampong Cham Province

Samraong Commune consists of 11 villages and 1,714 households, the farmers in this commune own cultivation land less than 1 ha. The main crops produced are rice and vegetables with main soil types being brown hydromorphics, regurs and cultural hydromorphics. The number of farmers that applied chemical fertilizer or inorganic fertilizers were 1,587 out of 8,123 peoples.

Baray Commune consists of 13 villages, 2,446 households, with average cultivation land less than 1 ha. The main crops cultivated are rice and vegetables. The soil types are the same in both communes, In Bary Commune, 1,479 farmers out of 10,637 people used chemical fertilizer (CDB, 2010).

Data Collection and Analysis

Secondary data collection: Relevant documents were collected from the research institutions journals and reports of the project implement and the experts who had studied in the study areas.

Primary data collection: Ones hundred farmers were selected randomly for interview in Samraong and Baray Communes. The contents of the interview and questionnaire surveys mainly focused on the general information of farmers, and agricultural condition, especially on soil fertility management.

Fig. 2 Conducting questionnaire survey

Data analysis: To describe farmers fertilization practices and amount of fertilizer applied, total nitrogen was used for calculating the amounts of fertilizers used in the study areas. Based on interview and questionnaire surveys the total amounts of nitrogen applied in each fertilizer was calculated with equation (1). Based on total amount of nitrogen applied, the degree of organic and inorganic fertilizers dependency was calculated with Equations (2) and (3).

$$\text{Total N (kg/ha/yr)} = \frac{Amount\ of\ fertilizer\ applied\ (kg/ha/yr) \times\ n\ \%\ (nitrogen\ of\ the\ fertilizer)}{100} \quad (1)$$

$$\text{Organic Fertilizer Dependence (OFD\%)} = \frac{\sum N\ in\ Organic\ fertilizer\ (kg/ha/yr)}{\sum Total\ N\ ((kg/ha/yr))} \times 100 \quad (2)$$

$$\text{Inorganic Fertilize Dependence (IFD\%)} = 100 - \text{OFD\%} \quad (3)$$

RESULTS AND DISCUSSION

Types of Fertilizers Uses among Responded Farmers

Based on the interview and questionnaire survey on fertilizers practices of farmers in Samraong and Baray Communes showed that farmers applied Urea and Diammonium phosphate (DAP) as inorganic fertilizers and manures and composts as organic fertilizer. The Urea, DAP and manure or compost fertilizer all contained nitrogen content. The commercial rate of nitrogen content in Urea is 46% and DAP is 18%. However, Kim and Mihara in 2018 analyzed the nitrogen content in Urea, DAP and manure used by farmers in Samraong and Baray Communes showed that the nitrogen in inorganic fertilizers were low compared to the commercial rates (Table 1).

Table 1 Common types of fertilizers applied and the nitrogen content of fertilizers

Name	Chemical formulae	N%	N% *
Urea	$CO(NH_2)_2$	46	43.37
Diammonium phosphate (DAP)	$(NH_4)_2 HPO_4$	18	15.43
Manure or compost			0.36

** Nitrogen content by Kim and Mihara, 2018*

Fig. 3 Chemical fertilizer (left) and compost manure (right)

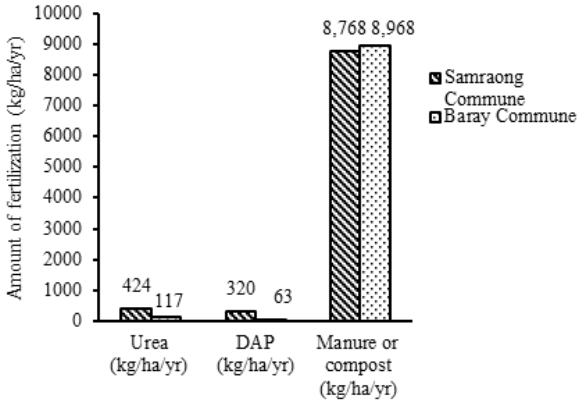

Fig. 4 Amounts of fertilizer applied in Samraong and Baray Communes

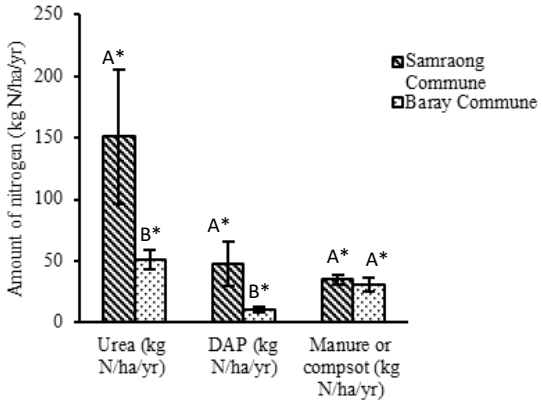

Fig. 5 Amounts of nitrogen applied in Samraong and Baray Communes

Farmers in Samraong and Baray Communes applied Urea in average is 424 kg/ha/yr and 117 kg/ha/yr, DAP is 320 kg/ha/yr and 63 kg/year/ha, and manure is 8,768 kg/ha/yr and 8,968 kg/ha/yr, respectively (Fig. 4). The amounts of fertilizers used in each fertilization were converted to the amounts of nitrogen contents (Fig. 5). As the results showed fertilizers applied in both Samraong and Baray Commune were significantly different in 95%, especially in inorganic fertilization practices. Farmers in Samraong Commune applied higher inorganic fertilizers than farmer in Baray Commune.

Farmers' Fertilization Practices

Farmers in Samraong and Baray Communes practiced organic, chemical, and organic in combination with chemical fertilizers. There were 4%, 12% and 84% of farmer household who applied organic, inorganic, and combine in Samraong Commune, respectively. 8%, 16% and 76% of farmer applied only organic, inorganic, and combine in Baray Commune, respectively (Fig. 6). As the result, both communes are likely combining organic and inorganic fertilizers for agricultural production.

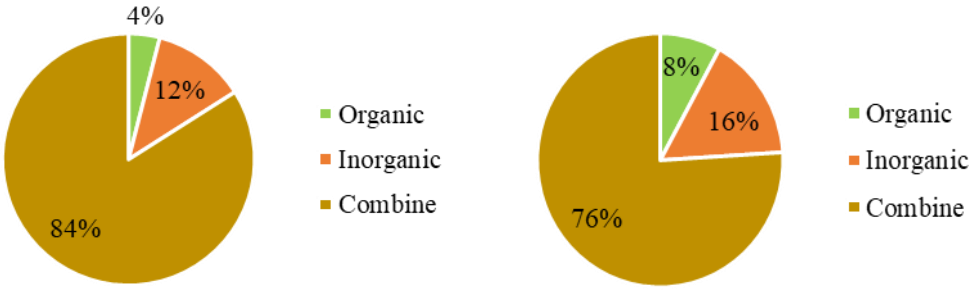

Fig. 6 Comparison between farmer households who applied different fertilizers in Samraong (left) and Baray Communes (right)

The amounts of nitrogen used in Samraong and Baray Communes in each fertilization practices were different. In Samraong Commune, nitrogen usage was high in inorganic fertilization practices and combine compared to organic fertilization practices. However, in Baray Commune the amounts of nitrogen use in organic, inorganic, and combine were not different. As comparing the nitrogen use in both communes showed that farmers in Samraong Commune applied more nitrogen in inorganic fertilizers and combine of organic and inorganic fertilization practices.

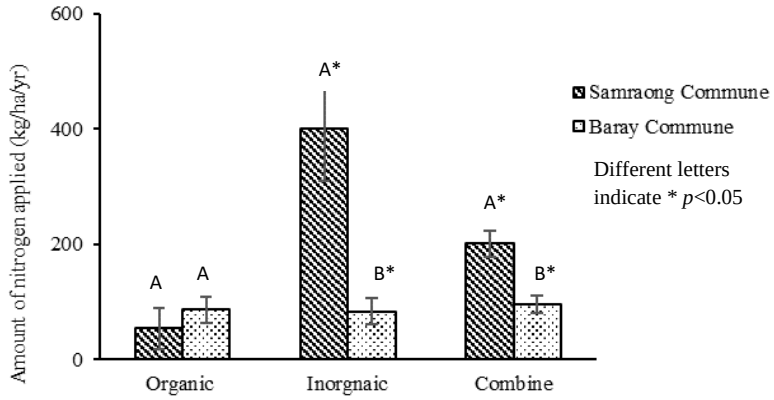

Fig. 7 Average amounts of nitrogen applied in each fertilization practices (kg/ha/yr) in Samraong and Baray Communes

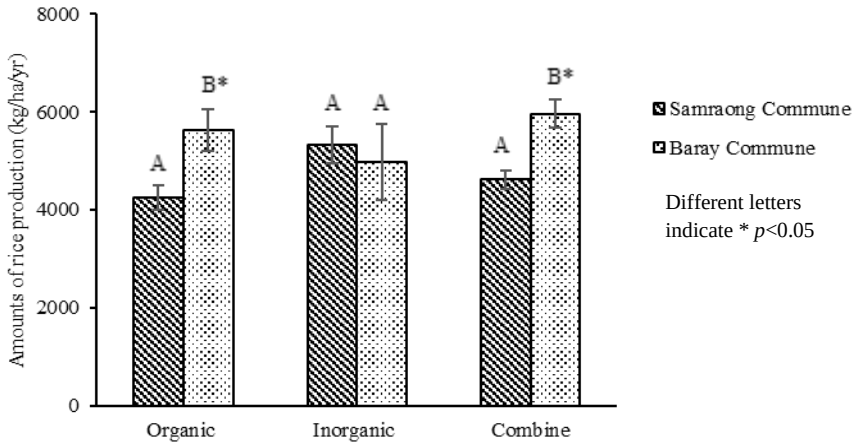

Fig. 8 Amounts of rice production (kg/ha/yr) in Samraong and Baray Communes

Effect of Different Fertilizer Practices on Rice Productivity

The amounts of rice production were significantly different at 95% interval in each fertilization practices in Samraong and Baray Communes. Comparing rice production between Samraong and Baray Communes showed that the rice production shown higher in organic and combine of organic and inorganic fertilizer practices in Baray Commune (Fig. 8). Also, the rice production was not different in inorganic fertilization practices in both communes. It was considered that organic fertilizer application helps to increase the rice productivity in Baray Commune. As farmers in Baray Commune applied less chemical and more organic fertilizer for long term, when organic fertilizer has been applied for long time, the production was high indicating on good soil quality.

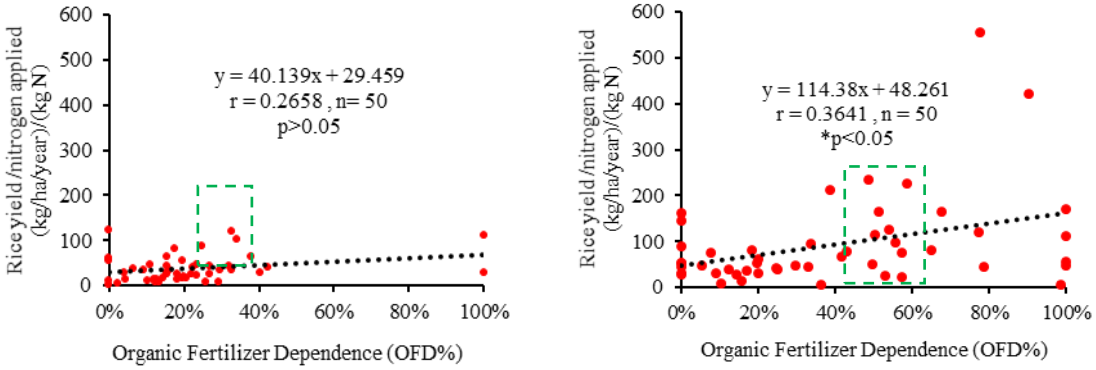

Fig. 9 Amounts of rice production (kg/ha/yr) in Samraong (left) and Baray Communes (right)

There was positive ration between organic fertilizer dependence (OFD%) and rice yields per nitrogen applied at 95% confidence interval in Baray Commune. The combine of organic fertilizer from 50% to 60% with inorganic fertilizers showing good results to increase the productivity in Baray Communes (Fig. 9). However, in Samraong Commune the good rate of organic fertilizer in combination with inorganic fertilizer was from 30% to 40%. As the results the combined application of organic fertilizers such manures or compost and inorganic fertilizer enhanced tiller number, panicle length and yield attribute of rice compared to only inorganic fertilizers application (Kakar et al., 2020).

CONCLUSION

Farmers in Samraong and Baray Communes combined organic and inorganic fertilizers, there are also a few farmers who applied only organic or only inorganic fertilizers. The main sources of nitrogen for farmers in Samraong Commune are likely from inorganic fertilizer, while in Baray Commune the sources of nitrogen both from organic and inorganic fertilizers. The use of nitrogen in Samraong Commune in inorganic fertilization practice and combine was higher, while the rice production was lower compared to Baray Commune. Farmer in Samraong applied more inorganic fertilizer, but the rice production was not different compared to Baray Commune when farmers applied fewer inorganic fertilizers. Organic fertilizer application helps to increase in rice productivity in Baray Commune, as farmers in Baray has been applied organic fertilizer for more than 10 years and less inorganic fertilizers. It was considered that when organic fertilizer has been applied for many years like Baray Commune, the production was high in organic fertilization and combined. Inconclusion of more organic fertilizer and less inorganic is strongly recommended to farmers in Samraong and Baray as organic fertilizer contributed to increase the rice productivity.

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Research article

Shedding Light on the Gender Gap in Cambodia's Agriculture Sector - A Case of Agricultural Cooperation in Kampong Cham Province

MARI ARIMITSU*
Extension Center, Institute of Environmental Rehabilitation and Conservation, Japan
Email: m.arimitsu@gmail.com

SHINOBU YAMADA
Research Center, Institute of Environmental Rehabilitation and Conservation, Japan

KUMIKO KAWABE
Extension Center, Institute of Environmental Rehabilitation and Conservation, Japan

MACHITO MIHARA
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan

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Abstract This study deals with the status of women who engage in agricultural practices in Kampong Cham Province, Cambodia. Specifically, it dissects the selection processes to determine which gives participant farmers access to training opportunities provided by an international non-governmental organization. The research was conducted to provide gender-disaggregated data while elucidating the gender gap that exists in opportunities for equal participation in and access to training and women's role within Cambodia's agricultural sector based on data analysis for the baseline survey and key informant interviews. This study concludes that there are specific gender roles, norms and biases, either visible or invisible, embedded and/or expected in the local community. These traits were manifested by participant farmers as well as officers who were responsible in selecting farmers. Individual interview revealed that gender norms regarding men as the head of the house and illiteracy were mentioned as two possible factors hindering women from participating in agricultural training, but when leaders who were responsible in selecting farmers were mindful about equal gender ratio, they could bring equal numbers of female participants. In order to ensure gender equality in access to skills development opportunities in the agricultural sector, trainings should focus on building effective program, and optimizing and acknowledging current female farmers' roles and contributions in the agricultural and development sector of the rural economy.

Keywords gender equality, sustainable agriculture, rural development

INTRODUCTION

A global commitment, Sustainable Development Goal No. 5, is a stand alone goal to end all kinds of discriminations against women and girls and also to empower them (United Nations). Similarly, Cambodia's 5-year strategic plan (Neary Rattanak) is designed to support women to access and claim their right to fully participate and benefit from economic and social development, and also participate as decision makers. Agricultural extension services play an essential role in agricultural development, poverty reduction, and food security (Feder et al., 2011), but women often lack the resources and opportunities they need, and face more severe constraints than men in accessing productive resources, markets and services (Raney et al., 2011). Agricultural extension services are particularly needed by smallholder farmers in developing countries as they usually have low levels

of education and limited access to information and resources to enhance their capacity and level of productivity.

The project on "Promoting Sustainable Agriculture Conditions for Poverty Reduction in Kampong Cham Province" is currently being implemented by an international organization based in Japan. The target populations are more than 25 local agriculture extension officers and 1,500 local farmers in the region where agro-chemical and their improper application is prevalent. According to FAO statistics, Cambodia's total fertilizer use increased from 38,693 tons in 2005 to 134,053 in 2018. The project was designed to alleviate farmers' poverty and improve their livelihood conditions by intoroducing and disseminating sustainable agricultural practice. Throughout the project, participant smallholder farmers have learned the techniques of sustainable agriculture, including composting, pellet composting, pest and disease management so that they can reduce the use of synthetic products which economically burden them and are harmful to the human bodies and environment. In the third year of the project, they will gain techniques on the collecting and shipping process so that they can sell their safer products with added price. The objectives of this study are 1) to elucidate the situation of the women's participant to the trainings that are to eradicate the poverty and bring knowledge and technique on sustainable agricultural practice and analyze the participation rate and the cause of it, and 2) to conduct analysis based on the interview over women's role and contribution to the agricultural management, which includes the management of the marketing, and the needs of the training.

METHOLODOGY

This study adopted both quantitative and qualitative approaches. The baseline survey of 500 principal farmers gathered in 2018 were examined in order to recognize the gender disaggregated data and elucidate the situation of the women's participant to the training. Additional key informant interviews with 40 individual female farmers and ministry officers were conducted in 2019 to complement the information which was missing from the original baseline survey. The interview was structured in accordance with the gender analysis, which examines how the roles, rights, and responsibilities of men and women interact and how that affects outcomes (Doss, 2013). The semi-structured questions were particularly focused on intersection between gender and recruitment, participation and women's roles and their needs in the region: 1) the process of how they were selected, 2) gender roles in agricultural practice, what are their everyday work in the field and at home, 3) does the training provided by the organization meets the needs and requests of women. Analysis included looking at the gender norms and the implications of those relationships on women's ability to participate in the training on sustainable agriculture. Interviewees were the participants and beneficiaries of the three-year project who know what is going on in the field.

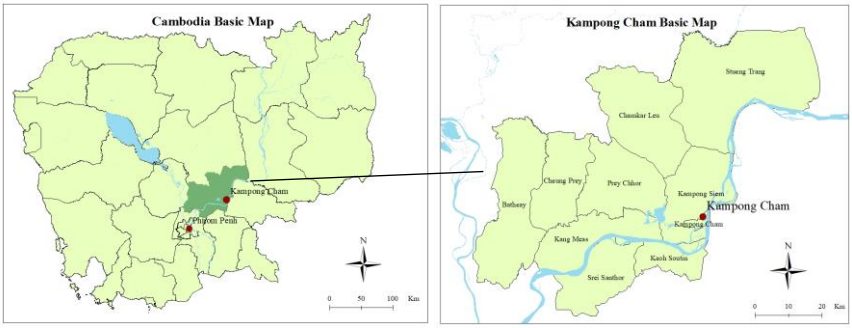

Fig. 1 Location of the study area of Kampong Cham Province and 10 districts

The target population was selected across nine districts in Kampong Cham Province that is Prey Chhor, 8; Batheay, 6; Srei Santhor, 3; Cheung Prey, 8; Kampong Siem, 5; Kang Meas, 2; Kaoh Soutin, 1; Stueng Trang, 5; and Chamkar Leu, 2. Farmers were selected based on availability and willingness to take part after the training.

RESULTS AND DISCUSSION

The Status of Female Participant's Rate

After the initiation of the project in 2018, a baseline survey was conducted targeted 500 participating farmers and was examined as gender segregated data. The baseline survey shows that the principal farmers consisted of 333 male participants (67%) and 167 female participants (33%). Out of 500 particicpants, 119 male participants (36%) and 59 female participants (35%) answered that they belong to some agricultural group in their villages. The opportunities provided were geographically varied as only four female farmers belong to compost and safe vegetable groups in Kampong Cham District, whereas nine female farmers and 27 male farmers belong to various agricultural groups in Stueng Trang District. The average size of their agricultural land is 1.07ha. The educational background was categorized by 1) Never been to school, 2) Primary school, 3) Secondary school, 4) High school, 5) College, 6) University. For all age groups, on average, men have a slightly higher educational background (2.43) whereas women's average is 2.23. According to the age group, both men and women hold particularly lower educational backgrounds in their 40s and 50s, particularly in their 50s (Female: 1.86, Male: 2.33). This can be from the fact that they were directly effected by the internal conflict within Cambodia during the 1970s where people's educational opportunities were deprived. Cambodia's gender gap in adult literacy rate is significantly improved in recent years, but the gap remains for elderly populations (UNESCO, 2015). The participants' age varies, but the average age of male participants is slightly higher than female participants (Female: 45 and Male: 47). The baseline survey didn't specify whether the household is either female or male. Hence, the income gap between male and female participants is not obtained. When they were asked what techniques they need, female farmers were particularly interested in seeds (48%), organic fertilizers (47%), planting (35%), and marketing (28%), where as male farmers showed their interests in organic fertilizers (47%), seeds (44%), planting (30%), and marketing (27%).

Fig. 2 Technical training on pest and disease management (farmers making bio-pesticide)

The first training for 500 principal farmers was conducted from December to March 2018 with the theme of "Improvement of Soil Fertility". It was a one-day training held in two different communes from 8:00 a.m. to 4:30 p.m. The venue was optimized in each district such as model farmers, Department of Agriculture offices, or community space. The training covered the role and function of soil in agricultural land, compost, pellet compost, and liquid fertilizers, and was led by trained ministry officers. The training included a demonstration on how to make compost and liquid fertilizers. The second training for the same principal farmers was conducted from January to March 2019 with the theme of "Pest and Disease Management" with adjustment of the time for the morning session to cocomplete earlier so that female farmers can return back their home for lunch preparation. The training focused on Integrated Pest Management (IPM), proper use of chemical fertlizers, and technical and practical knowledge about pest and disease control. The training also included a demonstration on how to make bio-pesticide (Fig. 2).

According to Table 1, the participating numbers of women were disproportionately small compared to that of men. However, in Cheung Prey, Kampong Cham, Kampong Siem Districts, the

female farmers were closer to half of the participants. In contrast, in Chamkar Leu District, the numbers of female participants were only 16% (Table 1).

Table 1 Numbers of principal farmers in the baseline survey conducted in 2018

District	Batheay	Chamkar Leu	Cheung Prey	Kampong Cham	Kampong Siem	Kang Meas	Kaoh Soutin	Prey Chhor	Srei Santhor	Stueng Trang
Male (%)	72%	84%	58%	54%	51%	72%	58%	69%	72%	74%
Female (%)	28%	16%	42%	46%	49%	28%	42%	32%	28%	26%

Source: Baseline Survey and List of Participants for Improvement of Soil Fertility in 2018

The individual interviews with the female farmers revealed how individual participants were chosen: 1) the specific individual participant was directly appointed by the local authority, or 2) the household of the participant was appointed by the authority, then a discussion was held within the house to designate the actual participant. Out of 35 participants interviewed, five answered that they were directly appointed by the authority. Four answered that the authority appointed their husbands. In the remaining 26 cases, participant selection was done within the family members based practical reasons such as availability and not on the notion that in a traditional gender role the important meetings and trainings are attended by men. Several farmers decided to rotate participation during the course of the trainings. One of the interviewees in Batheay said she was encouraged by the authority to rotate the participation when they are busy. The participants were mostly either husband or wife, but a few interviewees rotated the participation with their children. There were eight cases where husbands work in a non-farming sector, especially during the dry seasons from around December to May in Cambodia. One has gone to the Thailand to generate more income. 12 female farmers out of 35 participants came to the second training on "Pest and Disease Management" instead of their husbands or other family members. Hence, male and female participation is fluid, and the analysis of the baseline survey data may not cover the actual gender ratio as well as gender segregated data of the participants. The rate of the female participants was dramatically increased in some districts for the second training. For instance, in Cheung Prey, male participants in the first theme of the training, Soil Fertility, outnumbered the female, but at the second training on the theme of the Pest and Disease Management, female numbers significantly increased (Table 2).

Table 2 Numbers of principal farmers who participated in the second training in 2019

District	Batheay	Chamkar Leu	Cheung Prey	Kampong Cham	Kampong Siem	Kang Meas	Kaoh Soutin	Prey Chhor	Srei Santhor	Stueng Trang
Male (%)	-	85%	14%	60%	47%	58%	64%	66%	52%	63%
Female (%)	-	15%	85%	40%	53%	42%	36%	34%	48%	37%

Source: List of Participants for Pest and Disease Management in 2019

The key informant interview was also conducted with five chief ministry officers, consisting of one female and four males, who were responsible of selecting participant farmers. The officers from Cheung Prey and Kampong Siem noted their participants were selected by a Village Leader and a Commune Leader. For Cheung Prey District, the two leaders were sensitive to the gender ratio and tried to have equal numbers of male and female participants, although the officer himself was not aware of it. Similarly, a female officer in Kampong Siem wasn't aware of the gender neither ratio nor gender equality, but the leaders were. Prior to this project, both districts have provided some trainings on microfinancing and chicken raising specifically to female farmers. Evidently, the ratio of female participants was higher in those two districts compared to other districts (Table 1 and 2). The officer in Srei Santhor said he was conscious about gender equality and selected the participants simply based on people who are more actively engaging in agriculture, however, the female participant rate was relatively low in the two trainings. Additionally, the female participation rate was significantly low in Chamkar Leu District (Tables 1 and 2). A male

officer from Chamkar Leu answered that they appointed the household along with the Village Leader, and appointed the persons who actually do the farming and those are naturally males. Other noted from Chamkar Leu District that as much as they wish to include females, when they visited their houses, they usually ask their husbands who are the head of the house to respond to the officers. A male officer from Prey Chhor mentioned that females are relatively illiterate and they are not willing to join this kind of training. Gender norms regarding men as the head of the house and illiteracy were mentioned as two possible factors hindering women from participating in agricultural training, but when leaders who were responsible in selecting farmers were mindful about equal gender ratio, they could bring equal numbers of female participants.

The Roles of Female in Agricultural Practice and Access to Market

In this section, this paper will discuss about the roles and contributions of the female farmers in their agricultural practices in Kampong Cham Province. In details, the interview was conducted to study if there are any particular work that female farmers bear and also what kind of trainings are needed in the area. According to the key informant interviews with 35 farmers, specific gender roles exist in agricultural practices in the region. Most of the female interviewees answered that they engage in broad tasks such as soil preparation; preparing, making and applying the fertilizer and compost; sowing; collecting weeds; and drying rice after products are harvesting; and selling the products was largely taken care by women, whereas men engage in seemingly physically harder and mechanical tasks such as ploughing, harvesting, and spraying the pesticides. When they are raising the vegetables, female farmers bear more tasks including the harvesting. Most of the interviewees sell the products to the middle persons, and women are actively involved in the negotiation process. In the case of a single mother or a woman whose husband is disabled or working in the non-agricultural sectors, they employee other men and women to engage in their fields. Some of them bear more tasks than other women who work with their husbands. They tend to express more power than the other female interviewees, which was manifested by their use of phrases such as “male and female can do the same”, “there are no specific gender roles in agricultural field”, and “the training being provided by the organization will equally benefit both men and women”. On the other hand, women’s work in an agricultural field across the nine districts was xpressed in words such as “small” and “not too much”, due to the gravity of the physical workload.

At their households, all the female workers perform traditional gender roles: cooking, taking care children and livestock, or growing vegetables around the houses. The male officer in Chamkar Leu, too, generalized that house work is normally the work of women. Some of their husbands support the wife’s role in doing such tasks carrying water, cooking, taking care of children. Many of the interviewees were engaged solely in agricultural practice, but the interviewees also revealed that a few female participant farmers engaged in work outside of the agricultural field, such as working at a factory or crafting weed mattresses at home in order to seek the additional income for the family. However, according to the participants, women face severe constraints due to lack of knowledge and skills in a non-agricultural sector or their elderly age as factories or companies favour younger women as their employees. A study by Gender and Development of Cambodia in 2010 (Ministry of Women Affairs, 2014) noted that men perceive that they should fulfill the role as the head of the house, and women perceive normalizing male privilege. Consequently, women tend to see their capacity and power lower than men in the society. The interview showed that female farmers bear broad range of agricultural practices as well as domestic work, but some of them seen their ability lower than male partners, which may be based upon the traditional gender norms prevailing in the country.

Lastly, female farmers expressed concerns about the fixed marking price provided by middle persons. Some of them noticed that the selling price to the customer is a lot higher than the farmers’ sold price, but they see that there is no way that they can increase the value of it. Out of 35 interviewees, 20 expressed the need of the marketing skills. A female farmer answered that there seems to be no connection between the producer and the consumer because she sells it to a middle person. They want to build a strong relationship between the two. Building a relationship between

the producer and customer is a growing trend in agriculture throughout the world, and this can be promoted during the course of the project. Due to the low price that is given from the middle persons, two female farmers tried to sell the products in the market, but they faced multiple difficulties ranging from finding a spot in the market place to selecting a suitable price and attracting regular customers. One of them expressed the concern over transportation as she uses her own motorbike that she cannot carry many products at one time. The access to the local market was also depending on the geographical location of the marketplace versus where they live. The above two female farmers in Kang Meas and Kampong Siem Districts were able to access the local market because it is accessible from their houses. The marketing skills will benefit women greatly because majority of sellers in the market consist of female workers in Kampong Cham Province. Participating female farmers shared the information and techniques with husbands or other family members, and what they have learned is being practiced at their farmland. However, they are also seeking other specific trainings such as raising chickens, ducks, cows, fish, and crafting that they can do while doing the housework at home.

CONCLUSION

The knowledge gained in this study can be summarized as follows. First, regarding the trainings on promoting sustainable agricultural conditions for poverty reduction, the 2018 baseline survey showed that participating male farmers significantly outnumbered the female farmers. However, the participation in the second training revealed that the ratio of male and female participating farmers is fluid as some of them rotate the participation in accordance with their availability. In two districts, female farmers outnumbered the male farmers in 2019, where the persons who directly involved in the election process were particularly aware of having the equal numbers of men and women. Interviews lso revealed the gender biased selection methods by the officers who were responsible in selecting farmers at the initial stage. Secondly, female farmers bear broad range of agricultural practices, even though some of them seen their ability lower than male partners, which is based upon the traditional gender norms prevailing in the country. Female farmers would come to the training if the content is related to their regular work that they do in the field, such as soil preparation, pest and disease management, and the marketing. It is also a key to design the timing, period, and venue of the training when female farmers can participate, as their reproductive work at home is widely normalized. Additional training and/or awareness raising may be necessary for the local authorities who are responsible in selecting farmers in order to disrupt the gender biased selection process. The interview with the female farmers mentioned the higher needs of the training in marketing in the region, and some of the challenges they face. Their needs are also varied beyond the basic agricultural techniques. Therefore, in order to reduce the inequality for female farmers in getting agricultural information and knowledge, building an effective program based on their actual regular agricultural practice is required.

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Research article

The Influence of Agricultural Production Information on the Agricultural Management Scale in Rural Areas of Cambodia

SHINOBU YAMADA*
Research Center, Institute of Environmental Rehabilitation and Conservation, Tokyo, Japan
Email: sinobun4022@gmail.com

MARI ARIMITSU
Extension Center, Institute of Environmental Rehabilitation and Conservation, Tokyo, Japan

MACHITO MIHARA
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

KUMIKO KAWABE
Extension Center, Institute of Environmental Rehabilitation and Conservation, Tokyo, Japan

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Abstract The main object of this study was to quantitatively grasp the relevance among local farmers to analyze the characteristics of local farming and agricultural production information to build stable and sustainable farming needed by farmers. The research site was ten districts in Kampong Cham Province, Cambodia. The results of the analysis are summarized as follows: 1) It was confirmed that the index of agricultural production information varies depending on the districts; 2) Based on the Canonical Correlation Analysis results, cultivated land and annual income from agricultural activity, which are regarded to be the results of agricultural management, have relevance among factors such as attributions, crops, and agricultural production information was clarified. The cultivated land is affected by the index, which is aimed at expanding the scale of rice production. In addition, annual income from agricultural activity is affected by an index aimed at high-quality crop production based on new technology information, information about organic fertilizer and training. According to the results of the analysis, agricultural productivity expansions in Cambodia depends on providing information that can be adaptable to the intention of agricultural management of the local farmers.

Keywords Cambodia, canonical correlation analysis, multiple farming

INTRODUCTION

In Cambodia, per capita income has increased along with economic development. Consequently, a demand for various agricultural products in addition to rice has increased resulting in increased production of various agricultural products including vegetables. Currently, in rural areas, many local farmers intend to produce rice as usual, while many farmers produce vegetables and fruits using multiple farming. In order to mitigate poverty in rural areas, it is necessary to produce a variety of crops, centering on rice production, which is expected to expand in the future. The building of stable and sustainable agricultural management is essential. According to this background, the main object of this study was to quantitatively grasp the relevance among local farmers in different districts to analyze the characteristics of local farming and agricultural production information to build stable and sustainable farming needed by the farmers. In addition, this study focuses on multiple farming in Cambodia.

OBJECTIVE

The main object of this study was to quantitatively grasp the relevance among local farmers in different districts to analyze the characteristics of local farming and agricultural production information to build stable and sustainable farming needed by the farmers. The specific analysis of this study has the following two issues: 1) the index of agricultural production information required by local farmers per district; 2) the Canonical Correlation Analysis applies to attributions, crops and agricultural production information are associated with scale of cultivated land and annual income from agricultural activity considered to be a result of farm management. The Canonical Correlation Analysis is used in quantitative analysis of the relation between the agricultural management scale acreage allotment and regional structure (Ohtake and Aoyagi, 1988; Matsumoto, 1998).

METHODOLOGY

The research site was in Kampong Cham Province. Kampong Cham Province is located northeast of Phnom Penh, and southeast of Siem Reap. During the French colonial period, in Kampong Cham Province, the hilly terrain was developed as a rubber plantation zone. The population of Kampong Cham province is approximately 1.75 million and much of the population is engaged in agriculture. The target area of the questionnaire survey consisted of the following ten districts: Batheay district: 45 respondents (10.3% of the total respondents); Chamkar Leu district: 50 (11.4%); Chueng Prey district: 36 (8.2%); Kaoh Sotin district: 46 (10.5%); Kampong Siem district: 38 (8.7%); Krong Kampong Cham district: 48 (11.0%); Kang Meas district: 44 (10.1%); Prey Chhor district: 36 (8.2%); Srei Santhor district: 50 (11.4%); and Stueng Trang district: 44 (10.1%). The total number of respondents is 471, and the number of valid respondents is 437. In Kampong Cham Province, vegetables and fruit trees are widely produced while their main production is rice. As for the vegetables, cabbage and cucumber are often planted and produced throughout the year. Also, various vegetables and fruits including luffa, bitter melon, winter melon, Chinese spinach, leaf onion, lemongrass, green beans, papaya, and cashew etc. are produced. Additionally, at this site, the Institute of Environmental Rehabilitation and Conservation (ERECON) carries out a project on Promoting Sustainable Agricultural Conditions for Poverty Reduction in Kampong Cham Province in Cambodia (October/2017-September/2020). This project aims to promote sustainable farming practices to local farmers based on the cyclic use of natural resources.

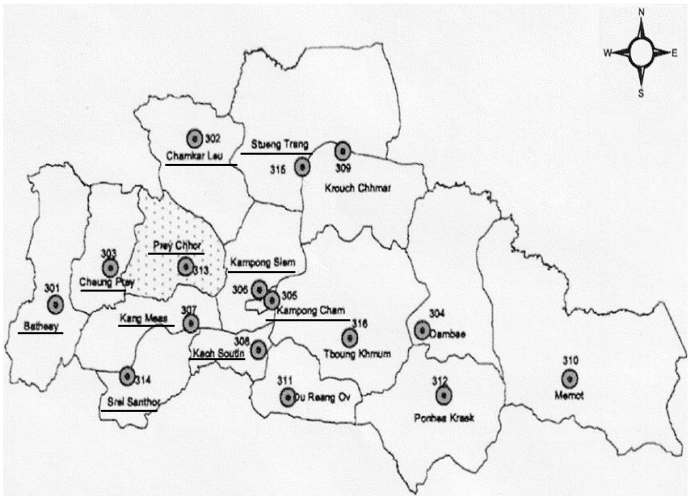

Fig. 1 Location of the study site in Kampong Cham Province

RESULTS AND DISCUSSION

The Index of Agricultural Production Information Required by Local Farmers per District

Table 1 shows the index of the questionnaire survey conducted, which contains categories for gender and age of the respondent, educational background, farm acreage, cropping pattern and farmers' revenues. Table 2 shows segregated results of indicators showing the characteristics of the agricultural production information for each district. In addition, multiple responses are gathered regarding the agricultural production information. For each district, the following characteristics are taken into consideration from the results in Tables 1 and 2.

Table 1 Average of agricultural management scale for each district

		Number of response																					
		All		Batheay		Chamkar Leu		Chueng Prey		Kaoh Sotin		Kampong Siem		Krong Kampong Cham		Kang Meas		Prey Chhor		Srei Santhor		Stueng Trang	
		437		45		50		36		46		38		48		44		36		50		44	
Index		(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
Gender	1. Male	282	64.53	32	0.71	42	0.84	16	0.44	26	0.57	19	0.50	25	0.52	34	0.77	20	0.56	36	0.72	32	0.73
	2. Female	155	35.47	13	0.29	8	0.16	20	0.56	20	0.43	19	0.50	23	0.48	10	0.23	16	0.44	14	0.28	12	0.27
Age	1.Less than 29 years old	17	3.89	2	0.04	3	0.06	0	0.00	1	0.02	2	0.05	0	0.00	1	0.02	1	0.03	3	0.06	4	0.09
	2.30-39years	113	25.86	15	0.33	20	0.40	7	0.19	6	0.13	10	0.26	7	0.15	14	0.32	7	0.19	8	0.16	19	0.43
	3.40-49years	140	32.04	21	0.47	15	0.30	9	0.25	20	0.43	12	0.32	15	0.31	17	0.39	9	0.25	10	0.20	12	0.27
	4.50-59years	116	26.54	2	0.04	7	0.14	12	0.33	16	0.35	11	0.29	17	0.35	6	0.14	18	0.50	22	0.44	5	0.11
	5.More than 60 years old	51	11.67	5	0.11	5	0.10	8	0.22	3	0.07	3	0.08	9	0.19	6	0.14	1	0.03	7	0.14	4	0.09
Educational	1. Never had been to school	42	9.61	5	0.11	3	0.06	7	0.19	2	0.04	0	0.00	14	0.29	2	0.05	0	0.00	2	0.04	7	0.16
background	2. Primary	228	52.17	24	0.53	34	0.68	21	0.58	20	0.43	22	0.58	17	0.35	20	0.45	18	0.50	25	0.50	27	0.61
	3. Secondary	133	30.43	14	0.31	11	0.22	5	0.14	19	0.41	13	0.34	14	0.29	14	0.32	17	0.47	20	0.40	6	0.14
	4. High school	33	7.55	2	0.04	2	0.04	3	0.08	5	0.11	3	0.08	2	0.04	8	0.18	1	0.03	3	0.06	4	0.09
	5.College/University	1	0.23	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.02	0	0.00	0	0.00	0	0.00	0	0.00
Total	1.Less than 0.5 ha	91	20.82	5	0.11	15	0.30	5	0.14	0	0.00	13	0.34	30	0.63	7	0.16	9	0.25	5	0.10	2	0.05
area	2.0.6-1ha	116	26.54	14	0.31	13	0.26	10	0.28	17	0.37	11	0.29	6	0.13	11	0.25	18	0.50	11	0.22	5	0.11
	3.1.1-1.5ha	117	26.77	12	0.27	10	0.20	14	0.39	13	0.28	6	0.16	8	0.17	16	0.36	3	0.08	25	0.50	10	0.23
	4.1.6-2ha	40	9.15	8	0.18	3	0.06	1	0.03	7	0.15	7	0.18	0	0.00	5	0.11	1	0.03	3	0.06	5	0.11
	5.More than 2.1ha	73	16.70	6	0.13	9	0.18	6	0.17	9	0.20	1	0.03	4	0.08	5	0.11	5	0.14	6	0.12	22	0.50
Cropping	1.Rice	394	0.36	43	0.46	34	0.27	35	0.36	45	0.36	32	0.32	42	0.35	38	0.32	35	0.43	48	0.35	42	0.44
pattern	2.Vegetables	389	0.36	37	0.40	48	0.39	31	0.32	43	0.35	35	0.35	46	0.38	42	0.36	33	0.41	50	0.37	24	0.25
	3.Fruit	307	0.28	13	0.14	42	0.34	32	0.33	36	0.29	33	0.33	32	0.27	38	0.32	13	0.16	38	0.28	30	0.31
farmers'	1.Less than 1,000,000 Riel	30	6.86	0	0.00	1	2.22	8	0.07	3	9.26	7	0.05	2	7.47	0	0.00	6	24.46	3	0.02	0	0.00
revenues	2.1,000,000-2,999,999 Riel	169	38.67	9	0.09	16	35.56	18	0.16	23	70.99	15	0.11	25	93.40	17	0.09	14	57.06	24	0.16	8	23.48
	3.3,000,000-4,999,999 Riel	122	27.92	12	0.12	12	26.67	7	0.06	11	33.95	11	0.08	12	44.83	18	0.10	10	40.76	15	0.10	14	41.08
	4.5,000,000-6,999,999Riel	57	13.04	5	0.05	13	28.89	2	0.02	6	18.52	1	0.01	5	18.68	6	0.03	3	12.23	4	0.03	12	35.22
	5.7,000,000-8,999,999 Riel	32	7.32	10	0.10	4	8.89	1	0.01	2	6.17	4	0.03	1	3.74	2	0.01	1	4.08	2	0.01	5	14.67
	6.More than 9,000,000 Riel	27	6.18	9	0.09	4	8.89	0	0.00	1	3.09	0	0.00	3	11.21	1	0.01	2	8.15	2	0.01	5	14.67

source : Survey Date

In Batheay District, the average annual agricultural income was the highest among the 10 districts. In the order of importance, they valued information about training, information about organic fertilizer, and new technology information. For Chamkar Leu District surveys indicated that more vegetables and fruits were produced than rice, based on the local cropping pattern. The farmers, in order of importance, valued information about organic fertilizer, new technology information and information about seeds. In Cheung Prey District, the average agricultural annual income is the lowest among the 10 districts and respondents have the highest average age. They most valued information about seeds, followed by information about training and market. Kaoh Sotin District has the third largest average management area among the 10 districts. The agricultural production information that was answered as important was in the order of information about seeds, information about organic fertilizer and market. In Kampong Siem District, it has the second lowest average management area and annual income out of 10 districts. The agricultural production information that was answered as important was in the order of information about seeds, new technology information and market information. In Krong Kampong Cham, it has the smallest average management area, because it located in an urban area in the province. The agricultural production information that was answered as important was in the order of information about organic fertilizer, information about seeds and planting information. In Kang Meas District, half of the respondents graduated from secondary school and high school. The agricultural production information that was answered as important was in the order of information about chemical fertilizer, information about seeds and planting information. In Prey Chhor District, almost all local farmers produce rice and vegetables, while fruits production is low. The agricultural production information that was answered as important was in the order of planting information, information

about organic fertilizer and seeds. In Srei Santhor District, the farmers have the third lowest average agricultural annual income among the 10 districts. The agricultural production information that was answered as important was in the order of new technology information, market information, and information about seeds. In Stueng Trang District, the farmers had the youngest average age, and the largest average management area. The average agricultural annual income was also high. They ranked agricultural production information as most important followed by, information about organic fertilizer, new technology information and information about seeds. The composite questionnaire answers the index of agricultural production information varies among the districts.

Table 2 Characteristics of agricultural production information for each district

		Number of response																			
		All		Batheay		Chamkar Leu		Chueng Prey		Kaoh Sotin		Kampong Siem		Krong Kampong Cham		Kang Meas		Prey Chhor		Srei Santhor		Stueng Trang	
		437		45		50		36		46		38		48		44		36		50		44	
Index		(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
Agricultural production information	Information about seeds	194	0.44	8	0.18	14	0.28	29	0.81	28	0.61	22	0.58	22	0.46	24	0.55	17	0.47	13	0.26	17	0.39
	Information about machinery	26	0.06	0	0.00	0	0.00	5	0.14	1	0.02	8	0.21	2	0.04	4	0.09	1	0.03	2	0.04	3	0.07
	New technology information	135	0.31	13	0.29	17	0.34	10	0.28	10	0.22	19	0.50	11	0.23	13	0.30	5	0.14	18	0.36	19	0.43
	Information about chemical fertilizer	32	0.07	1	0.02	4	0.08	4	0.11	3	0.07	8	0.21	6	0.13	1	0.02	4	0.11	1	0.02	0	0.00
	Information about organic fertilizer	199	0.46	18	0.40	18	0.36	13	0.36	24	0.52	15	0.39	30	0.63	30	0.68	18	0.50	12	0.24	21	0.48
	Market information	113	0.26	9	0.20	13	0.26	14	0.39	22	0.48	17	0.45	9	0.19	6	0.14	2	0.06	15	0.30	6	0.14
	Information about training	117	0.27	24	0.53	2	0.04	19	0.53	5	0.11	15	0.39	8	0.17	9	0.20	9	0.25	10	0.20	16	0.36
	Price information	32	0.07	2	0.04	1	0.02	8	0.22	6	0.13	6	0.16	1	0.02	2	0.05	0	0.00	1	0.02	5	0.11
	Information about harvest	15	0.03	0	0.00	0	0.00	4	0.11	2	0.04	4	0.11	1	0.02	0	0.00	0	0.00	0	0.00	4	0.09
	Planting information	138	0.32	5	0.11	10	0.20	13	0.36	21	0.46	6	0.16	18	0.38	19	0.43	25	0.69	6	0.12	15	0.34

Source : Survey Date

Table 3 Estimation results of canonical correlation analysis

			Canonical variables standardized coefficients	
Iindex			CV1	CV2
	Cultivated land	: Y1 (5 levels)	0.9958	0.3476
	Annual income from agricultural activity	: Y2 (5 levels)	0.0129	-1.0547
1	Gender	: X1 (dummy)	0.0467	0.2559
2	Age	: X2 (5 levels)	-0.2296	-0.2613
3	Educational background	: X3 (5 levels)	0.2534	0.0748
4	Rice	: X4 (dummy)	0.698	-0.1882
5	Vegetables	: X5 (dummy)	-0.259	-0.0244
6	Fruit	: X6 (dummy)	0.296	-0.5674
7	Information about seeds	: X7 (dummy)	-0.3184	-0.3051
8	Information about machinery	: X8 (dummy)	0.1119	-0.0629
9	New technology information	: X9 (dummy)	0.1061	0.2414
10	Information about chemical fertilizer	: X10 (dummy)	-0.0442	-0.139
11	Information about organic fertilizer	: X11 (dummy)	0.0296	0.2306
12	Market information	: X12 (dummy)	-0.0133	0.1894
13	Information about training	: X13 (dummy)	0.1343	0.2787
14	Price information	: X14 (dummy)	0.1084	-0.2773
15	Information about harvest	: X15 (dummy)	0.2783	0.0708
16	Planting information	: X16 (dummy)	0.0616	-0.1661

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Note Eigenvalue: CV1; 0.19, CV2; 0.13

The Influence of Agricultural Production Information on the Agricultural Management Scale

In this section, Canonical Correlation Analysis reveals that attribute, crop, and agricultural production information are related to annual income from arable land and agricultural activities and are considered a result of farm management. The Canonical Correlation Analysis is used to identify and measure the associations between two sets of variables. The analysis is applicable in the same way as multiple regression analysis, but it is more suitable when there are multiple objective variables. Therefore, the objective variables of Canonical Correlation analysis are Y1: cultivated land and Y2: annual income from agricultural activity. Further, explanatory variables are X1: gender; X2: age; X3: educational background; X4: rice; X5: vegetables; X6: fruits; X7: information about seeds; X8: information about machinery; X9: new technology information; X10: information about chemical fertilizer; X11: information about organic fertilizer; X12: market information; X13:

information about training; X14: price information; X15: information about harvest; and X16: planting information. In Table 3, the results from the estimation of the Canonical Correlation Analysis are shown in the research site.

According to the results of Canonical Correlation analysis, Canonical variate 1 shows cultivated land while Canonical variate 2 shows annual income from agricultural activity. Cultivated land: educational background, rice and fruits are affecting as attributions, and information about harvest is affecting as agricultural production information. Therefore, the cultivated land is affected by the index aiming at expanding the scale of rice production. For annual income from agricultural activity: gender is affecting as attributions, and new technology information, information about organic fertilizer and training are affecting as agricultural production information. Therefore, annual income from agricultural activity is affected by an index of new technology information, information about organic fertilizer and training, all of which are important for high-quality crop production. The results of the analysis suggest that the development of multiple farming in Cambodia is under the condition of expanding rice production and increasing the skills of local farmers in agricultural technology.

CONCLUSION

The main object of this study was to quantitatively grasp the relevance among local farmers to analyze the characteristics of local farming and agricultural production information to build stable and sustainable farming needed by the farmers in Kampong Cham Province, Cambodia. In addition, a Canonical Correlation Analysis applies to attributions, crops and agricultural production information are associated with annual income from agricultural activity and cultivated land that are considered as a result of farm management.

The results of the analysis are summarized as follows. According to the answers from questionnaire, it was confirmed that the index of agricultural production information varies depending on the districts. According to the results of Canonical Correlation analysis, the cultivated land is affected by the index aimed at expanding the scale of rice production. In addition, annual income from agricultural activity is affected by the index aimed at high-quality crop production based on new technology information, information about organic fertilizer and training. As a result of the analysis, it was suggested that for the development of multiple farming in Cambodia, in addition to the premise of expanding rice production, it is necessary to improve the skills necessary for the conversion of high-quality crop production.

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Research article

Moisture Content Prediction of Dried Young Papaya during Drying and Water Absorption

SOKLY SORM
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan

YOSHIKI MURAMATSU*
Tokyo University of Agriculture, Tokyo, Japan
Email: y-murama@nodai.ac.jp

MASANORI HASHIGUCHI
Keisoku Engineering System Co., Ltd., Tokyo, Japan

DAHAI MI
Keisoku Engineering System Co., Ltd., Tokyo, Japan

EIICHIRO SAKAGUCHI
Tokyo University of Agriculture, Tokyo, Japan

SHOTARO KAWAKAMI
Tokyo University of Agriculture, Tokyo, Japan

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Abstract The effective use of agricultural products and the development of processed foods with guaranteed safety and quality are needed in Kampong Cham Province, Cambodia. Young papaya is an important agricultural product in this area. Dried young papaya is one of the preserved foods. The main objective in this paper was to provide basic information for the optimization of drying process. Two types of young papaya, raw or fresh papaya and blanched young papaya, were used in this study to investigate the influence of drying pretreatment that is, blanching, on the changes in the moisture content during drying and water absorption. The hot air-drying characteristics of each sample were measured at three temperatures (30, 50, and 70°C), three air velocities (1, 2, and 3 m/s), and a relative humidity of 40%. The examination of the effects of temperature, air velocity, and blanching on the drying of samples resulted in the drying characteristics of the raw sample being very similar to that of the blanched sample. A linear relationship existed in the moisture content range between the initial moisture contents and 500% (d.b.). The exponential model was applied to predict the changes in the moisture contents of samples below500% (d.b.) at each drying condition. The drying rate constants in the period above or below500% (d.b.) were increased with increasing air temperature and air velocity and expressed as a linear function of both temperature and air velocity, respectively. The water absorption characteristics of the dried young papaya and the dried blanched young papaya that were dried after blanching were investigated at three temperatures (20, 30, and 40°C). Blanching before drying of the sample had the effect of slowing the water absorption rate. The water absorption rate constant tended to increase with increasing soaking temperature.

Keywords young papaya, drying characteristics, water absorption characteristics, blanching, temperature and air velocity dependency, prediction model of moisture content

INTRODUCTION

The effective use of agricultural products and the development of processed foods with guaranteed safety and quality are needed in Kampong Cham Province, Cambodia. Young papaya is an important agricultural product in Kampong Cham. Recently, in Japan, young papaya has been recognized as a regional biological resource for the diversification of primary producers into processing and distribution, and it is cultivated in the Kanto region.

Although young papayas can be eaten fresh, they can also be used after drying. Drying is one of the oldest preservation methods and does not require special machines or devices in almost all cases. Drying not only increases the shelf life of the product but also increases its food value. Dried young papaya has been sold as a processed food. Usually, dried young papayas are rehydrated to some degree before eating. Pretreatments, for example, blanching, are often added to enhance the quality of dried vegetables. Blanching, a mild thermal treatment similar in temperature-time intensity to pasteurization, is applied to fruits and vegetables primarily to inactivate enzymes that catalyse degradation reactions (Park et al., 2014). Lydia et al. (2017) investigated the effects of pretreatments, including soaking in certain solutions and drying methods, on some qualities of dried mango fruit.

Some researchers (EI-Aouar et al., 2003; Lagunez-Rivera et al., 2007; Fernando et al., 2008; Lemus-Mondaca et al., 2009; Udomkun et al., 2015) have measured and analysed the drying kinetics of papaya. Almost all previous papers have reported the drying characteristics of mature papaya. However, very few studies have measured the hot air-drying characteristics of young papaya with different air velocities, as performed in this study. In previous references (EI-Aouar et al., 2003; Lagunez-Rivera et al., 2007; Fernando et al., 2008; Lemus-Mondaca et al., 2009; Muramatsu et al., 2012; Udomkun et al., 2015), some mathematical models (drying models) were used to describe the relationship between the moisture content of the sample and drying time. Optimum drying and water absorption models, including the values of parameters, are particularly useful for easily predicting the changes in the moisture content of materials. Therefore, determination of the optimum model is important for practical use.

In this study, we examined the hot air-drying characteristics of two types of young papaya: raw and blanched young papaya at three different temperatures and air velocities. In addition, the water absorption (rehydration) characteristics of dried and dried blanched young papaya were also measured at three different temperatures. The results obtained in this study provide important basic information and are needed to optimize drying processes and to design dryers.

OBJECTIVE

The objectives of this study were 1) to examine the effects of air temperature, air velocity, and blanching treatment on the drying characteristics of the sample, 2) to investigate the influence of blanching treatment and soaking temperature on the water absorption characteristics of the sample, 3) to derive suitable mathematical drying and water absorption models to describe changes in moisture content with time, and 4) to obtain empirical equations to express the relationship between the drying or water absorption rate constants and the measurement conditions.

METHODOLOGY

Sample Preparation

Young papaya (Carica papaya) imported from Thailand was purchased at a supermarket in Tokyo, Japan. Before the test, the young papayas were stored in a refrigerator at approximately 4°C. After the peel was removed from the young papaya, the young papaya was cut into a rectangular parallelepiped (50 mm in depth, 20 mm in width, and 2.5 mm in height) by using a commercial vegetable cutter. We call this sample the “raw sample” in this manuscript. For the blanching treatment, the raw young papayas were immersed in boiling water at 100°C for 30 s and cooled in

cold water at 0°C for 2 min. We describe this sample as the “blanched sample” in this manuscript.

Hot Air-drying Test

The changes in the moisture content of raw and blanched samples using the hot-air drying method were measured at three temperatures (30, 50, and 70°C), three air velocities (1, 2, and 3 m/s), and a relative humidity of 40%. A constant temperature and humidity chamber (KCL-2000, EYELA Co., Ltd.) was used as a drying chamber in this study to maintain air temperature and humidity during the drying test. The air velocity was adjusted with a fan (CUDC 12B4, Japan Servo Co., Ltd.) connected to a DC power source (AD-8735D, A&D Co., Ltd.). A stainless-steel basket (50 mm in depth, 20 mm in width, and 2.5 mm in height with a 3 mm aperture) was utilized as a sample tray. Approximately 100 g of sample was placed on the sample tray and dried in the drying chamber. The sample tray was removed out from the drying chamber at a preset time to measure the mass change of the sample. The mass change of the sample was measured with a digital balance (GX-4000, A&D Co., Ltd.) and recorded at time intervals every 20 min for the initial 2 h and every 30 min from 2 h until the sample's moisture content became 15% (d.b.). After weighing the sample mass, the sample tray was quickly returned to the drying chamber. When the moisture content of the sample reached approximately 15% (d.b.), the mass of dry matter in the sample was determined using a forced hot air oven (VTEC-166, Isuzu Seisakusho Co., Ltd.) at 105°C for 24 h. Utilizing the measured value of the mass of dry matter in the sample, the changes in mass during drying were converted to changes in the moisture content of the sample.

Measurement of Water Absorption Characteristic

To measure the water absorption characteristics, the raw and blanched samples were dried by the hot-air drying method at a temperature of 30°C, an air velocity of 3 m/s, and a relative humidity of 40% with a drying apparatus as previously mentioned. We describe the dried sample that was added to the blanching treatment before drying as the “dried blanched sample” in this manuscript. Each dried sample was stored in a polyethylene bag and kept for 5-10 days at room temperature before the water absorption test to ensure the uniform distribution of moisture in the bag and equilibrate the moisture content of the sample. The moisture content changes of the samples soaked in water were measured at three different temperatures (20, 30, and 40°C). Approximately 1 g of sample was immersed in a glass beaker containing 200 ml distilled water in a water bath at a preset temperature. At time intervals every 1 min for the initial 6 min, 2 min from 6 to 10 min, 5 min from 10 to 30 min, and then 30 min from 30-90 min, the sample was removed from the water, and the surface of the sample was wiped with Kimwipes® (S-200, Nippon Paper Crecia Co., Ltd.) to remove residual liquid. These measurements were conducted until the moisture content of each sample reached the same moisture content as fresh young papaya (approximately 94% (w.b.)). The moisture content of the sample after soaking was determined by the oven method (105°C for 24 h).

RESULTS AND DISCUSSION

Hot Air-drying Characteristics

Fig. 1 (a) shows the changes in the moisture content of each sample at an air velocity of 3 m/s and a temperature of 30°C. The moisture contents of both samples decreased linearly with elapsed time from the initial moisture content to approximately 500% (d.b.) and decreased, exhibiting a gentle downward curve below 500% (d.b.). As shown in Fig. 1 (b), the slope of the relationship between the drying rate and moisture content at each sample was changed at approximately 500% (d.b.). Fig. 1 indicates that the drying characteristics, i.e., changes in the moisture content and drying rate of the raw sample had almost the same trend as the blanched sample and the hot air-drying process of both samples had two periods, i.e., the first and second periods. Similar tendencies were obtained for other measurement conditions not shown in Fig. 1.

In the first period (above 500% (d.b.)), the moisture contents decreased linearly with an increase in elapsed time. Therefore, the measured data at each sample and each measurement condition were fitted to Eq. (1).

$$M = -k_1 t + M_0 \tag{1}$$

where M: the moisture content (% (d.b.)), M_0: the initial moisture content (% (d.b.)), k_1: the drying rate constant in the first period (1/min), and t: the drying time (min). The measured value of M_0 and the values of k_1 determined by using the least squares method and the root mean square error (RMSE) are shown in Table 1. In the second period (below 500% (d.b.)), because the drying rate decreased linearly with decreasing moisture content, the following exponential model (Muramatsu et al., 2012) was used to analyse the changes in moisture content.

$$\frac{M - M_e}{500 - M_e} = \exp\left[-k_2\left(t - t_c\right)\right] \tag{2}$$

where M_e: the equilibrium moisture content (% (d.b.)), k_2: the drying rate constant in the second period (1/min), and t_c: the drying time at a moisture content of 500% (d.b.) (min). The value of t_c in Eq. (2) was calculated from Eq. (1). The measured drying data in the second period were fitted to Eq. (2) using the nonlinear least squares method, and the values of k_1 and M_e were determined at each sample and each measurement condition. The values of the parameters and RMSE of Eq. (2) are given in Table 2. The comparisons of the observed moisture contents with the results calculated from Eqs. (1) and (2) at an air velocity of 3 m/s for the raw sample are shown in Fig. 2. The solid lines in Fig. 2 show the results calculated from Eq. (1) or (2). As shown in Fig. 2, the measured results matched well with the calculated results. Under all measurement conditions, the changes in the moisture content of the sample caused by hot air-drying could be estimated by Eqs. (1) and (2).

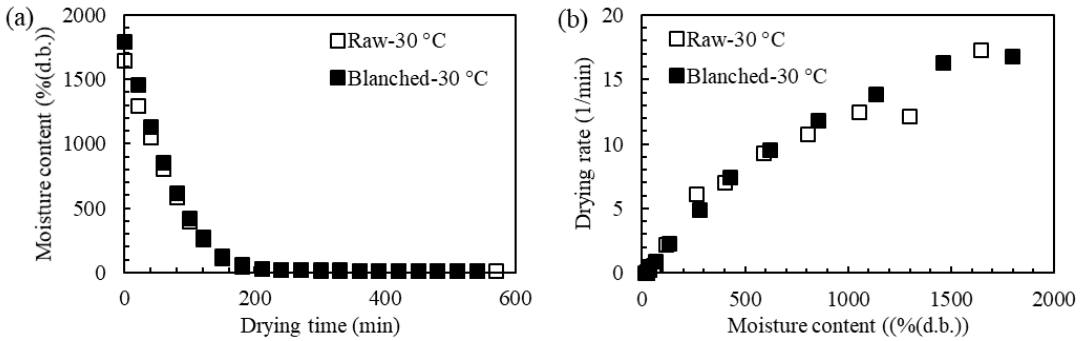

Fig. 1 Drying curve of each sample at an air velocity of 3 m/s and a temperature of 30°C (a) Changes in moisture content and (b) drying characteristics curves

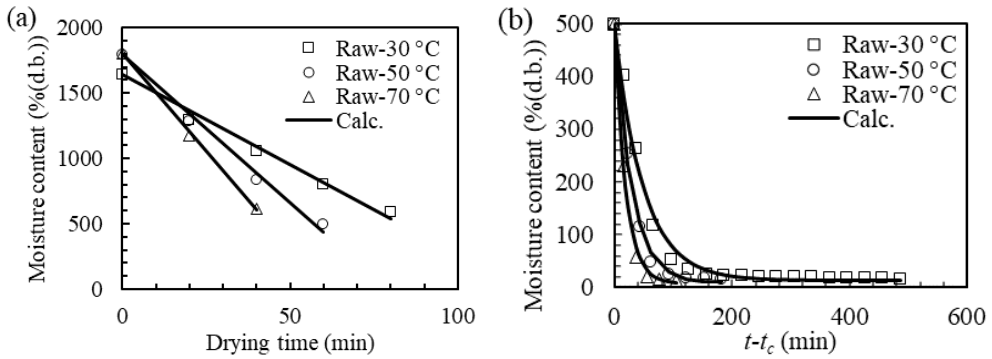

Fig. 2 Comparisons of observed moisture content changes with the results calculated from (a) Eq. (1) and (b) Eq. (2) at air velocity of 3 m/s for the raw sample during drying

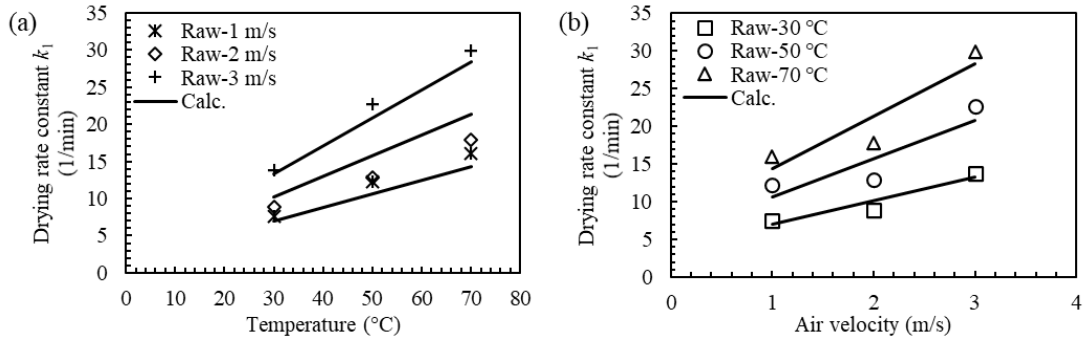

Fig. 3 Relationships between the drying rate constants in the first period (above a moisture content of 500 % (d.b.)) of the raw sample and (a): temperature and (b): air velocity

Table 1 Initial moisture content (M_0), drying rate constant in the first period (above 500 % (d.b.)) (k_1), and root mean square error (RMSE) of Eq. (1) under each set of measurement conditions

Sample	Air velocity (m/s)	Temperature (°C)	M_0 (% (d.b.))	k_1 (1/min)	RMSE (% (d.b.))
Raw sample	1	30	1525	7.572	19.2
		50	1625	12.23	20.9
		70	1615	16.03	2.6
	2	30	1359	8.909	25.8
		50	1253	12.87	14.7
		70	1331	17.83	3.0
	3	30	1643	13.76	47.0
		50	1797	22.63	54.3
		70	1800	29.92	20.0
Blanched sample	1	30	1926	9.189	27.8
		50	1963	14.35	31.6
		70	2008	19.77	10.2
	2	30	1807	10.69	63.2
		50	1576	15.12	12.9
		70	1661	21.51	2.2
	3	30	1794	15.31	39.3
		50	1896	23.82	47.3
		70	2302	37.15	18.1

The values of M_0 were measured data. The values of k_1 were determined by the least squares method based on the measured results in the first period (above 500 %(d.b.)). The values of RMSE were calculated from the measured results and the results calculated from Eq. (1).

As shown in Tables 1 and 2, the drying rate constants varied with temperature and air velocity. Figure 3 represents the temperature and air velocity dependencies of k_1 for the raw sample. Although the values of k_1 for both samples were not much difference between 1 m/s and 2 m/s, the values of k_1 at 2 m/s were higher than that at 1 m/s for each temperature. The first period (above 500% (d.b.)) was considered as the apparent falling drying rate period including the sample shrinkage, i.e., the constant drying rate period from the measurement results of changes in the sample surface temperature. In the constant drying rate period, the drying or water vaporization rate depends on the heat transfer coefficient, the thicknesses of boundary layers for temperature and air velocity, and so on. Since there was not much difference in the values of heat transfer coefficient and the thicknesses of boundary layers between 1 m/s and 2 m/s, the effect of air velocity on the drying rate in the first period might be weak below 2 m/s. The k_1 and k_2 of each sample increased almost linearly with the increase in air velocity at each temperature and the increase in the temperature at each air velocity. Therefore, we derived the following empirical equation to express the temperature and air velocity dependencies.

$$k_{1\text{ or }2} = aTV + bT + cV + d \tag{3}$$

where T: temperature (°C), V: air velocity (m/s), a, b, c, d: constant. The regression results for Eq. (3) are shown in Table 3. The solid lines in Fig. 3 are the results calculated from Eq. (3). The k_1 and k_2 values of each sample were represented as a function of both temperature and air velocity by Eq. (3).

Table 2 Drying time at a moisture content of 500 % (d.b.) (t_c), drying rate constant in the second period (below 500 %(d.b.)) (k_2), equilibrium moisture content (M_e), and root mean square error (RMSE) of Eq. (2) under each set of measurement conditions

Sample	Air velocity (m/s)	Temperature (°C)	t_c (min)	k_2 (1/min)	M_e (% (d.b.))	RMSE (% (d.b.))
Raw sample	1	30	135	1.224×10^{-2}	16.09	11.2
		50	92	2.058×10^{-2}	9.542	14.2
		70	70	2.940×10^{-2}	5.132	14.0
	2	30	96	1.708×10^{-2}	14.37	12.8
		50	59	2.549×10^{-2}	8.183	12.0
		70	47	3.649×10^{-2}	5.153	16.2
	3	30	83	2.052×10^{-2}	13.36	16.0
		50	57	3.438×10^{-2}	8.604	11.8
		70	43	5.157×10^{-2}	5.226	16.1
Blanched sample	1	30	155	1.136×10^{-2}	13.65	23.0
		50	102	1.845×10^{-2}	5.345	21.9
		70	76	2.785×10^{-2}	0.02047	24.5
	2	30	122	1.759×10^{-2}	14.63	9.9
		50	71	2.302×10^{-2}	5.895	18.8
		70	54	3.315×10^{-2}	0.4881	23.6
	3	30	85	1.931×10^{-2}	11.37	18.4
		50	59	3.643×10^{-2}	9.005	10.0
		70	49	4.249×10^{-2}	5.628	26.7

The values of t_c were calculated from Eq. (1) by using the values of M_0, k_1, and $M=500$. The values of k_2 and M_e were determined by the nonlinear least squares method based on the measured results in the second period (below 500 %(d.b.)). The values of RMSE were calculated from the measured results and the results calculated from Eq. (2).

Table 3 Values of the parameters and root mean square error (RMSE) of Eq. (3) for each drying rate constant and sample

Drying rate constant (1/min)	Sample	a (s/min·°C·m)	b (1/min·°C)	c (s/min·m)	d (1/min)	RMSE (1/min)
k_1	Raw	9.626×10^{-2}	8.708×10^{-2}	2.687×10^{-1}	1.238	2.052
	Blanched	1.407×10^{-1}	7.896×10^{-2}	-1.541	3.613	2.469
k_2	Raw	1.736×10^{-4}	2.163×10^{-4}	-1.305×10^{-3}	1.962×10^{-3}	1.438×10^{-3}
	Blanched	7.535×10^{-5}	3.151×10^{-4}	2.234×10^{-3}	-1.735×10^{-3}	2.251×10^{-3}

The values of a, b, c, and d were determined by the least squares method based on the values of k_1 and k_2 shown in Tables 1 and 2. The values of RMSE were calculated from the values of drying rate constant (k_1 or k_2) shown in Table 1 or 2 and the results calculated from Eq. (3).

Water Absorption Characteristics

The moisture content of dried and dried blanched samples increased with the elapsed time, exhibiting a gentle upward curve from the beginning of soaking at all three temperatures, as shown in Fig. 4. The water absorption rate of dried blanched samples was slower than that of dried samples at each temperature. The dried blanched sample was harder and had a smaller size than the dried sample. The difference in organizational structure for the samples after drying could be caused by the difference in water absorption characteristics. The exponential model Eq. (4) (Tagawa, et al. 1997) was used to analyse the changes in moisture content from the initial moisture content of 15% (d.b.).

$$\frac{M - M_s}{15 - M_s} = \exp\left(-k_3 t_{\mathrm{WA}}\right) \tag{4}$$

where M_s: saturated moisture content (% (d.b.)), k_3: water absorption rate constant (1/min), and t_{WA}: soaking time (min). The solid lines and broken lines in Fig. 4 represent the results calculated from Eq. (4). The values of k_3, M_s, and RMSE of Eq. (4) are shown in Table 4.

The k_3 of each sample increased with increasing soaking temperature and was related to soaking temperature by the following Arrhenius equation.

$$k_3 = d \cdot \exp\left[-E/R\left(T + 273.15\right)\right] \tag{5}$$

where R: ideal gas constant 8.314 (J/mol·K), d, E: constant. The values of d and E were 6.047×10^2 and 2.477×10^5 for the dried sample and 6.444×10^3 and 3.278×10^5 for the dried blanched sample, respectively.

Table 4 Water absorption rate constant (k_3), saturated moisture content (M_s), and root mean square error (RMSE) of Eq. (4) for each sample

Sample	Temperature (°C)	k_3 (1/min)	M_s (% (d.b.))	RMSE (% (d.b.))
Raw	20	2.417×10^{-2}	2572	43.8
	30	2.994×10^{-2}	2748	42.1
	40	4.640×10^{-2}	2525	37.6
Blanched	20	9.129×10^{-3}	3549	35.0
	30	1.499×10^{-2}	2999	38.0
	40	2.153×10^{-2}	2696	59.3

The values of k_3 and M_s were determined by the nonlinear least squares method based on the measured results. The values of RMSE were calculated from the measured results and the results calculated from Eq. (4).

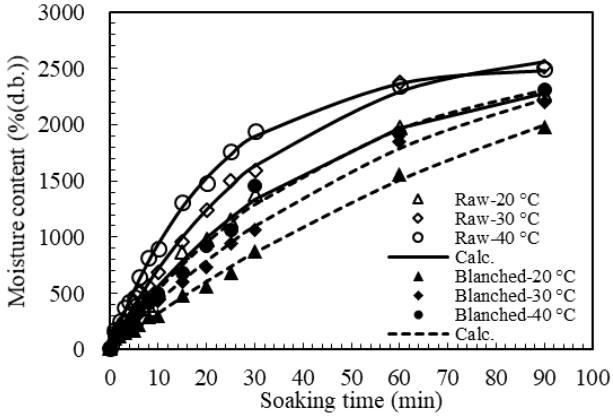

Fig. 4 Changes in moisture contents during water absorption for each sample

CONCLUSION

The hot-air drying characteristics of two types of young papaya, raw or fresh papaya and blanched young papaya, were measured at three temperatures (30-70°C), three air velocities (1-3 m/s), and a relative humidity of 40%. The drying characteristics of both samples had almost the same tendency. The linear function and the exponential model were used to express the changes in the moisture content of the sample with drying times above or below 500% (d.b.), respectively. The drying rate constant of each sample and each drying period (above or below 500% (d.b)) increased with an increase in air temperature and air velocity and was expressed as a linear function of both air temperature and air velocity, respectively.

The water absorption characteristics of the dried young papaya and the dried blanched young papaya were measured at three temperatures (20, 30, and 40°C). The water absorption rate of dried young papaya that did not receive the blanching treatment before drying was faster than that of the

sample that was blanched before drying (dried blanched sample). The exponential model could be applied to explain the water absorption process of both samples. The water absorption rate constant increased with increasing soaking temperature.

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Research article

Estimates of Factor Shares for Rice Production in Japan for the Period of 1922-1944

MITSUHIRO TERAUCHI*
Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Japan
Email: tera@nodai.ac.jp

SHINOBU YAMADA
Research Center, Institute of Environmental Rehabilitation and Conservation, Tokyo, Japan

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Abstract The After World War I, the development of the agriculture sector was delayed in contrast with the rapid growth of the industrial sector. Japanese agriculture accelerated by innovation after the economic revitalization following World War II. It clarifies the production structure of the rice production in Japan, and there is this study before the end of World War II after the First World War end during the analysis period. This study clarifies a change of factor shares of the rice production sector in this time. The purpose of this study is to elucidate the characteristics of the production structure of the rice production in Japan from 1922 through 1944, and the agriculture in Japan at this time is considered to be in a developing stage. The historic change of the rice production in Japan gives a suggestion for agriculture development in modern Asia. The measurement of factor shares of the rice production in the analysis period applies "a method to estimate land income as rest." In addition, it measures the Cobb-Douglas's type amount of production formation function. It clarify the contribution of the production input. The changes of factor shares are as follows. The change of factor shares is land, labor, fertilizer, cost of draft animals, agricultural machinery, materials, building for agriculture, seed in order of the average value from 1922 through 1944. As for the development of production technological system, it is a technological innovations land-saving and fertilizer-using. The results of estimate by the amount of production formation function are as follows. In the periods of 1922-1944, the input of the labor is excess level, the input of the fertilizer is under level and the input of the land is equilibrium level.

Keywords Japan rice production, factor shares, amount of production formation function

INTRODUCTION

World War I, the development of the agriculture sector was delayed in contrast with the rapid growth of the industrial sector. Japanese agriculture accelerated by innovation after the economic revitalization following World War II. It clarifies the production structure of the rice production in Japan, and there is this study before the end of World War II after the First World War end during the analysis period. It corresponds to the Meiji period and the prewar age of the Showa period, and this period is a stagnation period of agricultural production. This study clarifies a change of factor shares of the rice production sector in this time. The purpose of this study is to elucidate the characteristics of the production structure of the rice production in Japan from 1922 through 1944, and the agriculture in Japan at this time is considered to be in a developing stage. The historic change of the rice production in Japan gives a suggestion for agriculture development in modern Asia. The measurement of factor shares of the rice production in the analysis period applies "a method to estimate land income as rest." In addition, it measures the Cobb- Douglas's type amount of production formation function. It clarifies the contribution of the production input.

OBJECTIVE

The main object of this study is to analyze the measurement of factor shares of the rice production. In analysis, the measurement of factor shares of the rice production applies "a method to estimate land income as rest." In addition, it measures the Cobb-Douglas's type amount of production formation function. It clarifies the contribution of the production input. The data applying to analysis are as follows. Ishibashi 1961. "Teikoku Nokai Kome Seisanhi Cyousa Syusei (Imperial Agricultural Organization cost of rice production investigation collection)" is from 1922 to 1948 (Natl. Res. Inst. of Agricultural Economics) (Natl. Res. Inst. of Agricultural Economics publication, the 207th). A period of estimation of factor shares and the amount of production formation function by estimate is 1922 through 1945. Sample data are thyme series data for 24 years.

METHODOLOGY

The Estimates of Factors Share

The measurement of factor shares of the rice production in the analysis period applies "a method to estimate land income as rest." It is presented by the following:

$$Factor\ shares L = (PL \cdot L)/(P \cdot Q) \quad (1)$$

$$Factor\ shares K = (PK \cdot L)/(P \cdot Q) \quad (2)$$

$$Factor\ shares V = (PV \cdot L)/(P \cdot Q) \quad (3)$$

$$Factor\ shares S = 1-(PL \cdot L)/(P \cdot Q)-(PK \cdot L)/(P \cdot Q)-(PV \cdot L)/(P \cdot Q) \quad (4)$$

where Q is output; P output price; L labor input; K capital input; V fertilizer input; S land input; LP labor input price; KP capital input price; VP fertilizer input purice and S land input price (Hayami and Ruttan, 1985).

Amount of Production Formation Function

The function type assumed is the Cobb-Douglas's type production function. The function to estimate is the next formula (Tsuchiya, 1976).

$$X = A \cdot L^{\alpha} \cdot V^{\gamma} \cdot S^{\delta} \quad (5)$$
$$(0 < \alpha, 0 < \gamma, 0 < \delta,\ \alpha + \gamma + \delta \fallingdotseq 1)$$

It is presented by the following:

$$\ln X = \ln A + \alpha \ln L + \gamma \ln V + \delta \ln S + \zeta \quad (6)$$

where X is output; L labor input; V fertilizer input; S land input.

Examination of the Contribution of the Production Input

The marginal productivity of input X is MPX. P is an output price. PX is X input price. In the case of ①: MPX> (PX/P), the input of X is under. In the case of ②: MPX = (PX/P), the input of the factor of production is equilibrium. In the case of ③: MPX <(PX/P), the input of the agent of production is excess. It is represented by the following. ④Value of production elasticity of X>factor shares X. ⑤Value of production elasticity of X= factor shares X. ⑥Value of production elasticity of X<factor shares X.

Data Collection

As for the data, Miyuki Ishibashi et al,"Imperial Agricultural Organization cost of rice production investigation collection", the sample data are thyme series data for 24 years. The index to use for estimation is an unpolished rice yield ("koku"≒140-150kg), product value (Japanese yen), seed costs, manure costs, wages, material costs, labor force of livestock costs, agricultural machinery costs, building for agriculture. These variables are numerical value per "tan" (≒10a). The variable data of the measurement of the amount of production formation function are as follows. Q is the amount of production. Here, it adopted an unpolished rice yield. L is wages. It adopted the total of family labor and the employment labor. V is an ordinary input. It adopted seed and sapling costs, manure costs, agriculture drug costs, and the total of material costs. S is rice paddy area. It is measured using the variable shown above. The data of the Miyuki Ishibashi great work "Imperial Agricultural Organization cost of rice production investigation collection" were displayed by a "tan," and therefore it took advantage, and, on the occasion of a measurement, the numerical value was converted the planted area around one farmhouse. Therefore, the numerical value multiplied the planted area by it and converted it into numerical value per one farmhouse.

RESULTS AND DISCUSSION

The Development of Rice Production in Japan (1881-2012)

The analysis object period of this study is 1922-1944. In the history of Japanese agriculture, it confirms a characteristic of this time. A change of the rice production in Japan from 1881 through 2012 is shown in the figure. 1881 is standard age (1881 = 1.0). The development of rice production in Japan for the period of 1881-2012 is shown in Fig. 1.

World War I brought a boom after the war for Japan. By the progress of the industrial division, the Industrial production value overtook an agricultural production value after the World War I. The development of the agriculture sector was delayed under the parasitic landlord system in comparison with the rapid development of the industrial sector (Teruoka, 2008). After World War II, the Japanese economy continued rapid growth during a period from 1955 through 1973 (High economic growth period). In this time, the agriculture sector drastically improved production by the spread of artificial manure, pesticide, and agricultural machines. However, the consumption of rice was delayed, so there was overproduction. Therefore, a policy of reducing the rice acreage was started in 1970 (Hayami and Yamada, 1991).

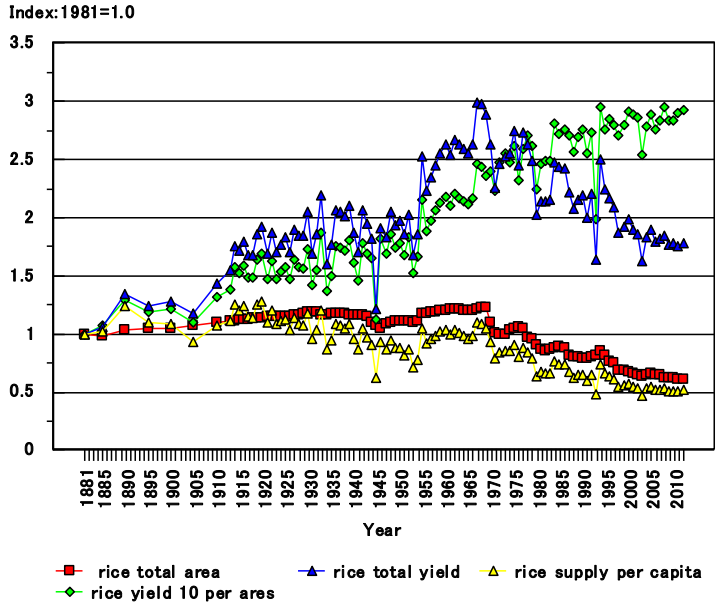

Fig. 1 Development of rice production in Japan (1881-2012)

The Change of the Element Input of the Rice Production (1922-1944)

A change of the element input of the rice production from 1922 through 1944 is shown in Fig. 2. In this Figure, the change of the input standard of each agent of production is shown in the standard in 1922 (1922 = 1.0).

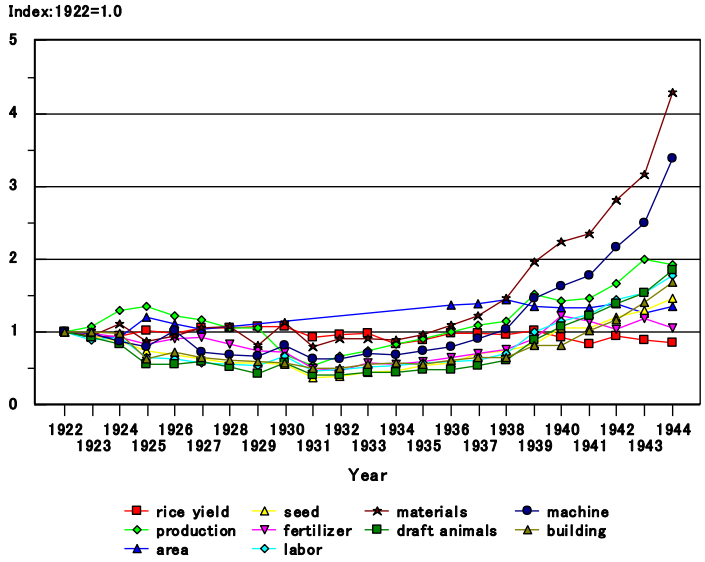

Fig. 2 The change of the element input of the rice production (1922-1944)

Table 1 Changes in factor shares for rice production in Japan (1922-1944)

Year	seed (%) ①	fertilizer (%) ②	labor (%) ③	materials (%) ④	draft animals (%) ⑤	machine (%) ⑥	building (%) ⑦	land (%) ⑧
1922	0.0147	0.2250	0.4618	0.0199	0.0651	0.0314	0.0341	0.1480
1923	0.0129	0.2047	0.3835	0.0173	0.0561	0.0286	0.0318	0.2651
1924	0.0100	0.1611	0.3294	0.0170	0.0419	0.0210	0.0259	0.3936
1925	0.0081	0.1410	0.2265	0.0129	0.0268	0.0184	0.0159	0.5503
1926	0.0082	0.1676	0.2392	0.0155	0.0302	0.0261	0.0204	0.4928
1927	0.0080	0.1787	0.2306	0.0182	0.0333	0.0194	0.0190	0.4928
1928	0.0081	0.1762	0.2454	0.0200	0.0319	0.0206	0.0200	0.4777
1929	0.0082	0.1606	0.2421	0.0154	0.0269	0.0202	0.0196	0.5070
1930	0.0121	0.2416	0.4498	0.0331	0.0548	0.0374	0.0293	0.1420
1931	0.0103	0.2035	0.4021	0.0291	0.0490	0.0359	0.0312	0.2389
1932	0.0089	0.1599	0.3420	0.0271	0.0400	0.0296	0.0263	0.3662
1933	0.0088	0.1740	0.3275	0.0245	0.0390	0.0295	0.0254	0.3712
1934	0.0081	0.1497	0.2992	0.0212	0.0347	0.0260	0.0232	0.4378
1935	0.0088	0.1457	0.2974	0.0210	0.0350	0.0255	0.0212	0.4454
1936	0.0085	0.1451	0.2762	0.0217	0.0315	0.0248	0.0208	0.4714
1937	0.0095	0.1455	0.2633	0.0223	0.0320	0.0263	0.0204	0.4806
1938	0.0096	0.1500	0.2819	0.0252	0.0352	0.0283	0.0193	0.4505
1939	0.0082	0.1355	0.3058	0.0258	0.0386	0.0303	0.0185	0.4374
1940	0.0109	0.1933	0.3753	0.0312	0.0494	0.0361	0.0198	0.2839
1941	0.0105	0.1748	0.3872	0.0316	0.0540	0.0377	0.0236	0.2805
1942	0.0107	0.1417	0.4049	0.0336	0.0543	0.0408	0.0240	0.2900
1943	0.0095	0.1328	0.3571	0.0315	0.0499	0.0393	0.0241	0.3557
1944	0.0112	0.1232	0.4231	0.0440	0.0624	0.0549	0.0296	0.2515

Note: ⑧＝1−(①+②+③+④+⑤+⑥+⑦)

The Cange of Fctor Sares of the Rice Poduction (1922-1944)

Table 1 shows the change of factor shares is land, labor, fertilizer, cost of draft animals, agricultural machinery, materials, building for agriculture, seed in order of the average value from 1922 through 1944. The change of these factor shares becomes land, labor, manure, labor force of livestock, agricultural machinery, materials, a building, the seed in order of a standard level. Factor

share of the capital such as labor force of livestock, agricultural machinery, the building shows a low value. On the other hand, labor, land and factor share of ordinary input materials such as the manure shows a high value. The period for the analysis was the time when it could not expect the expansion of the land area. Under such situations, the change of factor shares of the agent of production shows that the following production engineering system has been developed. As for the development of production technological system, it is a technological innovations land-saving and fertilizer-using (Sawada, 1991).

The Eamination of the Estimated Result of the Amount of Production Formation Function

The measurement results of the amount of production formation function are as follows.

$$\begin{array}{llll} lnX= & +0.0097 & +0.1233lnL & +0.3609lnV \quad +0.3627lnS \\ & (0.0051) & (0.4687) & (1.4125) \quad (0.5920) \end{array} \qquad (7)$$

$R^2 = 0.6030$

Firstly, the value of A is 0.0097. It is supposed that this suggests the existence of the neutral technological change. Secondly, the value of α is 0.1233. Thirdly, the value of γ is 0.3609. As for the fourth, a value of δ is 0.3627. As for the fifth, α+γ+δ is 0.8468, and the values are less than 1. It is similar to the linear homogeneous production function. This means that the constant returns to scale. This conclusion supports an original hypothesis. In other words, there are not the economies of scale in this production stage.

Examination of the Contribution of the Production Input

In a C-D's type production function, a value of the production of agent of production X elasticity and the distribution diagram of agent of production X have a characteristic to be equal. From it, the economical analysis of the input standard of the factors of production is possibility. It compares the value of the factors of production of factor share and the value of the production elasticity by the estimated result of the C-D's type amount of production formation function. And it adds economical analysis about the element input standard of each agent of production.

As for the labor input standard, an estimate of the labor (α) for 0.1233, as for the factor share of the labor are 1922-1930: 0.3120, 1931-1940: 0.3171, 1941-1944: 0.3931 and 1922-1944: 0.3283. In all periods, the numerical value of factor share is higher than a value of the production of factors of production elasticity, it is in this way supposed that the quantity of throwing down standard of factors of production is an excessive tendency.

As for the manure input standard, an estimate of the manure (γ) for 0.3609, as for the factor share of the labor are 1922-1930: 0.1841, 1931-1940: 0.1602, 1941-1944: 0.1431 and 1922-1944: 0.1666. In all periods, the price of the production of factors of production elasticity is higher than a value of factor shares of factors of production. It is in this way supposed that the quantity of throwing down standard of factors of production is a too few tendencies.

As for land input standard, an estimate of the land (δ) for 0.3627, as for the factor share of the labor are 1922-1930: 0.3855, 1931-1940: 0.3983, 1941-1944: 0.2944 and 1922-1944: 0.3752.

The period of 1941-1944 years, the price of the production of factors of production elasticity is higher than a value of factor shares of factors of production. It is supposed that the input standard of factors of production is a too few tendencies. However, in other time, as for the value of the production of factors of production elasticity, the value of factor share of factors of production is almost balanced. It is supposed that the input standard of factors of production is balanced.

The results of estimate by the amount of production formation function are as follows. In the periods of 1922-1944, the input of the labor is excess level, the input of the fertilizer is under level and the input of the land is equilibrium level.

CONCLUSION

The purpose of this study is to elucidate the characteristics of the production structure of the rice production in Japan from 1922 through 1944. The measurement of factor shares of the rice production in the analysis period. In addition, it measures the Cobb-Douglas's type amount of production formation function. It clarifies the contribution of the production input. The changes of factor shares are as follows. The change of factor shares is land, labor, fertilizer, cost of draft animals, agricultural machinery, materials, building for agriculture, seed in order of the average value from 1922 through 1944. As for the development of production technological system, it is a technological innovations land-saving and fertilizer-using. The results of estimate by the amount of production formation function are as follows. In the periods of 1922-1944, the input of the labor is excess level, the input of the fertilizer is under level and the input of the land is equilibrium level.

As a result of analysis, for the increase of the agricultural production, it was suggested that the development of the technique to reduce the limitation of the factor of production was important. The development of the agriculture section is important in economic development in modern Asia. When it thinks about a strategy of the agriculture development in modern Asia, it is suggested that it is necessary to consider the direction of the change of the production technique.

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Research article

Perspective on Urban and Peri-Urban Agriculture in Cambodia's Capital: Phnom Penh

CHES SOPHY*
Graduate School of Frontier Sciences, University of Tokyo, Japan
Email: sophy_ches257@yahoo.com

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

THOL DINA
Ministry of Land Management, Urban Planning and Construction, Cambodia

Received 30 January 2022 Accepted 22 April 2022 (*Corresponding Author)

Abstract Due to population growth and urbanization over two decades, Phnom Penh Capital's area has almost doubled from 375 square kilometer in 2001 to 692.46 square kilometer in 2019. Meanwhile, the number of farmers declined from 36.77% of the population in 2001 to 10% in 2015. Respecting these issues, the government of Cambodia prepared the Land use master plan of Phnom Penh City 2035. However, no clear implementation of the plan and the fast growth of construction have become the main concerns of international donors. Moreover, the integration of Phnom Penh with some areas of neighboring provinces will affect agricultural activities. Therefore, this research aims to ascertain more details of agricultural land use in Phnom Penh by responding to the Master Plan and to explain the current activities of urban agriculture or peri-urban agriculture in the capital. Owing to the pandemic, this research was conducted by solely reviewing and analyzing legal documents, reports from the government and donors, and other reliable sources. The Land use master plan clearly indicates the space reserved for the peri-urban agricultural activities; however, there are no details regarding agricultural policy dealing with the space reserved for peri-urban agriculture. The involvement of the Ministry of Agriculture, Forestry and Fisheries is also not explained. Based on the reports from donors and NGOs, lack of roles and responsibilities, limited capacity and limited finance have become the main concerns for the government regarding implementation of the Master Plan. Importantly, current rapid growth of construction does not pay any attention to the development of city plans. Housing complex projects have increased from 77 in 2011 to 178 projects in 2019. Some private businesses are practicing peri-urban agriculture on the outskirts of the capital by growing, selling some vegetables, and providing the space for the relaxation.

Keywords urban agriculture, peri-urban agriculture, agricultural policies, land use master plan

INTRODUCTION

Phnom Penh, the capital of Cambodia, is located in South-East Asia. All main activities including economics, politics, culture and diplomacy are centered in the capital which has the highest density of population 2,143,591 in 2021 based on the World Population Review. Phnom Penh covers the area of 692.46 square kilometer; consisting of 14 districts. Currently, Phnom Penh has expanded by integrating 20 other communes from neighboring province due to rapid population growth and urbanization. Back in 2001 Phnom Penh covered 375 square kilometers consisting of 70% for human settlement, 21% for agricultural activities, 8% covered by water, and remaining not in use (Em and Paule, 2005). The practice of urban agriculture did exist in the capital; however, the number of farmers declined from 36.77% of tge population in the capital in 2001 (Em and Paule,

2005) to only 10% in 2015 based on the World Bank Group on Urban Development in Phnom Penh (2017). With respect to rapid growth of urbanization and population, the Government of Cambodia has prepared the Land use master plan of Phnom Penh City 2035. However, no clear implementation of the plan and the fast growth of construction have become the main concerns of international donors. Moreover, the integration of Phnom Penh with some areas of neighboring provinces will affect agricultural activities. Therefore, this research aims to ascertain more details of agricultural land use in Phnom Penh by responding to the Master Plan; and to explain the current activities of urban agriculture or peri-urban agriculture in the capital.

METHODOLOGY

Owing to the pandemic, the study was conducted by solely reviewing and analyzing legal documents, reports from the government and donors, and other reliable sources.

RESULTS AND DISCUSSION

Land Use Pattern in Phnom Penh

Official data on two new integrated districts (Kambo and Boeung Keng Kang) in Phnom Penh is not available. Fig. 1 shows the administrative boundary of Phnom Penh with only 12 districts. Among the 14 districts, Chraoy Chongvar, Dangkao, Kambo, Mean Chey, Praek Phnov, Pur Senchey and Sensokh are considered to be the outskirt areas of the capital (Realestate, 2021).

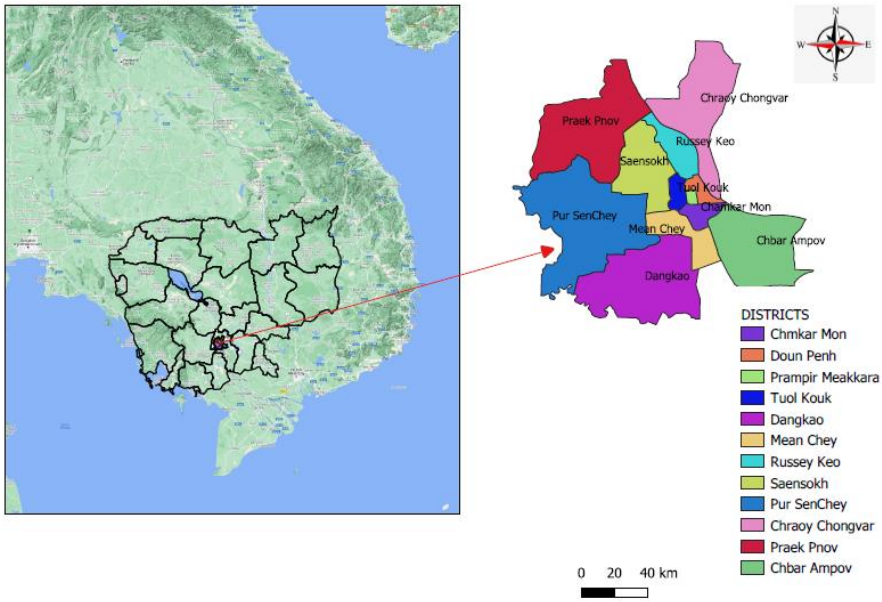

Fig. 1 Phnom Penh administrative map

Urban Agriculture in Phnom Penh

Decades ago, according to Khmer (2007), most of people living in Phnom Penh did not practice agricultural activities even despite of potential agricultural land. At that time, there were only a few NGOs working on urban and peri-urban agriculture. At the present time, core areas of Phnom Penh have been occupied by economic activities. Based on the data from Phnom Penh's Department of Agriculture, Forestry and Fisheries in 2019, some districts on the outskirts of Phnom Penh are used for growing rice and then for growing vegetables after the rice harvesting season.

Table 1 Agricultural land in Phnom Penh

District	Rice Growing Area (ha)	Ownership (ha)	Rent (ha)
Praek Pnov	1,409	1,372	37
Chraoy Chongvar	152	75	87
Chbar Ampov	6	6	-
Saen Sokh	247	217	30
Dangkao	3,273	2,247	1,026
Pur Senchey	310	80	230
Kambo	3,048	1,996	1,052

Source: Phnom Penh Department of Agriculture, Forestry and Fisheries (2019)

Land Use Master Plan for Phnom Penh Capital 2035

Because there is no clear land use pattern in Phnom Penh for the current situation and to deal with the rapid growth of population and urbanization, the government of Cambodia has prepared the Land use master plan of Phnom Penh Capital 2035. The main objectives of the master plan are to develop Phnom Penh to become a core center for development, an international standard city, a reserve for the development of necessary physical infrastructure, a metropolitan city and a special area for cultural heritage. Fig. 2 shows the map of the land use master plan of Phnom Penh capital 2035.

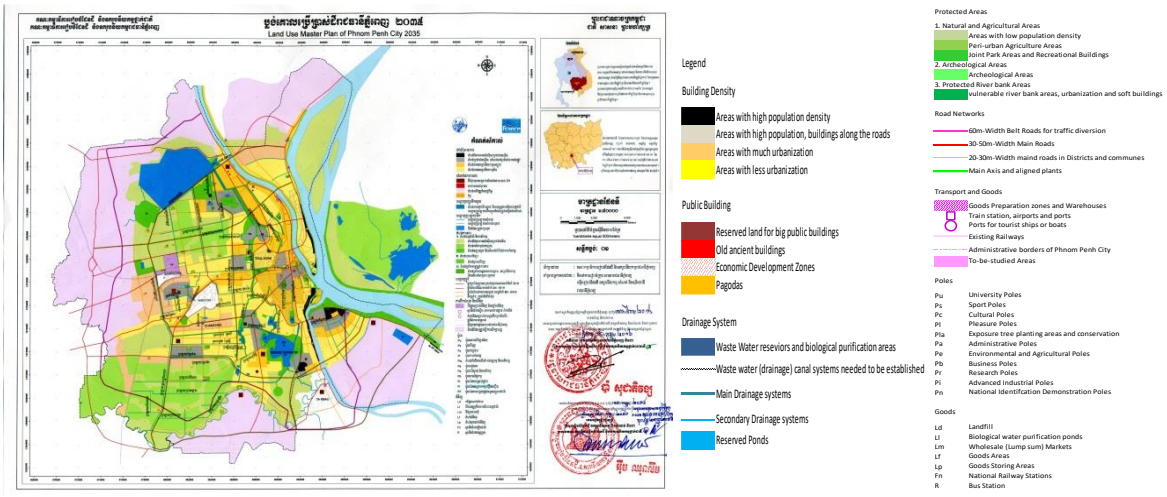

Fig. 2 Map of land use master plan of Phnom Penh capital 2035

Legend of the map was written in the Khmer language. The English-translated legend was provided next to the map. The second green symbol in the legend was used to indicate the space reserved for the peri-urban agriculture in Phnom Penh Capital.

In order to make the land use master plan realized and vitalized, the Phnom Penh sustainable city plan was designed to support the implementation of the Phnom Penh master plan for land use 2035. Fig. 3 shows the link between Land use master plan for Phnom Penh 2035 and the Phnom Penh sustainable city plan 2018-2030.

After obtaining the details of both the land use master plan and the Phnom Penh sustainable city plan, the study found that there is no clear explanation nor detail regarding the usage of reserved spaces for peri-urban agriculture as mentioned clearly in the map (referred to Fig. 2). Noticeably, there are also no details regarding the agricultural policies dealing with green spaces or space reserved for peri-urban agriculture in the land use master plan. In addition, the involvement of the Ministry of Agriculture, Forestry and Fisheries (MAFF) or other institutes is not mentioned nor indicated.

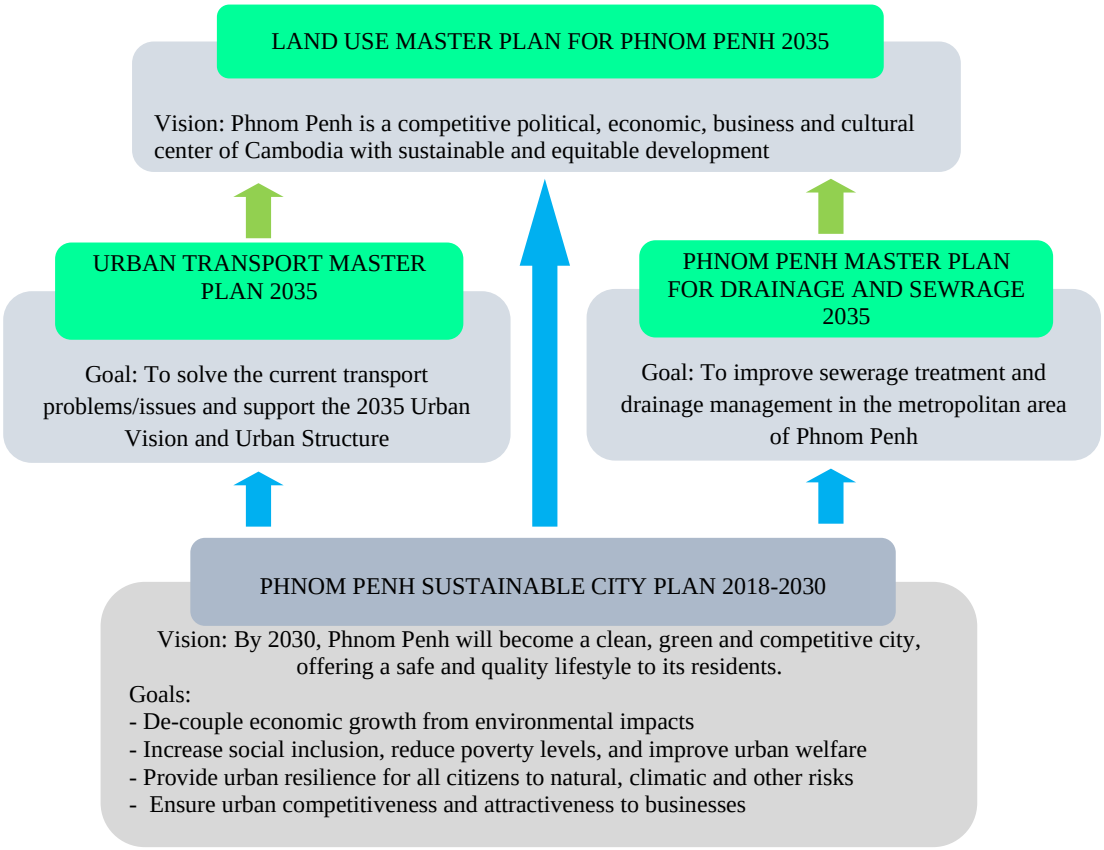

Fig. 3 Link between land use master plan for Phnom Penh 2035 and the Phnom Penh sustainable city plan 2018-2030
Source: Global Green Growth Institute (2019)

These challenges over the implementation of the master plan are a major concern. The World Bank also shares this concern over the lack of roles and responsibilities for the implementation of Master Plan, limited capacity and limited finance (World Bank Group, 2017).

Responding to the rapid growth of housing construction and other building complexes over the Phnom Penh Capital's areas, the World Bank also has raised this matter in the report (World Bank Group, 2017) and pointed out that this development in housing complex has neglected the Land use master plan; it seems that the real estate companies or construction companies do not follow the land use pattern that has been determined in the Master Plan. The housing complex projects have increased from 77 (Phnom Penh Capital Hall, 2011) to 178 projects in 2019 (The Phnom Penh Post, 2019).

Regarding the matter mentioned above, there is also a concern over the process on providing construction licenses to those real estate companies. All of these affect the land use pattern in Phnom Penh. It can be assumed that peri-urban agriculture has been affected by the rapid growth of urbanization and construction in the capital.

Urban Agricultural Policies

All agricultural policies and administration are under the responsibilities of and managed by MAFF. The overall goal of policy firmly focuses on increasing skills and knowledge, productivity, diversification, processing capacity, storage, distribution and marketing (Open Development Cambodia, 2016). Referred to the same source, the government has aimed for agribusiness to make up 30% of GDP (Gross Domestic Product) by 2025.

To achieve the goals or aims set by the government, there are several main agricultural policies established. Those policies are as follows:

- Cambodia Industrial Development Policy 2015-2025: This policy prioritizes the agricultural development as the key element. There are four prioritized developments to be achieved: development of the agro-industry, development of small and medium enterprises, development of transport and logistics, and development of skills training and worker development.
- Agricultural Extension Policy: The main goal of this policy is to ensure that knowledge and technology will be accessible to farming communities in order to increase the productivity.
- Crop-Specific Policy: This policy consists of other two main policies: Policy on the Promotion of Paddy Production and Rice Export; and Cambodia Natural Rubber Development Strategy 2011-2020.

There is no specific policy on urban and peri-urban agriculture in the capital; also data on agricultural activities is very limited. It can be assumed that the government has turned their attention to other main sectors that are currently growing very fast in the capital. However, there are some newly developed recreational places or resorts run by private sectors. Those activities include the growing of organic vegetables and fruit. The details will be explained below.

Urban and Peri-Urban Agricultural Activities

Urbanization and economic development in the capital have caused lifestyle changes. People living in the capital spend their weekends with family at private resorts or recreational places on the outskirts of the capital. Those resorts normally serve food and sell organic vegetables grown by them.

One of the popular places in this sector in Phnom Penh is Amarak Farm also known as Amarak Veggie Store, established in 2008, located at Koh Krobey Village, Prekthey Commune, Chbar Ampoeu District. It is about a one-hour drive by car from central Phnom Penh.

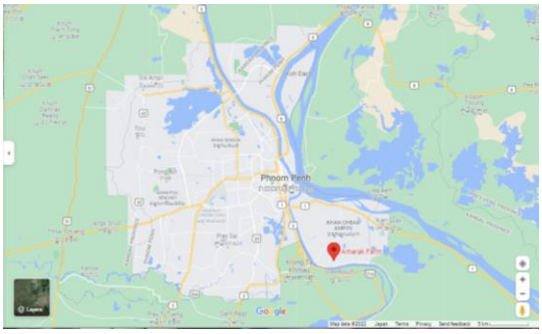

Fig. 4 Location of Amarak Farm **Fig. 5 Vegetable cultivation at the farm**

Source: www.amarakfarm.com; and www.google.com/map

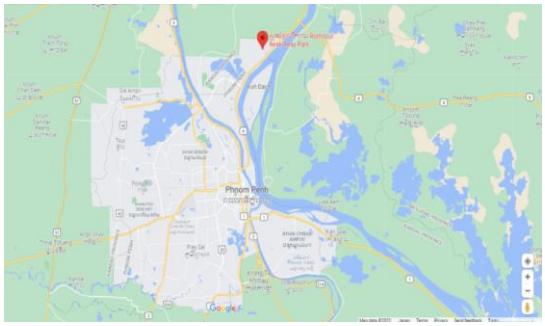

Fig. 6 Location of Romdoul Reak Reay Farm **Fig. 7 Vegetable cultivation at the farm**

Source: https://www.facebook.com/romdoulreakreay/photos/?ref=page_internal; and www.google.com/map

Based on the information on its homepage (www.amarakfarm.com), Amarak Veggie Store grows various kinds of salad and lettuce, herbs and fruits. The harvest is sent to local markets in Phnom Penh to sell as fresh and organic products. Besides, the vegetable production, Amarak

Veggie Store also provides other activities including camping, meeting places (or retreat centers), wedding receptions, picnics and other outdoor activities because this farm occupies a large area.

Going far to the Northern part of the capital, there is another resort called Romdoul Reak Reay Farm located in Chraoy Chongvar District. This farm occupies a large area, serves the food and grows various vegetables to sell at their place. This farm started a few years ago before the pandemic. However, they have extended their activities and diversified the farm.

Urban and peri-urban agricultural practice is active in the capital. Currently, there are many newly developed resorts or farms. However, there is no official data recorded about these activities.

CONCLUSION

During this transitional development of Phnom Penh due to rapid population growth and urbanization, Phnom Penh has expanded, and the construction of housing complexes and other buildings has increased. The government needs to pay more attention to implementing the plan to make the Land use master plan of Phnom Penh vitalized. Even data on urban and peri-urban agriculture in the capital is limited. Peri-urban agriculture in Phnom Penh Capital has been actively practiced as part of resort activities in the outer or outskirt districts. From this viewpoint, without proper implementation of the Land use master plan and management of the development of construction, reserved spaces for peri-urban agriculture in Phnom Penh capital will be affected.

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Research article

The Dynamics of Social Interactions of Children Playing around Rural Rivers in Japan

MASAYUKI NITTA*
Department of Civil and Environmental Engineering, Toyo University, Kawagoe, Japan
Email: nitta061@toyo.jp

YOSHIKI KUWABARA
Faculty of Agriculture, Yamagata University, Tsuruoka, Japan

MASAHIRO NAKAJIMA
Institute of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Japan

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Abstract In Monsoon Asia countries, rivers have intimate bonds with rural communities, which create diverse social interactions regarding community building such as recreation, education, and tourism. Especially, children tend to play around rivers, which is considered as one of the foundations of community building since playing fosters children's place-attachment to the local rivers. However, the number of children playing around rivers has been decreasing owing to expanding urbanization. This study aims to reveal 1) the influences of river use by family members and neighborhoods on children's river play, 2) the dynamics of children's social interactions in playing around rivers, and 3) the emergence mechanisms of children's social interactions in the play places. Questionnaire survey (127 local children from 9 to 11 years old), participatory observation, and hiring survey (49 local children from 9 to 11 years old) were conducted in the town of Gujohachiman, the Gifu Prefecture, Japan. Social network analysis (SNA) was applied to the observation data to examine the dynamics of social interactions in playing. As a result, river play frequency and preference of children were positively related to the frequency of daily use of rivers by their family members and neighborhoods. SNA showed that the interaction density of children playing around the river gradually increased while repeatedly fluctuating up and down. This dynamical change of interactions was caused by several leaders. The two factors for the emergence of children's social interactions were identified: introducing by the playgroup members and playing with caregivers. These results imply that rural rivers have the function for children to expand their local interpersonal relationships through playing, which are supported by local communities. Furthermore, children's play places around rivers have the potential to become the social interface for rural and urban communities.

Keywords rural rivers, children, play places, social interactions, social network analysis, environmental education

INTRODUCTION

In Monsoon Asia countries, rivers have intimate bonds with rural communities, which create diverse social interactions regarding community building such as recreation, education, and tourism. Especially, children tend to play around rivers (Senda, 1982; Kinoshita, 1992). However, children's water play around rivers has been decreasing owing to expanding urbanization.

As described in the Convention on the Rights of the Child, an outdoor play of children is essential for their sound development and it is required that the local communities support children's outdoor play towards sustainable community building in terms of their well-being. Various effects have been pointed out for nature play, including river play, such as emotional stability of children (Yoshinaga et al., 2006), improvement of athletic ability and intellectual ability

(Nakamura, 1999), an increase of independence (Kako, 2009), etc. Also, it is reported that playing around rivers is effective in improving children's spatial cognitive ability (Onishi, 2000), deepening their cognitive ability to living organisms (Ohgoshi et al., 2002; Ohgoshi et al., 2003), and improving children's social ability through interpersonal interactions (Sato and Takahashi, 2002; Sato et al., 2004; Enomoto and Nakamichi, 2021). In addition, river play fosters children's place-attachment to the local rivers, which leads them to nature conservation in the future (Satake and Kamihogi, 2006). Therefore, river play is important not only for community development but also for the conservation of river environments. So far, various studies have been conducted on the physical structure and biological environments that support children's river play (Fujiwara and Maekawa, 2003; Osawa, 2005; Terauchi et al., 2006; Horiuchi et al., 2009; Kakudo and Nishiyama, 2009; Imanishi and Matsumoto, 2016; Hasegawa et al., 2017).

However, there is no study that examines children's playing in the river from a social aspect and clarifies the dynamics of human interaction. It is important to quantitatively grasp the social interactions of children and to examine the relationships between children's river play and the local community, in order to conserve the children's river play in the future.

OBJECTIVE

The objectives of this study are to reveal 1) the influences of river use by family members and neighborhoods on children's river play, 2) the dynamics of children's social interactions in playing around rivers, and 3) the emergence mechanisms of children's social interactions in the play places.

METHODOLOGY

Study Area

The study was conducted in the Hachiman district of Gujo city (hereinafter called "Gujohachiman"), which is a rural area located in the middle of the Gifu prefecture, Japan (Fig. 1). The east, west, and north side of Gujohachiman are adjacent to the mountainous area, and the residential area is formed along the Yoshida River, which is an upper branch of the Nagara River. The area is also well known as "Water Town" since the water sources such as springs and wells have been maintained collectively by local communities in history.

Fig. 1 Location of study area

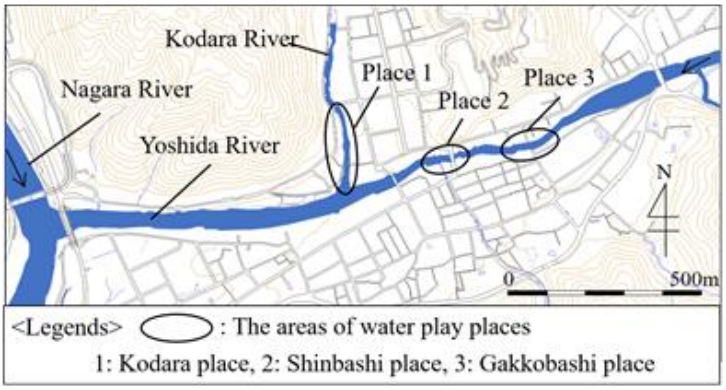


Fig. 2 The play places in the rivers in Gujohachiman

In the area, the river play of children was conserved as local culture. The local children play with water mainly in three places around rivers: Kodara place, Shinbashi place, and Gakkobashi place (Fig. 2). The three places are recognized as "play places" by the residents. Especially Shinbashi place is a popular sightseeing spot of Gujohachiman for urban tourists, because the place is known as "jumping spot," where children jump by the top of the Shinbashi bridge (12m above

water surface) into the Yoshida River. This place has been designated as one of the 100 Soundscapes of Japan by the Ministry of the Environment since 1996.

Data Collection

In order to collect the data for objective 1, Questionnaire survey was conducted to 127 students, who are in 4th to 6th grade (aged 9 to 11 years old) at the local primary school, on 15 September, 2010 (Table 1). The questionnaire survey was conducted at the integrated study classes. During children answered the questions, the teachers supervised them to secure the reliability of the answers. The response rate was 100%. The respondents answered the 18 questions regarding daily river play around rivers. In this paper, the results of 7 questions out of 18 questions were used: the preference and frequency of river play (2 items), the living environments (3 items), social interactions at playing with water (4 items). After the questionnaire, we conducted supplementary hiring to twelve children regarding to their river play.

Table 1 Respondents of questionnaire survey (n=127)

Sex	Grade		
	4th	5th	6th
Boys	22	16	27
Girls	20	16	26
Subtotal	42	32	53

In order to collect the data for objectives 2 and 3, observation and hiring survey were conducted on 29 local children from 9 to 11 years old from the 3rd to 5th September. The subjects of the survey were selected by those who answered the questionnaire. During the children playing around the three water play places, investigators recorded the number of children, the playing behavior of each child, and the playing location with one-minute intervals until all children left the play places. After the all children left the play places, the investigators conducted open-ended group interviews to them. The interview consists of the following questions:

- Where do you play with water around rivers usually?
- Why do you play there?
- Have you ever played with an infant or adult, who you did not know before?

Analysis

In order to analyze the relationships between the preference and the frequency of children's river play and their living environments (objective 1), simple tabulation and cross-tabulation were conducted on the data obtained by questionnaire survey. Secondly, the p-value was calculated using the results of cross-tabulation. These computations were done using the SPSS program, version 10.0.

As for objective 2, Social Network Analysis (hereinafter called "SNA") was applied to the observation data (Freeman, 2004; Nooy et al., 2012). The dynamics of children's social networks were analyzed by using density, which is an index of SNA. The density is calculated by using Eq. (1) as follows:

$$D_i = \frac{2m_i}{n_i \times (n_i - 1)} \quad (1)$$

Where

D_i: Density of children's social networks at the time i

n_i: The number of children existing in the play places at the time i

m_i: The number of children's ties at the time i

Density (Di) is an index of how close the social interchange between children playing in the play places at the time i is. If the density is high, the children make relatively large groups to play together. If the density is low, children play individually or in small groups.

As for objective 3, how children become acquainted with another child, infant or adult was analyzed based on the observation data. Focusing on the matter of how the children's communication started, the emergence mechanisms of children's social relationships in the play places were classified by the acquaintances' attributes: child, infant, and adult.

RESULTS AND DISCUSSION

Status of River Use of Children

Table 2 shows the preference and the frequency of river play of the subjects by sex. The ratio of those who prefer river play was 91.3% in total. As a result of chi-square analysis, the ratio of boys, who prefer river play (96.9%) was significantly higher than the ratio of girls (85.5%, $p < 0.05$). As for the frequency of river play, the ratio of those who play with water more than once a week was 50.4% in total. As a result of chi-square analysis, the ratio of boys, who play with water more than once a week (67.7%), was significantly higher than the ratio of girls (32.3%, $p < 0.001$). Water play around rivers was generally preferred by many children. In particular, it was found that boys tended to prefer playing around rivers.

Table 2 Children's preference and frequency of water play around rivers by sex

	The number of children by their preference of river play ("prefer" vs "not prefer") and its ratio*		The number of children by their frequency of river play ("once a weelk or more" vs "less than once a week") and its ratio***	
	Prefer	Not prefer	Once a week or more	Less than once a week
Boys (n=65)	63 (96.9%)	2 (3.1%)	44 (67.7%)	21 (32.3%)
Girls (n=62)	53 (85.5%)	8 (14.5%)	22 (36.1%)	42 (67.7%)
Subtotal (n=127)	116 (91.3%)	11 (8.7%)	64 (50.4%)	63 (49.6%)

*Significant difference is indicated by *p < 0.05, **p < 0.01, and ***p < 0.001, determined by chi-square test.*

Table 3 Relationship between the experiences to get to know new persons during river play and the number of members of river play

The experience of children to getting to know new persons during river play	The number of children by the number of members to play with around the river*	
	With 1 or 2 members	With more than 3 members
Yes, I had experiences to getting to know new persons during river play	31	36
No, I had no experience getting to know new persons during river play	39	19

*Significant difference is indicated by *p < 0.05, **p < 0.01, and ***p < 0.001, determined by chi-square test.*

As for the number of members to play with around rivers, all children answered "*playing with someone (friends or caregivers)*", which means no one played alone around rivers. As for the experiences of children to getting to know new person during river play, 53.6% of the children (n=127) had experiences to getting to know new person during river play. Table 3 shows the relationship between the experiences to get to know new persons during river play and the number of members of river play. As a result of chi-square analysis, the children, who play with more than three members, tended to have the experiences to get to know new persons during river play, compared to the children, who play with two or three members ($p < 0.05$).

Table 4 shows the relationships between the daily river use of family members and neighbors and children's preference and frequency of river play. The children, whose family members and neighbors used the river in daily life, tended to prefer river play (95.5%), compared to those whose family members and neighbors did not use the river in daily life (86.9%, $p < 0.05$). Further, looking

at the frequency of playing in the river, 63.6% of children, whose family members and neighbors used the river in daily life, answered that they played around the river for a week or more. On the other hand, the ratio of children, whose family members and neighbors did not use the river in daily life, was 36.9%, significantly lower than that of children whose family members and neighbors used the river in daily life ($p < 0.001$). Regarding this result, there were several opinions from eleven children such as:

"*Since I was baby, my grandfather (or grandmother, uncle, aunt) went to rivers and played together with me and he (or she) told me how to play around rivers*".

In addition, there were opinions from eight caregivers such as:

"*Because we all local residents played around rivers during childhood, so we know that playing with water is very fun and it is very important for child development*".

Thus, it is concluded that the daily use of rivers by family members and neighbors had a positive effect on children's preference and frequency of river play, and the children's river play was supported by the adults at home and in the neighborhoods.

Table 4 Relationships between daily river use of the family members and the neighbors and the children's preference and frequency of river play

	The number of children by their preference of river play ("prefer" vs "not prefer") and its ratio*		The number of children by their frequency of river play ("once a weelk or more" vs "less than once a week") and its ratio***	
	Prefer	Not prefer	Once a week or more	Less than once a week
Someone of the family members and neighbors uses the rivers in daily life (n=66)	63 (95.5%)	3 (4.5%)	42 (63.6%)	24 (36.4%)
None of the family members and neighbors use the rivers in daily life (n=61)	53 (86.9%)	8 (13.1%)	22 (36.1%)	39 (63.9%)

*Significant difference is indicated by *p < 0.05, **p < 0.01, and ***p < 0.001, determined by chi-square test.*

Dynamics of Children's Social Interactions in Playing Around Rivers

Fig. 3 shows the dynamics of the social interactions of 21 children played at the Gakkobashi place from 16:25 to 17:34. The density of the social interactions went up and down over time, which means that children were playing while repeating gathering and dispersion. The interaction networks of the children at each time from 16:40 to 17:10 are illustrated in Fig. 4. The black circle with the alphabet indicates the individuals of the children (ID: from "a" to "u") and the lines show that they had interactions, which means playing together.

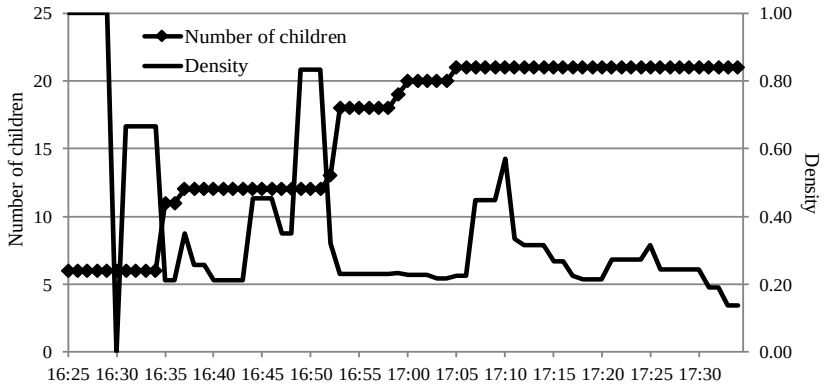
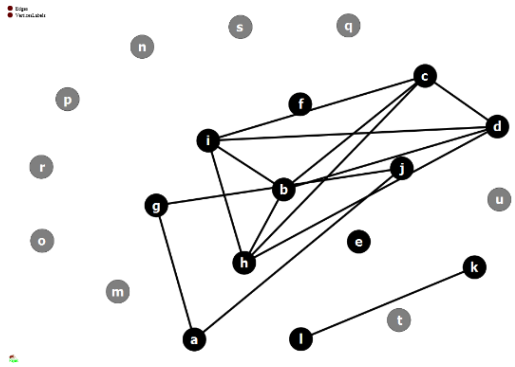
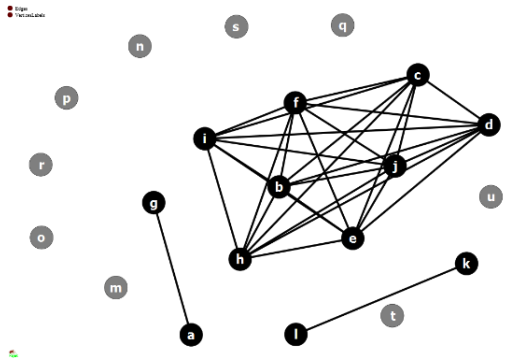


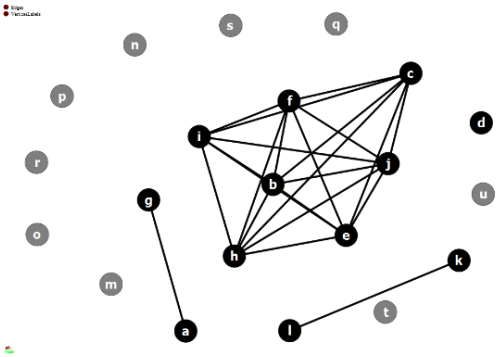
Fig. 3 Dynamics of children's social interactions in playing at the Gakkobashi place



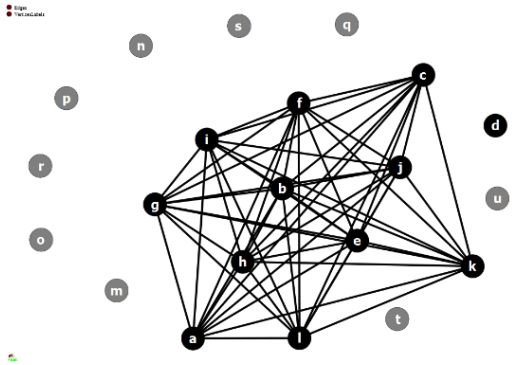
a) Interaction network of children at 16:40



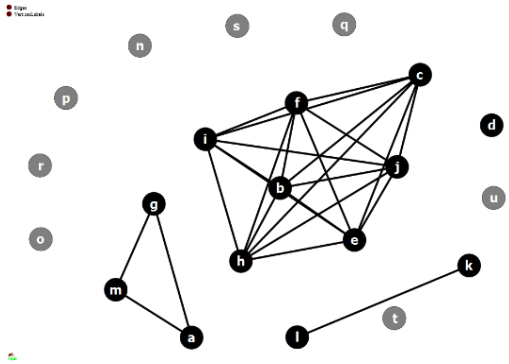
b) Interaction network of children at 16:45



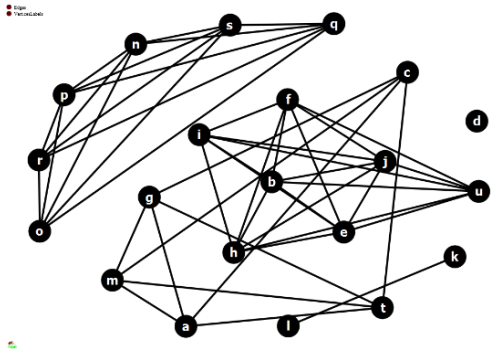
c) Interaction network of children at 16:47



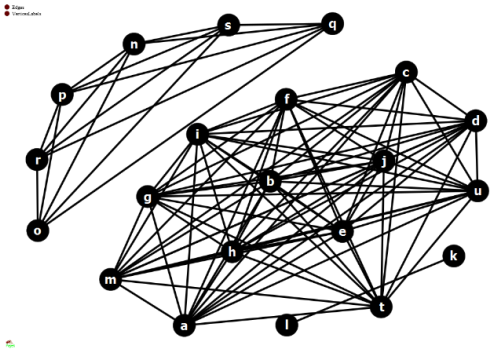
d) Interaction network of children at 16:50



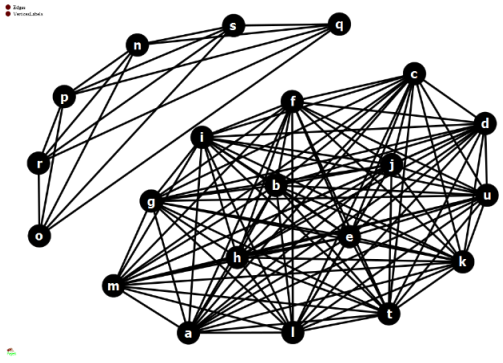
e) Interaction network of children at 16:52



f) Interaction network of children at 17:06



g) Interaction network of children at 17:07



h) Interaction network of children at 17:10

Fig. 4 Interaction network of children in the river playing at each time from 16:40 to 17:10

At 16:40, twelve children were playing and four playgroups were formed (Fig. 4a), and the density at this time was 0.21 (Fig. 3). Then, at 16:45, the playgroups changed, forming a bigger group of eight children and two pairs (Fig. 4b), and the density was 0.45. Further, at 16:47 child

"d" started playing alone, so the group was dispersed (Fig.4c), and the density was decreased at 0.34. At 16:50, the two pairs (child ID: a, g, l, k) started playing with a group of seven children, forming a large playgroup of 11 children (Fig. 4d), and the density increased at 0.83. Then, again, the children were dispersed and the group was divided into four groups at 16:52 (Fig. 4e), and the density was 0.32 at this time. At 17:06, six new children appeared and started group play (Fig. 4f) and the density was decreased at 0.30. At 17:07, as the two playgroups merged (Fig. 4g), the density increased at 0.75. Finally, the children formed two big groups to play and the density was 1.00 at 17:10 (Fig. 4h).

In this way, the children played while repeating gathering and dispersion, forming a larger playgroup. Fig. 5 shows the integrated diagram of the interaction networks between 21 children that occurred from 16:25 to 17:34. The thickness of the tie indicates the length of time to play with, and the longer the time, the thicker the tie. The ties between child b, d, h, i were very thick. These children were the leaders among the playgroups. For example, they decided what kind of play and where to play next. Therefore, it can be said that the daily relationships of the children were expressed by quantifying the interactions among them that changed over time during river play.

In this section, it was found that the children gradually expanded their playgroups as they repeatedly gathered and dispersed during river play.

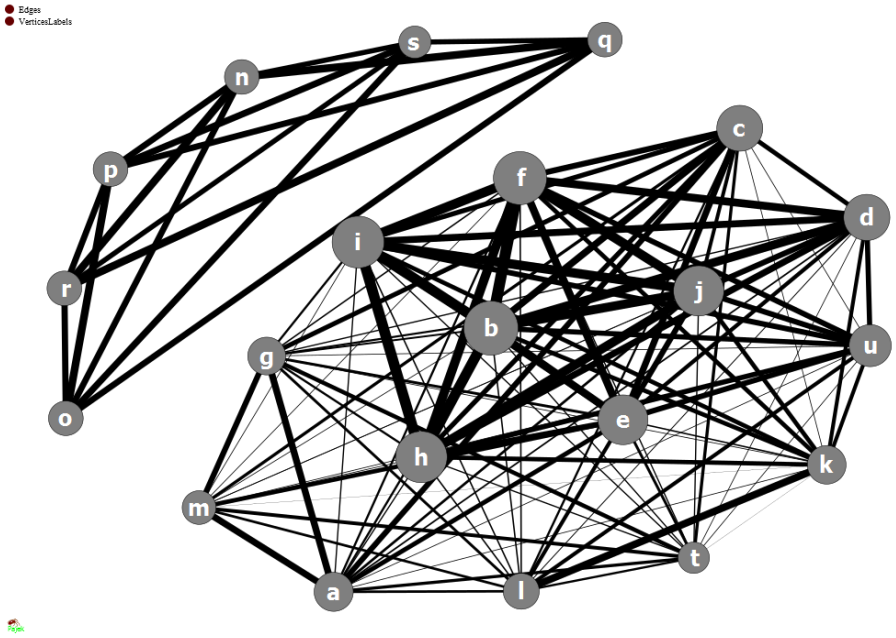


Fig. 5 Integrated interaction networks of 21 children observed from 16:25 to 17:34

Factors for The Emergence of Children's Social Interactions

Through the observation survey and hiring survey, two factors for the emergence of children's social interactions were identified: (1) introducing by playgroup members and (2) playing with caregivers.

(1) Introducing by playgroup members: From the results in the previous section, it was found that children gradually expanded their playgroups as they repeatedly gathered and dispersed during river play. Regarding this social interaction processes, the following opinions were given by the three children who were playing:

"We all (local children) play usually in the three play places (Gakkobashi, Shinbashi, and Kodara place). So local children playing with water around the rivers have many chances to know each other very well."

In addition, the following oral data were obtained from the four children:

"When we find some friends in other playgroups during river play, we play together with all group members via the friends."

Therefore, it can be said that there was a social exchange process by introducing to playgroup members. This process is modeled in Fig. 6. In the Gujohachiman, children's play places in rivers are fixed, so children's playgroups appeared in close proximity when playing in the river. At this time, when groups 1 and 2 appeared, if the member "a" and "b" were acquainted, they first left the group and had a conversation (Fig. 6). This formed a small play subgroup. Then, the children "a" and "b" were invited to play together in each playgroup, and all of them played together to form a large playgroup. Then, everyone became friends through river play together.

In this way, the cases that social interactions occurred through an introduction by playgroup members were observed 17 times during the observation survey. The reason why the children's play group gradually expanded in the previous section was due to the introduction by playgroup members.

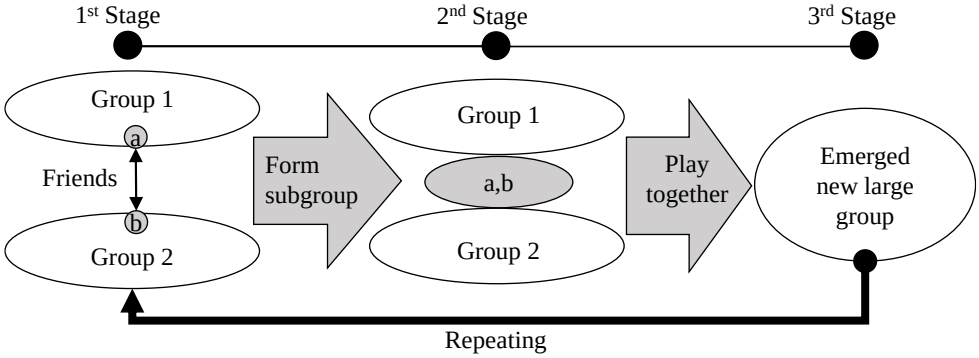


Fig. 6 Social interaction process model by introducing by playgroup members

(2) Playing with caregivers: The second is to play with caregivers. In this area, children were often seen playing in the river, so visitors from outside the area, tourists, often played around the rivers with their family members. From a viewpoint of the tourists, during the observation survey in the Shinbashi place, social interactions from the toursts to the children were observed seven times per hour. In addition, the following oral data were obtained from the ten tourists:

"It looks very fun that the local children play with water dynamically and actively."
"I (or We) want to play together with them."

On the other hand, it was also observed that children actively played with adults. When the children played with an adult, they could play, such as riding on adults' backs or throwing them on the water surface, which the children could not do with children. Once the children started to play with an adult, who is a caregiver of another child, they all played together finally. This process was shown in Fig. 7. The adult "c" is a caregiver of the child "a", and once the child "b" started to play with the adult "c" (the first stage in Fig. 7), the child "a" and "b" played with the adult "c" (the second stage in Fig. 7). Then The adult "c" introduced the child "b" to child "a" and they played all together finally (the third stage in Fig. 7). This process was confirmed eleven times during the observation survey.

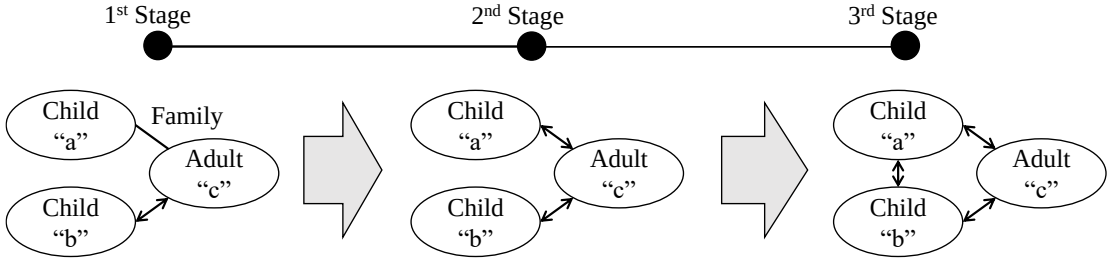


Fig. 7 Social interaction process model of playing with caregivers

CONCLUSION

There were several findings from this study.

Firstly, river play frequency and preference of children were positively related to the frequency of daily use of rivers by their family members and neighbors. Secondly, the SNA showed that the interaction density of children playing around the rivers gradually increased while repeatedly fluctuating up and down. Thirdly, the two factors for the emergence of children's social interactions were identified: introducing by the playgroup members and playing with caregivers.

In addition, although the hiring survey of this study was conducted in 2010, the authors also conducted supplementary interviews with local children playing around the river in this area in 2016, and have confirmed that the children yet played around river dynamically and their social interaction was formed through river play by introducing by playgroup members and caregivers (Nitta et al, 2017).

These results imply that rural rivers have the function for children to expand their local interpersonal relationships through playing, which are supported by local communities. Furthermore, children's play places around rivers have the potential to become the social interface for rural and urban communities, since the tourists were attracted by the children playing around the rivers dynamically and social interactions have occurred.

ACKNOWLEDGEMENTS

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Research article

Income Generation and Expenditure of Organic Rice Farming Households: Case Study of Preah Vihear Province, Cambodia

CHANMONY SOK*
Graduate School of Agriculture, Tokyo University of Agriculture, Japan
Email: Chanmony0223@gmail.com

TOMOHIRO UCHIYAMA
Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Japan

NINA N. SHIMOGUCHI
Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Japan

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Abstract In Cambodia, organic rice farmers commonly engage in integrated farming and off-farm activities to supplement their income. To identify factors for income optimization, this study attempted to assess the income and expenditure structure of organic rice farm households in the Preah Vihear Province, Cambodia. Guided with a structured questionnaire, a total of 90 and 50 randomly selected farmers were interviewed in 2019 and 2021, respectively. This study utilized both descriptive and multiple regression analyses. Overall, farmers tended to expand their cultivation area and increase income from off-farm jobs. Particularly, large-scale farmers (5ha<) significantly expanded their farmland area and increased their livestock and off-farm activities, while small-scale farmers (5ha>) reduced their farmland area and increased their off-farm activities. Moreover, the multiple regression analysis revealed that secured spare time from combine-harvester usage opened opportunities for farmers to engage in off-farm jobs. These off-farm jobs, particularly by male farmers, boosted their respective annual income. On the other hand, existing loans gave several farmer respondents negative profit in 2020. Thus financial management seemed to be a factor affecting farmers' incomes in rural areas. For further study, farm household employment choice behavior, particularly on labor mobility and off-farm activities, is recommended.

Keywords expenditure, income, off-farm activities, organic rice, rural area

INTRODUCTION

Agricultural development is the most effective way to reduce poverty (World Bank, 2008). Two effective agricultural development strategies are commonly practiced: engaging in organic agriculture and growing energy crops (Markandya and Setboonsarng, 2015). In Cambodia, agriculture contributed to poverty reduction from 50% in 2007 to 9.4% in 2017. Moreover, rice is the predominant crop, occupying 80% of the total crop area, and about 90% of the poor live in rural areas and rely on rice farming for their primary income sources (NIS, 2013). The agriculture sector still shared around 20% of GDP in 2019 (MAFF Cambodia, 2020). However, evidence suggests that rural households' livelihoods draw on various activities in developing countries. From rural development and food security viewpoints, it is critical to understand the structure of farm households' earnings and income levels (Helmers et al., 2004; Tong and Phay, 2013). Located in the Northern part of the country, Preah Vihear province is one of the main producing area of organic rice in Cambodia. This rural province produces organic rice once a year. Thus, all farmers have off-farm activities and produce other crop to support their daily lives. Commonly, farmers produce rice, other crops, and livestock (e.g. cattle, poultry), and do other off-farm activities as

wage-earners and migrants to the city or neighboring country to do other jobs to maximize their incomes (Preah Vihear Provincial Department of Agriculture, 2019). Little research has been performed on organic farm households' expenditure and income generation, especially in rural areas (Uddin and Takeya, 2006). However, no researcher has measured the expenditure and income generation of organic rice farm households in integrated farming based on-farm size and family structures (e.g. gender, age, family member, and off-farm activities) in Cambodia.

OBJECTIVE

This study aims to assess the income and expenditure structure of organic rice farm households in the Preah Vihear province, Cambodia, to determine the most suitable choice for organic rice farm households to maximizing income. Specifically, this study aims to identify the characteristic of organic rice farm households in the study area; clarify the structure of income sources of farm households; and assess their expenditures.

METHODOLOGY

Study area: Data collection was conducted in Preah Vihear province, the largest organic rice producing area and largest contract farming area in Cambodia. This region was characterized as a rural area, with 85% of the population (approximately 60,605 households in 2019) relying on agriculture. Hence, farmers were the main actors in this rural area.

Sample selection: Questionnaire survey and in-depth interviews were conducted randomly of 50 organic rice farmers in contract farming during the fields survey 2021. Collected data were processed and compared with the previous field survey of 90 respondents in 2019 in the same study area. Qualitative data were also collected regarding constraints, opportunities, and other impact factors, including environmental and social factors.

Data analysis: Descriptive and multi-regression analyses were utilized. The multiple-regression model below was adopted from Uddin and Takeya (2006) study.

$$\text{Ln AI} = \ln a + b_1 \ln X1 + b_2 \ln X2 + b_3 \ln X3 + b_4 \ln X4 + b_5 \ln X5 + b_6 \ln X6 + b_7 \ln X7 + b_8 \ln X8 + U_i$$

Ln = Natural logarithm
Y = Annual income of farm household
a = Constant or intercept of function
X1 = Total owned land
X2 = Working days per year on farm activities by male
X3 = Working days per year on farm activities by female
X4 = Working days per year off-farm activities by male
X5 = Working days per year off-farm activities by female
X6 = Family member
X7 = Family member engage in Agri.
X8 = Age of head household

$b_1 \ldots b_8$ = Coefficients of respective variables;
U_i = Error terms.

RESULTS AND DISCUSSION

Farmer respondents were divided into three groups according to their owned land size, as shown in Table1. Family members and members engaged in agriculture decreased yearly, for overall farmers and or group categories. From 2018 to 2020, farmers seemed to increase their cultivation areas. However, only farmers who own land more than 5 ha increased their cultivation areas, and farmers who own land larger than 10 ha expanded all their cultivation areas in a fast pace. In contrast, farmers who own land less than 5 ha seemed to decrease their rice cultivation. From field observation, farmers tend to operate inherited land and sell some of their land. They were more involved in off-farm activities than on-farm activities.

Table 2 shows income sources and expenditure of farmer respondents in the study area. The main job of farmer respondents are organic rice farming. However, since organic rice could only be produced once a year, farmers need to do other jobs to increase their annual incomes as shown in

Table 2, such as other crops farming (cassava, cashew nut), vegetable farming, livestock, and off-farm jobs (e.g. wage earner from other farm, construction workers, small grocery owner, government officer). From Table 2, income from rice farming remained high, but income from off-farm jobs farmers are increasing annually. In general, farmers had lower incomes in 2020 except for those who owned less than 5 ha. Farmers who owned land more than 5 ha relied more on organic rice farming compared to other farmers, thus the impact of natural disasters was also high. At the same time, farmers are also increasing income from livestock, and other crop farming, Farmers who own larger than 10 ha increased their livestock farming income in a fast pace. From the interview, farmers said that even though the use of agricultural machinery is still limited, either owned or rented, and it has secured them more time to do off-farm jobs or expand their cultivated land.

Table 1 General characteristic of farmers respondents from 2018 to 2020

Items	Overall			Less than 5 ha			5 to 10 ha			More than 10 ha		
	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
Number of household	**90**	**50**	**50**	**42**	**25**	**20**	**37**	**20**	**21**	**11**	**5**	**9**
Family member (person)	4.6	4.2	4.0	4.2	3.6	3.4	4.8	4.2	4.1	5.4	5.2	5.2
Member engage in Agr. (person)	3.4	3.1	2.9	3.1	2.6	2.5	3.7	3.2	3.1	3.9	3.6	3.4
Education (years)	5.1	5.5	5.6	5.4	5.8	5.4	5.7	5.2	5.2	5.1	5.2	6.3
Age (years)	43.6	46.4	47.4	45.1	45.6	49.5	45.2	46.4	47.4	52.1	51.1	43.9
Rice cultivation area (ha)	3.8	4.1	4.3	3.2	2.3	2.1	4.1	4.1	4.3	6.7	8.8	9.2
Other crop cultivation area (ha)	1.3	1.6	1.9	0.2	0.7	0.9	1.3	1.6	1.9	2.9	4.0	3.7
Fallow land (ha)	1.1	0.7	0.6	0.1	0.2	0.1	1.0	0.7	0.6	2.8	2.0	1.2
Total owned land (ha)	**6.2**	**6.3**	**6.8**	**3.5**	**3.2**	**3.2**	**6.0**	**6.4**	**7.2**	**12.4**	**14.8**	**14.8**

Source: Field survey, 2019 and 2021

Table 2 Income sources and expenditure of farmers by year and groups

unit: thousand riels/household

		Overall			Less than 5 ha			5 to 10 ha			More than 10 ha		
		2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
	Number of Households	90	50	50	42	25	20	37	20	21	11	5	9
Income sources	Rice	4,790	5,624	4,300	3,819	3,494	2,312	5,680	5,934	4,316	12,155	13,449	9,477
	Other crops	1,363	593	1,739	512	685	869	639	1,218	1,906	2,400	2,508	3,585
	Off farm	2,617	5,716	6,389	3,066	6,273	7,977	2,344	5,049	4,705	2,200	5,473	6,645
	Vegetable	n/a	749	637	n/a	472	517	n/a	627	772	n/a	1,200	600
	Livestock	1,814	1,884	2,884	1,565	1,934	2,165	1,718	2,350	2,316	1,502	8,003	8,489
	Total incomes (1)*	**10,584**	**14,566**	**12,429**	**8,962**	**12,858**	**13,840**	**10,381**	**15,178**	**14,015**	**18,257**	**30,633**	**28,796**
Expenditure	Food	6,627	6,859	6,999	5,535	5,730	5,848	5,471	5,665	5,782	8,211	8,503	8,679
	Children	1,390	1,423	1,457	1,163	1,190	1,219	1,194	1,223	1,253	3,417	3,500	3,585
	Loan	779	969	981	449	558	565	535	666	675	1,943	2,422	2,453
	Transportation	632	813	823	760	979	991	442	571	578	865	1,118	1,132
	Utility	230	350	358	190	290	297	184	282	289	480	736	755
	Phone	235	351	360	195	291	297	189	283	289	246	369	377
	Other	517	666	955	374	482	694	460	594	856	1,010	1,306	1,887
	Total Expenses (2)	**10,409**	**11,429**	**11,934**	**8,665**	**9,521**	**9,911**	**8,476**	**9,284**	**9,721**	**16,172**	**17,955**	**18,868**
	(1) - (2)	175	3,137	495	297	3,337	3,929	1,905	5,894	4,294	2,085	12,679	9,929

Source: Field survey, 2019 and 2021 *Note: *All the production costs of farming are excluded from incomes 1USD=4,050 riels*

All the essential daily or monthly expenditures of farm households are included in Table 2 except the production cost of farming. More than 50% of total expenses accounted for food consumption. Farmers are also willing to invest more in their children's education, about 15% of total expenses, and more than 15% for farmers with land larger than 10 ha in 2020. Moreover, the annual loan tends to increases because farmers are more engaged with loans to increase cultivated land or other purposes, and farmers who own larger than 5ha are more involved with the loan.

Farmers mainly borrowed from banks, micro-finance, and a small amount of money from agricultural cooperatives, with the monthly interest rates ranging from 1.75% to 2.5%. In addition, phone payment is increasing because recently, farmers have recently started to use smartphones to receive more information. Lastly, other expenses in Table 2 included health care, social/religious ceremonies, and house repair. As shown in Table 2, farmers could not sufficiently save in 2020, and from observation, several farmers lost their profit in 2020, which will be further discussed in Table 3.

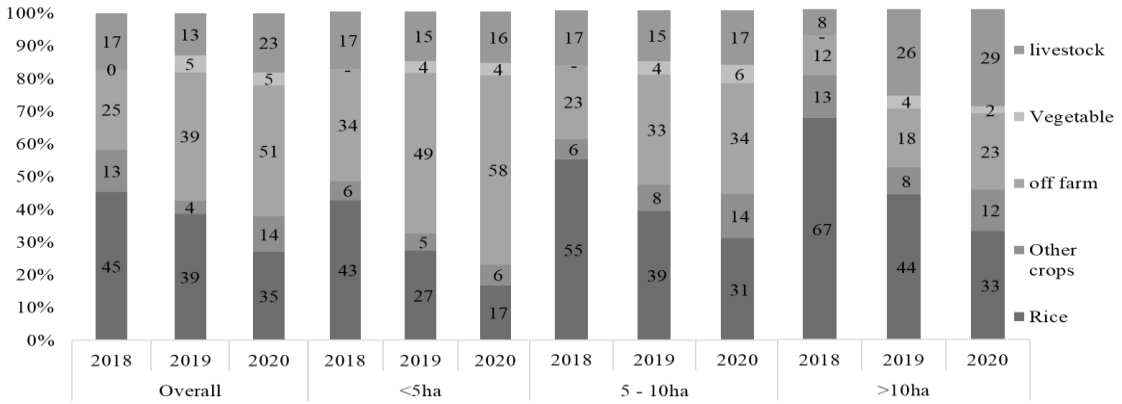

Fig. 1 Percentage of income sources by farmer groups

Source: Field survey in 2019 and 2021

Table 3 Income sources and expenditure of farm households who lost profit in 2020

unit: thousand riels/household

	Items	Overall	Less than 5 ha	5 to 10 ha	More than10 ha
Income sources	Number of Households	13	5	6	2
	Rice	3,727	2,246	4,247	6,346
	Other crops	1,812	1,164	1,907	3,425
	Off farm	5,809	8,910	3,346	5,123
	Vegetable	-	-	-	-
	Livestock	1,216	578	1,651	1,605
	Total incomes (1) *	**12,564**	**12,899**	**11,152**	**16,499**
Expenditure	Food	6,687	6,213	6,995	6,760
	Children	2,320	2,190	2,190	2,798
	Interest	3,253	2,202	2,814	6,032
	Transportation	1,083	1,862	704	669
	Utility	441	514	404	416
	Phone	381	451	350	336
	Other	1,014	576	1,114	1,497
	Total Expenses (2)	**15,179**	**14,007**	**14,570**	**18,508**
	(1) - (2)	**(2,615)**	**(1,108)**	**(3,418)**	**(2,009)**

Source: Field survey, 2021

*Note: *All the production costs of farming are excluded from incomes, 1USD=4.050 riels*

Although most farmers reported that the main job is rice farming, Figure 1 clearly shows a natural shift of farmer income sources to off-farm activities. Moreover, only farmers who own land less than 5 ha rapidly increase off-farm jobs and decrease share income and cultivated rice farming land from 2018 to 2020. This can be attributed to farmers selling of inherited rice cultivated land. In addition, farmers who own land 5 to 10 ha are increasing off-farm, and other crops farming and farmers who own land larger than 10 ha are more increasing in livestock because they have larger land and capital.

During the field survey in 2021, some farmers had no profit due to high expenses, as shown in table 3. All those farmers spent more on paying loan interests, while the income in 2020 decreased. From field observation, farmers who owned land between 5 to 10 ha engaged more in loans to expand their land cultivation and other activities. Unfortunately, the rice yield was low, which decreased income, and farmers could not afford the repayment. In addition, some farmers who owned less than 5 ha needed to sell their lands to afford the repayment to the bank, which made farmers decrease their owned land, while those who owned land of more than 5ha sold their livestock and other machinery to repay the loan. Those problems made these farmers further smaller in scale. Therefore, farmers seemed to need to understand more about financial management to lower risk in the future.

Table 4 shows the result of multiple-regression on total annual income with working labors, family members, and age of farm households in 2020 by dividing into two groups: farmers who owned less than 5ha and a combination of all farmers who owned land larger than 5ha. It should be noted that the farmers who owned more than 10 ha were not grouped separately due to small

sample size of nine respondents. As a result, besides the land size, off-farm activities significant increased the total annual income. Working off-farm jobs for male has boosted their annual income, especially farmers who owned less than 5 ha. On the other hand, working on the farm for females resulted to negative impact because female farmers are only good at transplanting and harvesting. During land preparation, most female families go together to cook for their husbands or family members at the fields and do side-works nearby, such as picking some dead trees. On-farm work of males is much better during land preparation and other works. Besides that, family members, members engage in agriculture, and the age of the head of households are not significant to increase the income.

Table 4 Multiple-regression of model of farm households' incomes based on groups

< 5 ha (2020) (20 respondents)	Estimate	Std. error	t-value	Pr (>|t|)	
(Intercept)	11.214	1.483	7.558	0.000	***
Land size	0.612	0.345	3.724	0.011	*
Working on-farm male	0.139	0.094	1.462	0.171	
Working on-farm female	-0.073	0.137	-1.534	0.303	
Working off-farm male	0.330	0.136	2.422	0.032	*
Working off-farm female	0.292	0.236	2.082	0.064	*
Family members	0.227	0.238	0.942	0.360	
Family members engage in farming	0.190	0.272	1.991	0.116	
Age	0.145	0.350	0.416	0.580	

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*
Multiple R-squared: 0.6657, Adjusted R-squared: 0.5247

> 5ha (2020) (30 respondents)	Estimate	Std. error	t-value	Pr (>|t|)	
(Intercept)	14.766	3.191	4.627	0.000	***
Land size	1.324	0.253	5.221	0.000	***
Working on-farm male	0.554	0.270	2.051	0.053	.
Working on-farm female	-0.550	0.281	-1.954	0.064	.
Working off-farm male	0.208	0.073	2.815	0.010	*
Working off-farm female	0.105	0.060	1.739	0.097	.
Family member	0.091	0.230	0.396	0.696	
Family member engage in farming	0.140	0.130	1.080	0.292	
Age	0.079	0.132	0.603	0.553	

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*
Multiple R-squared: 0.742, Adjusted R-squared: 0.640

Source: Field survey in 2021

Table 5 Total annual income and labors input by group in 2020

	Items	Overall		Less than 5 ha		5 to 10 ha		More than 10 ha	
	Number of households	50	%	20	%	21	%	5	%
Income sources (Thousand riels/HH)	Rice	4,300	35	2,312	17	4,316	31	9,477	33
	Other crops	1,739	14	869	6	1,906	14	3,585	12
	Off-farm	6,389	51	7,977	58	4,705	34	6,645	23
	Vegetable	637	5	517	4	772	6	600	2
	Livestock	2,884	23	2,165	16	2,316	17	8,489	29
	Total income	12,429	100	13,840	100	14,015	100	28,796	100
Labors input (People/HH)	Total labors	436	100	462	100	366	100	550	100
	Rice (male)	47	11	33	7	51	14	74	13
	Rice (female)	49	11	34	7	52	14	79	14
	Other crops (male)	21	5	10	2	21	6	44	8
	Other crops (female)	19	4	10	2	21	6	36	7
	Off-farm (male)	201	46	231	50	159	44	227	41
	Off-farm (female)	101	23	143	31	61	17	91	16

Source: Field surveys in 2021 *1 USD = 4,050 riels*

Even the regression analysis showed that farmers could boost their annual incomes by engaging in off-farm activities in the current situation, farmers who used about 22% of total labor inputs on rice farming only received about 35% of total income (Table 5). On the other hand, farmers who used about 70% of total labor on off-farm activities received about 51% of total income. This conveys that farmer may achieve more labor and income efficiencies by organic rice farming. However, seasonality of organic rice farming and difficulty in expanding land for organic rice cultivation (mainly small-scale farmers) are the core reasons on further shifting to off-farm activities.

CONCLUSION

In general, the cultivation area has been increasing from 2018 to 2020. Farmers who own land more than 5 to 10 ha increased all the cultivated lands, especially on other crops. However, farmers who own less than 5 ha seemed to rapidly increase their off-farm jobs and decrease their rice land.

Regarding expenditure, farmers spent more than 50% of total expenses on their food consumption, followed by 15% spendings on their children's education. This trend is prevalent to farmers are currently more engaged in loans. Unfortunately, several farmers (especially farmers who owned land less than 5ha) could not repay the loan in 2020, forcing them to sell their lands or other properties to repay the loan and making small-scale farmers further smaller in scale.

However, rice farming still seemed to offer opportunities for farmers to boost their annual incomes in terms of labor inputs and incomes if farmers could expand their rice land and do proper financial management.

Nevertheless, instead of expanding rice cultivation, farmers (especially farmers who owned less than 5ha) tend to increase their annual income by engaging in off-farm jobs in the current situation. On the other hand, farmers who owned less than 5 ha are better off in securing more spare time to do off-farm jobs, especially males, have more potential to boost the farm households' annual incomes.

Therefore, farm households' employment choice behavior, particularly labor mobility, off-farm activities, and loans, is recommended for further study to find more solutions for maximizing the farm households' income.

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Research article

Economic Assessment of Tea Smallholder Farmers under Contract Farming in Rungwe District, Tanzania

ISSA ABRAHAMAN KACHENJE*
*Graduate School of Agriculture, Tokyo University of Agriculture, Japan**
Email: 13822001@nodai.ac.jp

NINA N. SHIMOGUCHI
Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Japan

KATSUMORI HATANAKA
Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Japan

RAMADHONA SAVILLE
Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Japan

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Abstract In Tanzania, tea is considered as one of the most exported crops. The main stakeholders of the tea industry are smallholder farmers and estates. Smallholder tea farmers are required to engage in contract farming, as stipulated in the Tea Regulation of 2010. This study attempted to assess contract farming and its impact to production and income of tea smallholder farmers in Rungwe District, Tanzania. A total of 48 randomly selected smallholder farmers were interviewed using a semi-structured questionnaire in September 2020 and October 2021. Agribusiness company officials, government officials and extension officers were also interviewed to clarify the condition and issues of the contract farming scheme. Descriptive analysis and cost and return analysis were utilized. Results show that yield, income, and profitability increased from 2016-2019. These can be attributed to steady supply of inputs, easy access to technical assistance, and early adoption of new technology under contract farming scheme. Moreover, the price of smallholder green leaf has improved, with farmers receiving a second payment hence improve their overall revenue returns.

Keywords: contract farming, smallholder farmers, tea, profitability, Tanzania

INTRODUCTION

Tea is a globally manufactured and widely consumed beverage (Hicks, 2009; Onduru et al., 2012). Kenya, Malawi, Uganda, Tanzania, Zimbabwe, South Africa, and Rwanda are the principal tea-producing countries in Africa, with tea contributing considerably to their economy (FAO, 2014). By the year 2023, the continent's export volume is expected to reach 743,384 metric tons (FAOSTAT, 2015).

Tea is the fifth most exported crop in Tanzania, the tea sector accounts for an average of approximately USD 50 million every year, when it comes to foreign exchange earnings. Tea industry also contribute to the huge amount of employment opportunities as it employs more than 50,000 families and indirectly it affects to as many as 2 million Tanzanian citizens (Baffes, 2004). Moreover, the nature of tea production necessitates a significant amount of labor, implying that the sector can employ a large number of people. Tea can be harvested all year round, making it one of the few crops that can generate a relatively consistent income when compared to seasonal crops like maize.

Tea cultivation was only done on a large scale under the supervision of several tea estates during colonial and early post-colonial times, which meant that smallholder farmers were non-

existent. Smallholder tea production legally began only after the independence in 1960s. At that time the government had actively pushed smallholders' involvement in the tea sector (Maghimbi et al., 2011; Gibbon, 2011). This marked the starting point for the co-existence and relationship between the smallholders and estates in the tea sector. The relationship was later on cemented with the introduction of programs such as contract farming and sales agreements. Further, smallholders are required by law to have at least a one-year sales agreement in place. This is due to a number of factors: Firstly, the tea leaves' perishable nature; green leaves can only be stored for around six hours before they must be processed. Secondly, tea processing also demands complex and costly machinery, which is why the majority of tea processing firms are owned by large corporations. As a result, smallholders are reliant on tea processing plants owned by large tea companies. This mandates close collaboration between smallholder farmers and estates that possess processing plants, hence makes sales agreements and contract farming necessary in Tanzania tea sector.

OBJECTIVE

The main goal of the study was to assess contract farming and its impact to production, income, and profitability of tea smallholder farmers in Rungwe District, Tanzania.

METHODOLOGY

Study Area

This study was conducted in Rungwe district (see Fig. 1) located in the Southern tea growing zone. Two villages from the Rungwe district namely Katumba and Lugombo village were purposively selected because these villages large concentration of smallholder farmers operating under a contract system. A total of 48 randomly selected smallholder farmers were interviewed using a semi-structured questionnaire in September 2020 and October 2021. Agribusiness company officials, government officials and extension officers were also interviewed to clarify the condition and issues of the contract farming scheme.

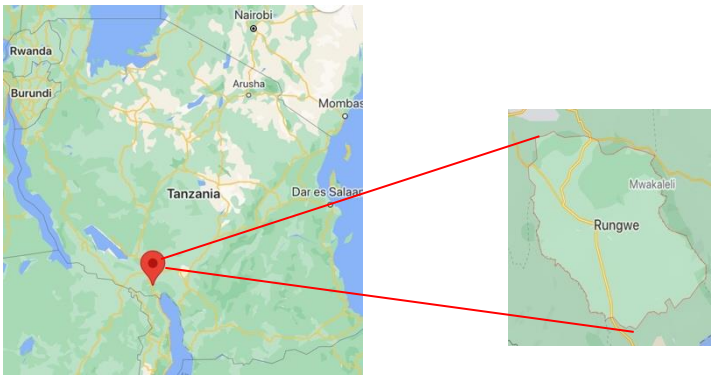

Fig. 1 Map of the study area
Source: Google map

Methods of Study

For evaluating the impact of these Contract Farming schemes on yield, income, and profitability of tea per unit area, cost and return analysis was utilized. Furthermore, the study compared the yield, income, and profitability of smallholder tea farmers from the year 2016 to 2019.

Fixed costs, such as family labor and land charges, were separated from variable costs, such as herbicides, chemical fertilizers, pesticides, and hired labor. The gross return was then obtained by multiplying the marketable produce by the year's average price per kilogram. The profit was then calculated by subtracting the total cost from the gross return.

RESULTS AND DISCUSSION

This study estimated the cost of producing green tea leaves for smallholder tea producers in the Rungwe district of Mbeya, Tanzania, as well as the revenue generated. In the study area, Pesticides, herbicides, and farm labor both family and hired labor are among the inputs used by smallholder tea farmers. On the other hand, Chemical fertilizers, such as NPK fertilizers, Glyphosate, Urea, and SA fertilizer, are also used. Additionally, other farm inputs include safety Goggles, Gloves, Gum Boots, Raincoat, Mouth Mask, Shears, and Spray Pump are often used by smallholders in the study area. This section analyzed the production costs and profitability of smallholder farmers participating in Contract Farming in greater detail. Most of these inputs are provided on credit to smallholder tea farmers in the study area by their contracting estates. The inputs are distributed according to a well-established process that is overseen by smallholder association leaders and extension officers. The loaned inputs are paid for by deducting from the overall earnings that smallholder farmers are expected to gain without any interest.

Yield of Green Tea Leaves Produced by Smallholder Tea Farmers

The yield of a crop is calculated by dividing the amount of crop harvested by the harvested area of that crop. Mathematically, the yield can be calculated by dividing production data by harvested area data.

According to the findings, the marketable yield for smallholder tea leaves in 2016, 2017, 2018, and 2019 was 1,093 kg/ha, 1,175 kg/ha, 1,247 kg/ha, and 1,347 kg/ha, respectively. This is attributable to a steady supply of inputs, easy access to technical assistance, and the adoption of new technologies in the study area's contract farming scheme. Similarly, the contracting company has stepped up its efforts to provide smallholder farmers with inputs such as fertilizers and herbicides at significantly lower prices than market prices, allowing them to have easy access to supplies at a reasonable price.

Table 1 Comparison of the average yield for smallholder tea farmers

n=(kg/ha)

Items	2016	2017	2018	2019
National	814	1,082	1,203	1,035
Study area	1,093	1,175	1,247	1,347

Source: Field survey in 2020

The Costs of the Inputs for Green Leaf Tea Production

The overall production cost was estimated, which included not only the cash payment but also the estimation of the opportunity cost for smallholder farmers. There are two types of costs in agriculture: variable and fixed. In general, variable costs fluctuate according to the degree of production. Fixed costs, on the other hand, are expenses that do not change regardless of production level. According to Mamun et al. (2018), the total cost (TC) can be obtained by adding the total variable cost (TVC) to the total fixed cost (TFC), as illustrated in the equation below.

$$TC = TVC + TFC \quad (1)$$

Where *TC is total costs, TVC is total variable cost and TFC is total fixed cost.*

In this study, the total cost was calculated by adding the costs of chemical fertilizers, herbicides, farm equipment, and labor used by smallholder farmers for producing green tea leaves in the study area.

Moreover, in an effort to improve green tea leaves production volume and quality in the study area, the amount and frequency of provision of various farm inputs such as herbicides, chemical

fertilizers and other equipment were increased which resulted into the increased cost of production as shown in the table 6.1. According to the findings, the total production cost of green tea leaves per hectare was 65.65 TZS/ha, 73.32 TZS/ha, 102.13 TZS/ha, and 112.07 TZS/ha in 2016, 2017, 2018, and 2019 respectively.

Green Tea Leaves Price in the Study Area

In the study area, for the years 2016, 2017, 2018, and 2019, the contracting company's green tea leaves price per Kg in the research region was 231 TZS/Kg, 240 TZS/Kg, 315 TZS/Kg, and 320 TZS/Kg, respectively. These prices offered to smallholders in the study area are higher than the government's recommended price (basal price), implying that farmers in the study area benefit more than green tea leaf growers in other tea producing areas, such as the Korogwe district in the northeast zone, where smallholder tea producers receive no more than the government's recommended price.

Table 2 Total production cost and profitability of smallholder tea production

(Unit: 000' TZS/ha)

Items	2016	2017	2018	2019
Observed smallholders	(n=48)	(n=48)	(n=48)	(n=48)
Average cultivated area (ha)	0.3	0.3	0.3	0.3
Yield (Kg/ha) (AA)	1,093	1,175	1,247	1,347
Chemical fertilizer costs (C1)	8.14	9.09	12.66	13.90
Herbicide's cost (C2)	10.80	12.34	18.10	20.09
Farm Instruments (C3)	2.04	2.28	3.18	3.49
Hired labor cost (C4)	15.62	17.45	24.31	26.67
Total variable cost (TVC)=(C1+C2+C3+C4)	36.61	40.89	56.96	62.50
Family labor cost (C5)	27.77	31.02	43.21	47.42
Total labor cost (C6) = C4+C5	43.39	48.46	67.51	74.08
Total production cost (C7)=TVC+C5	65.65	73.32	102.13	112.07
Gross revenue (GR) = (AA*Farm gate price)	252.48	282.00	392.81	431.04
Gross income (GI) = (GR-TVC)	215.87	241.11	335.85	368.54
Gross profit (GP) = (GI-C5)	188.10	210.09	292.64	321.12

Smallholder Tea Farmers' Revenue, Income and Profitability in the Study Area

The gross income (GI), gross revenue (GR) and Gross profit (GP) were estimated using data from the field survey 2020 and 2021 to better understand the impact of tea leaves production on the smallholders' livelihood. The study then simulated the comparative profitability of growing green tea leaves in various years from 2016 to 2019. This will help to determine the trend of gross income, gross revenue, and profitability received by smallholder tea farmers each year, as well as ranking the profitability received over this period of time.

Gross revenue (GR) means the amount received by farmers presumably that their entire volume of marketable yield is sold at the farm gate price. Dammert and Mohan (2015) support that the concept of Gross Revenue is calculated as yield multiplied by farm gate price. Further, Gross income (GI) is computed by subtracting total production costs from Gross Revenue, excluding family labor costs. Finally, gross profit is derived by subtracting family labor costs from gross income.

The results showed that in 2016, 2017, 2018, and 2019, the gross revenue for smallholder tea leaves production was 252.48 TZS/ha, 282 TZS/ha, 392 TZS/ha, and 431.04 TZS/ha, respectively. Likewise, the results showed that in 2016, 2017, 2018, and 2019, the gross Income for smallholder tea leaves production was 215.87 TZS/ha, 241.11 TZS/ha, 335.85 TZS/ha, and 368.54 TZS/ha, respectively.

Table 3 Price of green tea leaves in TZS

Items	2016	2017	2018	2019
Tea leaves price/kg	231	240	315	320

Source: Field survey in 2020.

CONCLUSION

Firstly, land ownership of smallholder tea farmers was overwhelmingly male dominated, suggesting that land ownership for women is a major issue in African traditions and culture as a result of gender biased traditions. As a result, women's ability to participate in Contract Farming (CF) in Africa is compromised. Also, low level of education among the smallholder tea farmers was also observed. in terms of farm size, smallholder tea farms were relatively small (averaging 0.30 hectares). Inadequate farm size, on the other hand, may limit households' ability to expand their cultivation and fully exploit the benefits provided by Contract Farming programs in order to maximize productivity while utilizing the far more advanced technologies. Finally, the findings revealed that farming is the principal economic activity of the entire sample of respondents in the study area.

In the study area, smallholder tea farmers received prices higher than the government's recommended price, implying that farmers in the study area benefit more than green tea leaf growers in other tea-producing areas, such as the northeast zone's Korogwe district, where smallholder tea producers receive no more than the government's recommended price. Furthermore, smallholder farmers in the study area benefited not only from the higher price than the government recommended, but also from the introduction of a first and second payment system after the company's sales of the made tea, based on cost sharing and final market price, which improved their overall revenue returns.

Over the four years for which data were gathered, the trend of Marketable Yield has risen. As a result, in 2019 the highest marketable yield was obtained, whereas in 2016 the lowest yield was obtained. Furthermore, data obtained shows that smallholder farmers in the study area produced higher yields than the country's average yield for each of the four years examined. This is owing to a steady supply of inputs, easy access to technical assistance, and the adoption of innovative technology in the study area's contract farming scheme. Similarly, the contracting company has stepped up its efforts to provide smallholder farmers with inputs such as fertilizers and herbicides at much cheaper prices than market prices, allowing them to have easy access to supplies at an affordable price. And because of the higher price and yield, smallholders in the Contract scheme were able to generate more gross revenue, gross income, and profit compared to national average for smallholder tea farmers. In general, contract farming in the tea sector appears to be profitable for respondent smallholder tea farmers in the study area.

However, the need for a higher price for their tea leaves, difficulty adapting to new technologies, insufficient input supplies, insufficient funds to hire extra farm labor, and insufficient farm equipment were shown to be the challenges that smallholders experience.

Generally, the contract farming system in the study area has a positive impact on production, income, and profitability of tea smallholder farmers, despite the existence of some constraints. In light of the findings and conclusions, the study recommends that the government, agribusiness companies, smallholder famers association and other stakeholders develop a common strategy and ways for smallholder tea farmers to have better access to capital in order to boost their adaptability

to new technologies, buy sufficient farm input and farm equipment, and have sufficient funds to hire extra farm labor to further improve their profitability.

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Research article

Performance Assessment of Simple Covered Lagoon Digester in Large-scale Pig Farm in Cambodia

CHAN MAKARA MEAN
Biogas Technology and Information Center, Royal University of Agriculture, Phnom Penh, Cambodia
Email: meanmakara321@gmail.com

LYHOUR HIN*
Biogas Technology and Information Center / Faculty of Agricultural Engineering, Royal University of Agriculture, Phnom Penh, Cambodia

LYTOUR LOR
Biogas Technology and Information Center / Faculty of Agricultural Engineering, Royal University of Agriculture, Phnom Penh, Cambodia

DYNA THENG
Biogas Technology and Information Center / Faculty of Agricultural Engineering, Royal University of Agriculture, Phnom Penh, Cambodia

MAKARA LAY
Biogas Technology and Information Center, Royal University of Agriculture, Phnom Penh, Cambodia / Department of Science and Technology, Linköping University, Norrköping, Sweden

BART FREDERIKS
Biogas Technology and Information Center, Royal University of Agriculture, Phnom Penh, Cambodia

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Abstract Simple covered lagoons are used to treat wastewater from commercial pig farms in Cambodia into biogas. The electricity is generated from biogas using a generator. However, high level of H_2S corrodes or breaks down the generator. This study aims to desulfurize biogas with commercial ferrous oxide pellets (Fe_2O_3). The effects of desulfurization system on biogas production, electricity generation, and CO_2 reduction are discussed. The results show that H_2S was reduced from 2,000 ppm before treatment to around 50 ppm after treatment. CH_4 (57.7 ± 8.76%) and CO_2 (24.7 ± 2.67%) contents were not affected by desulfurization. O_2 content was changed from 0.3 to 4.8%. High O_2 level was a sign of pipe leakage, lowering CH_4 and eventually electricity production. The increase of O_2 level decreased CH_4, thus lowering generator performance. Actual electrical output power produced from biogas was 368.5 ± 29.3 kW, with loading rates of 57.6 ± 4.6% and generator efficiency of 26.8 ± 1.7%. Estimated amounts of 22,818 tCO_2equ were reduced by the biogas system. The desulfurization system was highly effective in H_2S removal without affecting biogas quality. For the long-term biogas systems in Cambodia, local-made desulfurization systems should be tested and compared with imported products.

Keywords biogas, CO_2 reduction, simple covered lagoon, CH_4, desulfurization, electricity generation

INTRODUCTION

Globally, the energy sector that covers electricity, heat, and transport contributes to 73.2% of GHG emissions, whereas livestock accounts for 14.5% (Quinton, 2019). To produce one kWh of

electricity, 0.657 kg CO_2 is produced. Meanwhile, a fattening pig ready for slaughter produces 448.3 kg CO_2 (Philippe and Nicks, 2015).

To tackle these issues, zero-emissions in all sectors are discussed in the 26th United Nations Climate Change Conference of the Parties (COP26) held in Glasgow, Scotland, with its intended achievements to keep global warming below 1.5ºC this century, specifically targeting CH_4 reduction (UNEP, 2021). According to IPCC (2014), CH_4 is 28 more potent than CO_2 regarding the 100-year global warming potential, so letting it into the atmosphere is much more harmful to the environment. Climate change mitigation in livestock production can be done by anaerobic digestion (AD) technology (Achinas et al., 2017).

In Cambodia, commercial pig farms have increased due to their ability to control the environment necessary for fast pig growth and effective disease prevention (MAFF, 2019). In those farms, evaporative cooling systems are used to maintain temperatures of 25 to 27ºC inside the barns (Thanapongtharm et al., 2018). In consequence, electricity consumption is an average of 30 kWh per head (Putmai et al., 2020). Daily wastewater generated from sows, fatteners, and piglets is 64, 24, and 20 m^3 $head^{-1}$, respectively (Kulpredarat, 2016). It has been reported that the pig farm with fattening pigs above 3000 heads have a potential to produce biogas through AD technology.

A common AD type used to treat wastewater from commercial pig farms in Cambodia is a simple covered lagoon digester, with 44 units reported in 2019 (NBP, 2019). They are preferred due to its low-cost construction, easy operation (Rahman and Borhan, 2012) and its suitability for wastewater that contains 0.5 - 2% of dry matter (DM). Hin et al. (2021) found that wastewater from pig farms in Cambodia contains 0.9% DM.

Biogas is a gas mixture that contains CH_4 (60 - 70%), CO_2 (30 - 40%), and other trace elements (Okoro and Sun, 2019; Safferman et al., 2007). CH_4 is the only source of energy to produce heat and electricity for farm use. Nevertheless, biogas contains high hydrogen sulfide (H_2S) concentration up to 3,500 ppm (Hin et al., 2021; Dumont, 2015). H_2S is corrosive to the engine and toxic to humans. H_2S level must be limited to 200-500 ppm for generator operation (Rodrighez et al., 2014). Generally, H_2S removal can be done physically by regulated air injection (Hines et al., 2019), chemically by application of sodium hydroxide (NaOH), potassium hydroxide (KOH), or Ferrous oxide (Fe_2O_3) (Zulkeflia et al., 2016), or biologically by the use of biofilters (Barbusiński and Kalemba, 2016). However, proper desulfurization techniques are little known in Cambodia, especially for large-scale biogas systems. The study aims (1) to compare biogas quality before and after being treated with ferrous oxide (Fe_2O_3) fed in a Chinese commercial desulfurization system, (2) to determine the working capacity of the biogas generator, and (3) to evaluate biogas production, electricity production, the generator efficiency, and CO_2 reduction equivalence.

MATERIALS AND METHOD

Materials

The tools used in this study included A biogas 5000 analyser, supplied by Geotech, UK and Hioki PW3365-20-01/5000 power logger (Hin et al., 2021).

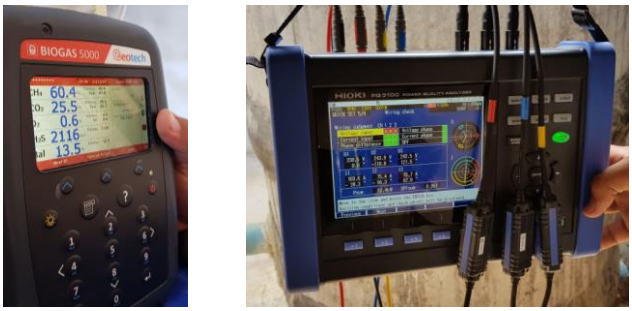

Fig. 1 Geotech biogas 5000 (left) and Hioki PW3365-20-01/5000 power logger (right)

Methods

The research was conducted from January to August 2021 in a large-scale pig farm that raised 38,000 fattening pigs and 3,100 sows under cooling evaporative systems in Sihanoukville Province, Cambodia. The farm used a full biogas system: a simple covered lagoon digester (76,000 m^3 volume), a biogas desulfurization system fed with 2,400 kg of Fe_2O_3, a flow meter with maximum flow rate of 500 Nm^3 biogas, two 640-kW second-hand biogas generators, and a flare used to burn excess biogas. The desulfurization rate was 0.5 kg Fe_2O_3 per 1 Nm^3 biogas.

The biogas 5000 analyser was used to measure biogas quality before and after being treated through the desulfurization system filled with Fe_2O_3 at blowing pressure of 5.6 kPa. Due to travel restriction inside the farm, the data were recorded once a month for 7 consecutive months. Each time, measurements were made three times to obtain average values. The power logger was attached to the generator wiring for 3 hours at a time of data collection to measure actual output power produced from biogas. However, actual output power could be measured only with the post-treated biogas because there was only one outlet pipe connecting the biogas desulfurization system to the generator.

Data Sampling

The collected data were CH_4 (%), CO_2 (%), H_2S (ppm), and O_2 (%). Hourly biogas flow ($Nm^3\ h^{-1}$) and biogas temperature (^oC) were also recorded by using the flow meter that exists in the system. Additionally, four formulas were used in this study as follows. In formula one, CO_2 reduction equivalent (tCO_2 equ.) by avoidance of CH_4 emission equals CH_4-to-CO_2 equivalent x CH_4 density x Annual CH_4 production, while CO_2 reduction by avoidance of grid electricity equals electricity-to-CO_2 equivalent x annual electricity demand met by methane production. CH_4-to-CO_2 equivalent is 28, and electricity-to-CO_2 equivalent is 0.657 kg CO_2 per kWh (Hin et al., 2021). In formula three, Electrical loading rate (%) equals output power divided by the rated power. Formula four is the generator efficiency (%) which was calculated by dividing the output power by the power chemically produced through the internal combustion of biogas. Net caloric value (NCV) of biogas with 60% CH_4 is equal to 20 MJ Nm^{-3}. Thus, the chemical power (kW) produced by biogas combustion is equal to hourly biogas consumption by the generator multiplied by NCV and divided by 360.

Data Analysis and Interpretation

Data were analyzed using the R studio version 4.1.1. Paired sample t-test was employed to compare the biogas quality before and after desulfurization. A simple linear regression was used to identify relationship between CH_4 and O_2. A contour plot was used to determine the effects of biogas flow and CH_4 concentration on active output power produced from the generator. Descriptive statistics were utilized to depict generator performance, biogas generation, and CO_2 reduction.

RESULTS AND DISCUSSION

Biogas Quality

Biogas quality before and after desulfurization system was compared (Fig. 2). Differences in H_2S were detected ($P < 0.001$; Fig. 2a) and it was reduced from 2,061 ± 138.9 ppm before treatment to 50.1 ± 10.2 ppm after treatment. However, one month after the utilization of Fe_2O_3, H_2S rose to more than 200 ppm. The pre-treated H_2S level is similar from previous studies (Dumont, 2015) and (Hin et al., 2021). On the other hands, CH_4 and CO_2 was 57.7 ± 8.76% and 24.7 ± 2.67%, respectively and was not affected by desulfurization (Fig. 2b). These values were lower, when compared to the literature by Safferman et al. (2007) for pig manure in Europe and by Hin et al. (2021) for pig manure in Cambodia and by Wongsapai et al. (2008) in Thailand. Low CH_4 and CO_2

values tends to be affected by the atmospheric air that penetrated into the system through pipelines or the edges of the lagoon plastic cover sheet.

Relationship of CH_4 with O_2 and Average Load with Biogas Flow and CH_4

We studied the relationship between CH_4 and O_2 to determine why CH_4 content was relatively low, as seen in Fig. 2b. Fig. 3a shows that CH_4 decreased with the increase of O_2 ($P < 0.001$; $R^2 = 0.92$). When O_2 increases by 1%, CH_4 decreases by 4.64%. Normally, O_2 level in raw biogas is low. A recommended level of O_2 entering the lagoon should be in the range of 0.3-3% (Hines et al., 2015). So, its high content in this study may signify air penetration into the system, which can be through the pipelines, water traps, or the edges of the lagoon plastic cover sheet. In case leakage is found at the lagoon, high O_2 inhibits methanogenic activities because CH_4 is strictly produced under anaerobic conditions (Botheju and Bakke, 2011). The result of this study is similar to that conducted by Hin et al. (2021). Thus, proper detection is required to inspect pipelines, water traps, and the covered lagoon.

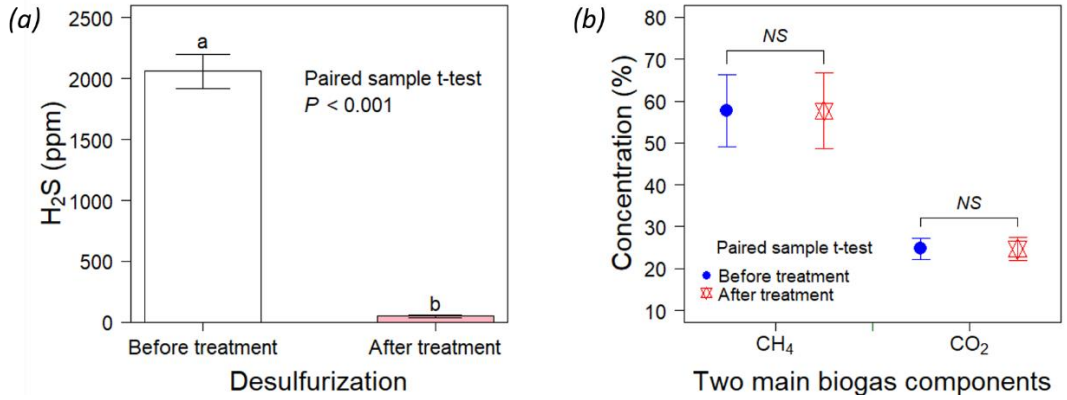

Fig. 2 Comparison of H_2S (*a*) and CH_4 and CO_2 (*b*) before and after desulfurization (Mean ± SD; N = 21)

Paired sample t-test was used for the analysis. Different alphabetic letters denote significant differences at the error level of 0.05, and NS means non-significance.

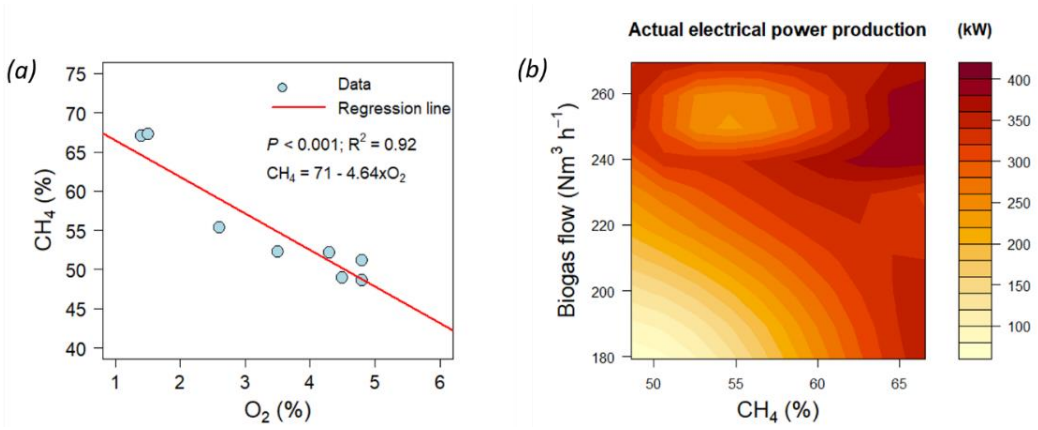

Fig. 3 Relationship between CH_4 and O_2 (*a*), and determination of average load as a function of biogas flow and CH_4 (*b*)

The low CH_4 reduces the biogas generator performance. Figure 3b indicates an average load as a function of hourly biogas consumption and CH_4 content. With the same biogas flow rate, low CH_4 content reduces the amounts of electrical power produced. To maintain the same electrical power produced with low CH_4, unusual high biogas flow rates were recorded, which leads to the

overuse of daily produced biogas. In contrast, CH_4 content of 60 - 65% gives better generator performance and reduce the hourly biogas consumption at the same output power.

Specific Biogas Characteristics for Generator Operation

Fed into the generator, the biogas was pushed by an electrical blower at 5.6 ± 0.5 kPa. Its temperature averaged 37.0 ± 5.1ºC, rated best for biogas production (Babaei and Shayegan, 2020). Biogas system produced 4,478 Nm^3 day^{-1}, but the actual daily biogas consumption was 4,862 ± 64.6 Nm^3 day^{-1} (Table 2). Therefore, the amount of biogas consumption was 8.6% greater than the biogas production.

Table 1 Biogas production, electricity consumption, and CO_2 reduction equivalent

Description	Unit	Mean ± SD
Biogas temperature	ºC	37.0 ± 5.1
Estimated daily biogas production	Nm^3 day^{-1}	4,478
Recorded daily biogas consumption	Nm^3 day^{-1}	4,862 ± 64.6
Biogas flow rate	Nm^3 h^{-1}	237.6 ± 29.6
Actual generator power	kW	640
Specific biogas consumption	Nm^3 kWh^{-1}	0.64 ± 0.08
Actual output power	kW	368.5 ± 29.3
Chemical power produced by biogas combustion	kW	1365.9 ± 174.9
Loading rate	%	57.6 ± 4.6
Genset efficiency	%	26.8 ± 1.7
CO_2 reduction equivalent	tCO_2equ yr^{-1}	22,818
CO_2 reduction equivalent per head	tCO_2equ yr^{-1} $head^{-1}$	0.56

In Table 1, the generator was a 640-kW biogas generator, and actual electrical output power produced from biogas was 368.5 ± 29.3 kW, so the loading rate of the generator was estimated at 57.6 ± 4.6% of its full capacity. With the hourly biogas flow rate of 237.6 ± 29.6 Nm^3 h^{-1}, the theoretical electrical power generated from biogas was estimated at 1365.9 ± 174.9 kW. Therefore, the generator efficiency was 26.8 ± 1.7%, and it was higher than the study by De Souza et al. (2016) and Jeong et al. (2009). The specific biogas consumption in this study was 0.64 ± 0.08 Nm^3 kWh^{-1}, which was lower than that studied by De Souza et al. (2016), whose finding was 0.76 m^3 kWh^{-1}.

CO_2 Reduction Equivalent

Using the biogas system reduces the enormous amounts of CO_2 and CH_4 emissions. In this study, the CO_2 reduction equivalent was estimated at 22,818 tCO2equ yr^{-1}, or 0.56 tCO2equ yr^{-1} $head^{-1}$. CO_2 reduction was lower than that studied by Hin et al. (2021). However, it was higher than Peerapong and Limmeechokchai (2017), whose founding was 0.47 tCO_2eq yr^{-1} $head^{-1}$ and for Thai pig farms. The difference in CO_2 emission reduction tends to link with estimated daily manure production.

CONCLUSION

The use of desulfurization system greatly reduced H_2S, but did not affect CH_4 and CO_2 contents. Biogas quality was undermined by higher O_2 levels in it. With low biogas quality, actual electrical power produced from biogas was also low. However, considerable amounts of CO_2 can be cut with this biogas system. The limitations of this study are that the biogas generator performance could be evaluated only with already treated biogas because it is the actual farm operation and altering the system or reconnecting raw biogas pipes to the generator are very costly. Further research will

improve biogas quality with locally made desulfurization systems and prolong the age of iron oxide pellet use to reduce labor and increase system operation efficiency.

ACKNOWLEDGEMENTS

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Research article

Migration Characteristics of Communities in the Forestlands in Ifugao, Philippines

CARMELITO C. VALDEZ*
College of Agriculture and Forestry, Ifugao State University, Potia Campus, Philippines
Email: valdezcarmelito@gmail.com

GEMMA B. DUMANSI
Ifugao State University, Potia Campus, Philippines

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Abstract The Ifugao province as a mountainous land of indigenous people, described as a watershed framework that provides domestic and agricultural services. Greater portion of the province was declared as Forestland. Due to increase in population, communities tend to occupy and possess certain part of the forest to provide their basic needs. Understanding the migration characteristics on the Forestlands in the province of Ifugao may lead to a solution harmonizing the role of different stakeholders in maintaining the biological, physical and social aspect of the upland for a sustainable development. The study employed qualitative method of research and adopted the purposive sampling technique, in data gathering wherein, respondents are certified migrant in the forestlands of Ifugao province. It revealed that migration in the Forestlands in Ifugao province is being influenced by many combined factors and being prompted by poverty and aggravated by climate change. Socio-economic aspect is the primary reason why people tend occupy portion of the Forestland. They acquire portions of the Forestland as a source of living as they are engaged in farming as their main source of livelihood.

Keywords indigenous people, resource management, land use system

INTRODUCTION

Philippines is about 30 million hectares, half of which is classified as forestland, 47 percent is classified as alienable and disposable land and the remaining three (3) percent is unclassified forestlands. Alienable and disposable (A&D) lands refer to those areas which may be issued with permanent title and/or used for varying purposes such as for residential, agricultural, commercial and other uses. Of the country's 14.19 million hectares of A&D lands, 9.63 million hectares are already titled (DENR, 2017). On the other hand, Forestlands are lands belonging to the state and cannot be alienated unless provided by law. Much of the Forestland are hilly and mountainous with slope of ≥ 18% hence are deemed not suitable for agricultural purposes as legally defined by the Revised Forestry Code of 1975 (Esplana and Quizon, 2017).

Most of the Forestlands of the country are occupied by indigenous communities. The Philippines is a culturally diverse country with an estimated 14-17 million indigenous people (IP's) belonging to 110 ethno-linguistic groups, they are concentrated in Northern Luzon and Mindanao and some in Visayas (De Vera, 2007; UNDP, 2010). Indigenous Peoples/Indigenous Cultural Communities (IP/ICC) refer to a group of people sharing common bonds of language, customs, traditions and other distinctive cultural traits, and who have, under claims of ownership since time immemorial, occupied, possessed and utilized a territory (IPRA Law). Thirty three percent (33%) of the IP population is located in the Cordillera Administrative region and sixty one percent (61%) are living in the mountain ranges of Mindanao (UNDP, 2010). As the population in the uplands continuously increasing, the demand for a land to cultivate and for housing is becoming more important thus, the widespread opening of forest for livelihood in the Philippines is pragmatic and natural resources become degraded.

The Cordillera Administrative Region (CAR) is composed of six provinces Abra, Apayao, Benguet, Ifugao, Kalinga and Mountain Province. It is considered as the watershed cradle of the north (UNDP, undated) and characterized as rugged, hilly and mountainous in topography. The region has a total land area of approximately 1.8 million hectares. Almost 1.5 million hectares are classified as forestlands and 0.3 million hectares is alienable and disposable lands (FMB-DENR, 2013). Cordillera culture is characterized by its diversity. The major indigenous cultural communities who occupy the Cordillera are the Ibaloy and southern Kankana-ey in Benguet Province, the Ifugaos of Ifugao Province, the Bontok and northern Kankana-ey of Mountain Province, the Kalingas of Kalinga, the Isnag of Apayao, and the Tingguian of Abra. There are numerous smaller distinct ethnic groups and subgroups within these provinces, such as the Balangao, Kalanguya, and Karao. The groups vary in their political, kinship, economic, and religious organizations (Mendoza and Brett, 2004).

The Ifugao province in particular is a landlocked watershed province bounded by a mountain range to the north and west that tempers into undulating hills towards the south and the east. The highest elevation is 2,523 meters above sea level (masl) with the rice terraces lying above 500 masl. Ifugao province is located at the southern portion of the Cordillera Administrative Region (CAR) found at the heart of Luzon Island of the Philippines. It is home to the indigenous peoples who call themselves “Ifugaos” and is host to one of the world-renowned rice terraces clusters that the UNESCO World Heritage List of cultural and natural properties considered to be of “outstanding universal value. In the land Classification of The Philippines 2013 as published by the Forest Management Bureau of the Department of Environment and Natural Resources (FMB-DENR, 2013) Ifugao province has approximately 251,778 hectares and 90 % (226,369 has.) of which is declared as forestland only 10% (25,409 has.) is considered as Alienable and disposable lands (A&D). The province has growing population and communities in the forestlands are tremendously increasing.

This study aimed to examine the migration characteristics and identify major drivers of forestland occupation in the province of Ifugao, Philippines.

METHODOLOGY

Research Design

This study utilized qualitative research. Data were gathered through Focus Group Discussion (FGD) to the Forestland migrants in Ifugao, Philippines. Moreover, the data were validated through a key informant interview (KII). Likewise, actual field visit was conducted to document current scenarios of upland faming, resource management and practices in the area.

Sampling and Respondents

Purposive sampling technique was employed in this study. Identified Forestland migrants that represents different sectors of the upland community were interviewed for this purpose, particularly sectors coming from youth, Barangay officials, elders, upland famers, women’s group and technical personnel from the Department of Environment and Natural Resources (DENR), and Department of Agriculture (DA).

Use of Vignette in the Study

The focus group discussion (FGD) in each of the study sites were conducted in a panel and consolidated in a common understanding of the respondents in a scheduled interview session with the researchers per group or representation in the area. There are seven (7) interview sessions with the different respondents to represent the Forestland migrants (n = 5), Barangay officials (n = 5), elders (n = 3), upland farmers (n = 5), representative from women’s group (n = 5), and technical personnel from the Department of Agriculture (n = 5), and Department of Environment and Natural

Resources (n = 5). On the completion of the data gathering through the focus group discussion (FGD), each group were asked on their understanding on the migration and migration characteristics in the province of Ifugao in the Philippines. particularly on the pattern of migration related to their age, educational attainment, ethnicity, gender, marital status, religion, culture, income, source of income, farming practices, crops being planted and natural resources management since they are living in a vulnerable forest landscape in the province. This vignette pattern was applied in the three selected study sites in the province of Ifugao in the Philippines.

The consolidated result of the study was presented to the different respondent representatives through key informant interview (KII) to confirm the veracity and reliability of the data gathered during the focus group discussion.

Study Sites

The municipalities of province were stratified into three categories according to elevation: The low elevation (192 - 500 meters above sea level); the Mid-elevation (501 - 1000 meters above sea level) and; High Elevation (Above 1000 meters above sea level). To represent the mentioned categories of the different municipalities of the province, convenient method was considered in the selection of the study sites. Accordingly, Barangay Little Tadian in the municipality of Alfonso Lista, Barangay Itab in the Municipality of Aguinaldo and Barangay Nattum in Mayoyao were selected to represent the Low elevation, Mid-elevation and High elevation, respectively.

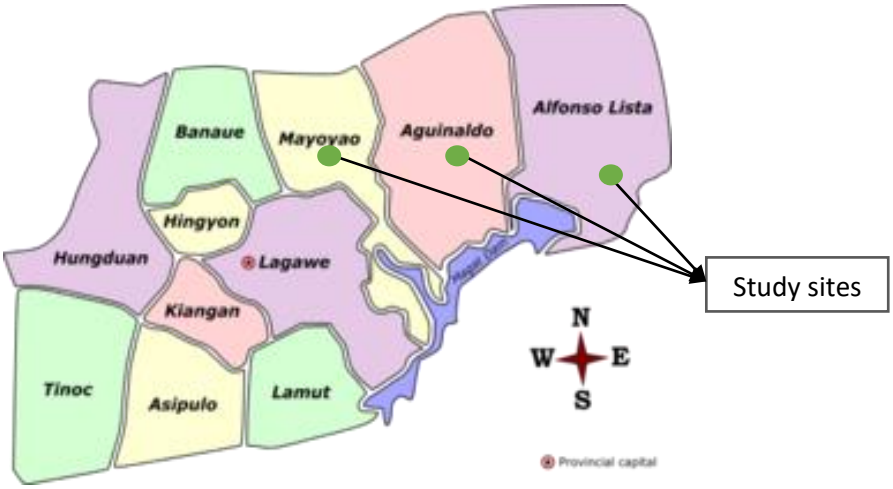

Fig. 1 Map of Ifugao, Philippines

RESULTS AND DISCUSSION

Migration can be a temporary outlet for population pressure but often it only creates a new population pressure and new environmental scenario in the area of in-migration. The typical migration pattern worldwide has been from rural to urban areas (Amacher et al., 1998) however, this pattern has reversed in the 1980's particularly in the South East Asia and the Amazon as migrants leaving impoverished cities to settle in sparsely inhabited upland and forest frontiers and Philippines is an example of this situation (Amacher and Hyde, 1996).

Summary of the Vignette

The study focused on the migration characteristics of communities in the Forestlands in the province of Ifugao in the Philippines. This study was participated by the different stakeholders of the forestland of Ifugao in Philippines such as migrants, women's group, elders, Barangay officials, technical personnel from the DA and DENR respectively. As a result of the study, migration to the forestland in the province of Ifugao in the Philippines confirmed three (3) major causes to include

cultural, demographic and socio-economic factors that is consistent with the findings of Li et.al (2014) consequently, there are factors affecting migration intensions in an ecological area such as demographic factors, socio-economic factors and other factors (political-economic factors and eco-environmental factors).

Three (3) Major Causes of Migration in the Forestlands in Ifugao, Philippines

A. Cultural factor: Majority of the Forestland settlers in Ifugao in the Philippines belongs to the Indigenous People (IP) of the province, some are coming from the neighboring provinces of Nueva Vizcaya, Isabela, and Mountain Province. Indigenous people in Ifugao have a natural connection to forest resources because it is their nature to engage in hunting wild animals for food, and sustainable forestry as they acquire lumber for domestic purposes in their woodlots (Muyong). They also extract wild honey for their personal consumption and some are for sale as they augment their income. More importantly, it is their culture to seek for a fertile land for agriculture production or technically known as *kaingin*.

B. Demographic factors: Demographic factors are the general indication of a group in the general population in the forestland in the province of Ifugao such as age, gender, marital status and religion.

Accordingly, migration to the forestlands in the province by the community happens usually during the young to middle adult ages from 18-38 years old because during this stage individuals are active explorer, traveler and adventurous as they seek job, belongingness, enjoy the value of nature, and in the search of partner in life. In addition, people would like to settle in a place wherein they are going to construct their own houses, established sustainable source of living, invest time and properties in an area, and this is usually happening in the young adult stage. Consistent with the argument of Abu et al. (2014) that during older age, people may not migrate because their attachment to their community tends to be stronger than that of younger age. On the other hand, male have higher incidence of migration in the Forestlands in Ifugao, Philippines because they are usually the once engaged in the search of livelihood for the family including acquisition of land to be tilled, hunt for wild animals, harvest wild plants and fruits. Moreover, establishment and settlement in an area is a role of males in the upland particularly in the province of Ifugao in the Philippines.

Majority of the respondent in the different locations in accordance to the criteria set in this study pointed that families occupy portion of the forestland in the province of Ifugao with their relatives and establish a community in the area. Communities in the Forestlands of Ifugao is composed of different spiritual sectorial belief such as Pentecostal, Roman Catholic, Evangelical, and Baptist Ministry. Accordingly, their religious belief binds them together and guide them for a peaceful and happy well-being. The significance of Religion to the migration characteristics of communities is relevant to the interpretation of Hirschman (2004) that relatives and distant individuals move towards an area of worship and religious networks of similar belief, supported by the idea of Portes and Rumbaut (2006) that religious practices is a source of social capital and an important variable in determining the path of assimilation within the segment of social structure. However, religion do not figure predominantly in migration (Cadge and Ecklund, 2007).

C. Socio-economic factors: Socio-economic condition is an important factor in shaping development goals of a community. In general, it analyses how economic activity affects and is shaped by social processes. It is one of the major bases in the determination of inequalities and importance in development. In this particular study, educational attainment, household size, occupation and land holdings were considered in the migration characteristics of communities in the Forestlands in Ifugao, Philippines.

Majority of the Forestland migrants in Ifugao in the Philippines are Elementary graduate and high school level, some populations are high school graduate and college level, only few of the populations are considered professional who finished their formal education in college and earned their Baccalaureate Degrees. In terms of household size, large family can describe the composition of Forestland migrants in the area, which is characterized by an average of eight (8) household

members that is composed of a father, mother and children. On the other hand, the primary occupation of the migrants is upland farming, some are involved in wood carving, and carpentry.

Kaingin in Mayoyao, Ifugao, Philippines
(Planted with upland Rice)

Kaingin in Aguinaldo, Ifugao, Philippines
(Planted with Corn)

Fig. 2 Kaingin within the forestlands in Ifugao, Philippines

Generally, families are moving towards the Forestlands in Ifugao in the Philippines because of socio-economic pressure brought about by poverty and aggravated by climate change. People tend to occupy certain portion of the Forestland to acquire land holdings for them to establish their houses and more importantly to have lands to till and generate income for subsistence. They open portions of the Forestlands by *slash and burn* through cutting and clearing the original vegetation and are planted with agricultural crops such as upland rice, corn, vegetables and some potion are converted into grazing land. Accordingly, planting of agricultural crops in the Forestland can be harvested in 3-4 months and generate income in a shorter period of time compared to engagement of tree farms or tree plantation that will take 10-15 years before the fast-growing tree species can be harvested and atleast 30 years for an indigenous or native species. Moreover, their engagement in agricultural production can provide basic needs for their family such as food, clothing and medicine, and send their children to school. Upland farmers generally cultivate potions of the Forestland on the basis of occupancy, residency and agricultural engagement in the area. In the absence of any tenure instrument, their cultural rights as the original tenant over the land is being respected by the community.

The trend of migration to the Forestland in the Ifugao in the Philippines is increasing, communities are already in place and agricultural production areas are becoming dominant in the area. The increasing number of populations in the Forestland were observed to have negative impact on the natural agro-ecological system in the area. As a result of agricultural production in the moderate to steep slopes areas in the Forestland, there is a significant increase in soil erosion, and siltation in the water ways. Biodiversity of flora and fauna also are affected since the crops being grown by the communities are not indigenous particularly the vegetables, and corn that are cultured for a medium to large scale production. Moreover, the introduction of chemicals in the maintenance of their farms particularly herbicides, and insecticides brought damages to both micro and macrobiotic diversity of the area.

CONCLUSION

The migration characteristics of communities in the Forestlands in Ifugao in the Philippines is characterized by a dynamic and complex cultural, demographic, and socio-economic factor. Nowadays, the continuous increase in the population in the Forestland is brought about by poverty that cause families to occupy, posses, and utilize portion of the Forestland for agricultural production for subsistence and provision of basic needs by the people.

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Research article

Discussion about A Model in Operation and Accumulation of Joint-Use Fund Management by Rice Farmer-groups

YUKI TOYAMA*
United Graduate School of Agricultural Sciences, Tottori University, Tottori City, Japan
Email: yukiuki1019@gmail.com

ASRES ELIAS
Faculty of Agriculture, Tottori University, Tottori City, Japan

KUMI YASUNOBU
Faculty of Agriculture, Tottori University, Tottori City, Japan

PANATDA UTARANAKORN
Faculty of Agriculture, Khon Kaen University, Khon Kaen District, Thailand

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Abstract Substantial number of rice farmer-groups are established under the promotion of group farming policies in Thailand. The groups voluntarily form joint-use funds and operate their business with them. The objective of this study is to make the model of joint-use fund management by rice farmer-groups with two approaches: 1) observing the characteristics of successful cases in the rice farmer-groups established by two policies in Northeastern Thailand; and 2) simulating a fund management on the groups based on one case group in Khon Kaen province. The case groups established funds using the resources provided by the government. Through operating the group's business, members invest in-cash or in-kind input and pay the service charges into the fund. Then the accumulated capital was used for providing returns to members' investments and scaling-up the groups' business. Based on actual accounting data of one case group, we simulated revolving joint-use fund by rice farmer-group. The result showed that the group assumed to accumulate enough amount of assets to provide sufficient service for all members using the initial fund derived from government support. A conceptual model of joint-use fund management for the rice farmers group was described. The model will be utilized to guide rice farmer-groups in developing their business and becoming independent from government support.

Keywords group farming, community, government support, northeastern Thailand

INTRODUCTION

Small and family-run farms are evaluated as important agents to achieve a stable and sustainable food supply (FAO and IFAD, 2019; FAO, 2014). Generally, in the area where small family farms are dominant, most farmers face challenges to scale-up their business because of land fragmentation and lack of production resources (HLPE, 2013). On the other hand, group farming is one of the major means to improve the productivity of small family farms facing resource constraints. It helps to achieve economies of scale and respond to the external environment. For instance, East Asian countries (e.g. Japan and South Korea) achieved a dramatic improvement in agricultural productivity through spreading group farming (Wong, 1977).

In Thailand, the government adopted group farming concept into agricultural development policies and established many farmer-groups, especially related to rice production. Some studies mentioned that the rice farmer-groups received in-cash and in-kind resource supports from government and operated their business through managing and utilizing joint-use funds (Ohara et al., 2021; Tanaka and Yasunobu, 2019). It is also indicated that a substantial number of groups stopped their operation in the early years because of the difficulty to continue their business

(Uchook, 2018). At present, the joint-use funds are voluntarily operated by members of the groups. However, to the best of our knowledge, there is no manual and/or guideline regarding how such kind of activities have been implemented. Therefore, to suggest a model of handling joint-use fund is supposed to be benefitable for encouraging farmer-groups to continue/expand their business.

OBJECTIVE

We consider a model of joint-use fund management by rice farmer-groups in Thailand through achieving the following objectives: 1) To investigate the characteristics of joint-use fund management among the groups which continuously accumulate the fund; 2) To simulate the cycle of accumulating joint-use fund and scaling-up the business; and 3) To conceptualize joint-use fund management for depicting a model based on the above results.

METHODOLOGY

To achieve the objectives of this study, we adopted the following approaches. First, we explored the actual situation of how rice farmer-groups manage their own business and joint-use fund, with the cases of rice farmer-groups established by the encouragement of policies. Then, we conducted the simulation of revolving joint-use fund based on one case which conducted the lending business of combine harvester and kept its account record, and finally, the conceptual model was induced from the results.

Survey Site Selection

In this study, we selected cases of rice farmer-groups located in Khon Kaen and Ubon Ratchathani provinces in, the Northeastern region. The groups were established under the promotion of two political programs: Community Rice Seed Center (CRSC) and Large Land Plot of Rice (LLPR), proceeded by the Ministry of Agriculture and Cooperatives (MOAC), Thailand.

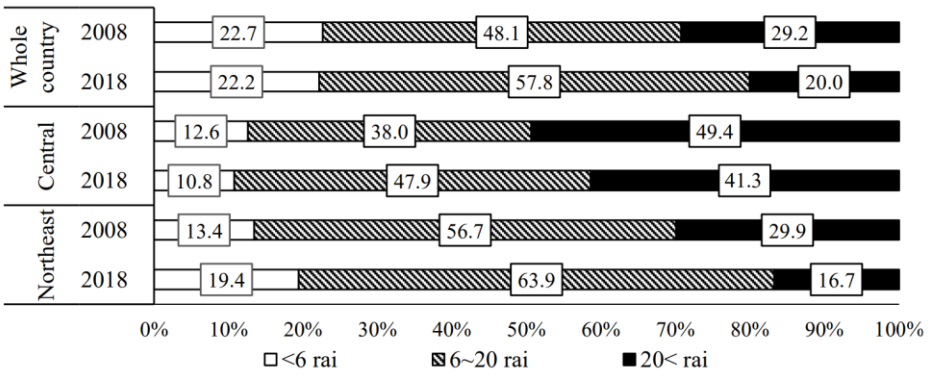

Fig. 1 Changes in the distribution of rice production scale among farmers in Thailand
Source: Author's creation with the data opened at the website of Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, Thailand [https://www.oae.go.th].
Remark) 1 rai = 0.16 ha.

To consider modeling of joint-use fund management, the domain (area and crop) which needs the model is suitable for the target in this study. In Thailand, Northeastern region and Central region are the main production areas of rice. The production scale of rice on each farm in Northeastern region is smaller than Central region and group farming policies aiming at small-scale rice farmers are mainly extended in Northeastern region. Moreover, in Northeastern region, the ratio of large-scale farmers is decreasing in total number of rice producers. Fig. 1 shows the changes in production scale of rice among farmers from 2008 to 2018. At the national level, the ratio of farms operating more than 20 rai (= 3.2 ha, 1 rai = 0.16 ha) decreased from 29.2% to 20.0%

and this tendency was especially clear in Northeastern region; the decrement on the ratio of farms operating more than 20 rai in each region is as follows: whole country, -31%; Central, -16%; Northeast, -44%. From the above, the model proposed by this study will be mainly applied to the field in Northeastern Thailand and it is reasonable to adopt rice farmer-group located in Northeastern Thailand as the cases.

Sampling and Data Collection

Various policies related to group farming have been introduced in Thailand. This study aimed the groups established under two policies targeting rice farmers: Community Rice Seed Center (CRSC) and Large Land Plot of Rice (LLPR).

CRSCs have been established since the beginning of 2000s (1,650 CRSCs was existed in 2016/2017) as a local supplier of rice seed (Orachos, 2018). To cope with the shortage of rice seed certified the quality, Thai government tried to realize the self-supply of rice seed in each rural communities through establishing the groups of rice farmers for engaging the multiplication of certified rice seed provided by the government institutions (Moonfoui et al., 2007). LLPRs are also rice farmer-group targeting to perform the economics of scale on rice production in Thailand. The program was started from 2016 and 3,759 plots were established until March 2022, and about 60% of them were in Northeastern region (DOAE, 2022). The activities of LLPRs are jointly procurement and use of capital, equipment, and materials (e.g., machinery, miller, storage, rice seed, group fund), joint shipment to the contracted miller and produce GAP certified rice or rice seed. Both two policies are promoted by the Rice Department, the Ministry of Agriculture and Cooperatives, and certain number of LLPRs are established based on existing CRSCs.

Surveyed groups were 34 CRSCs (Ubon Ratchathani: 21 in 90 groups, Khon Kaen: 13 in 92 groups), and 4 LLPRs in 48 groups in Khon Kaen province. All groups were sampled randomly. Regarding the case CRSCs, the data was originally used in Tanaka and Yasunobu (2019). Face-to-face interview was conducted for group leaders with structured questionnaire in August and September 2015. The data of case LLPRs included both of which deriving from Ohara, et al. (2021) and which was collected by authors. On our survey, group interview to a few members including leader was conducted regarding how to manage joint-use fund in August 2018 and July 2019.

RESULTS AND DISCUSSION

Exploring Actual Situation of Joint-Use Funds Management among CRSCs and LLPRs

Table 1 shows how CRSCs accumulated their joint-use funds. All groups accumulating more than 100,000 THB (1 Thai Baht (THB) = 0.031 US$, average in 2021) managed their funds more than 10 years. The larger funds have the tendency that the average amount of fund per member is larger. The groups which accumulate and enlarge the funds continuously supposed to succuss increasing the amount of resource which each member can use.

Table 1 Accumulation of joint-use funds among CRSCs

Accumulation class of joint-use fund (unit: THB[*1])	Frequency (N = 19[*2])	Average number of members	Average term of accumulating fund (unit: years)	Average amount of fund (unit: THB)	Average amount of fund per member (unit: THB/member)
~99,999	5	31.0	5.6	49,547	1,411
100,000~149,999	4	35.5	14.5	130,000	4,040
150,000~199,999	6	41.0	13.2	166,417	5,170
200,000~	4	42.0	13.8	282,413	7,859

Source: Reorganized by author with the data treated by Tanaka and Yasunobu (2019).
*Remarks) *1: THB is an abbreviation of Thai Baht (1 THB = 0.031 US$, average in 2021).*
**2: Excluded 8 groups which did not answered amount of fund from 34 surveyed groups.*

Table 2 Activities for input and use of joint-use funds among CRSCs (N=27)

Input to fund	Frequency	Use of fund	Frequency
In kind return of rice seed with interest	18	Loan service	18
Share sales	8	Purchasing materials	13
Membership fee	7	Purchasing seeds from members	12
Resales of provided materials	4	Investment for machinery and facility	8
Machinery use charge	4		

Source: Reorganized by author with the data treated by Tanaka and Yasunobu (2019).
Remarks) Using the data of 27 groups, excluding 7 groups which did not have joint-use fund from 34 surveyed groups.

The activities for accumulating and using joint-use fund among the case groups are itemized in Table 2. All case groups received certain amount of free rice seed as government support. Eighteen groups divided the seed to members and then members return for the dividend in kind with interest after harvesting. Apart from that, some groups collected membership fee or sold shares to members. The groups having machinery provided lending service for members. Regarding use of the funds, the most major use of join-use fund was loan service for supporting members' livelihood. Other ways of using the fund were joint procurement of materials, investment for expanding equipment, and compensation of rice seed sales for members.

On the other hand, in the cases of LLPRs, main income sources were revenue of machinery lending and investment from members through selling share (Table 3). In terms of the share system, 3 of 4 case groups sold group's share to members. The shareholders could get dividend depending on the amount of group's revenue and the number of possessed shares. All case groups provided members with a lending service of machinery leased by the government. The price of lending charge was lower than the charge of private contractors in the area. In case non-members rent the machinery, the charge was higher than the price for members. However, the groups rarely lend machinery to non-members because they did not possess enough number of machines to provide service for all members. To prepare enough amount of machinery and equipment, and provide services without competition, groups need to revolve their initial fund deriving from government support and to accumulate joint-use fund for capital investment. In contrast to CRSCs, no LLPRs provided loan service to members. Since LLPRs have operated for a few years, they did not have enough amount of fund to launch financial business.

Table 3 Accumulation and use of joint-use funds among LLPRs

		Group A	Group B	Group C	Group D
Number of members		200	67	204	52
Govt. support	Free lending of machinery	1 trailer 2 harvesters	1 tractor 1 harvester 1 trailer 1 drill seeder	1 drill seeder 1 harvester	4 drill seeders
	Provision of rice seeds (2016~2019)	KDML105[*1]: 15 t RD6[*1]: 8.6 t	KDML105: 13 t RD6: 2 t	KDML105: 2.25 t RD6: 15 t	KDML105: 30 t RD6: 150 t
Input to fund		Share sales Rice sales Machine use charge	Share sales Rice sales Machine use charge	Share sales Rice sales Machine use charge	Seed sales Machine use charge
Use of fund		Running cost[*2] Dividend of share Reward of committee	Running cost Dividend of share Reward of committee	Running cost Dividend of share Reward of committee Community welfare	Running cost Reward of committee Machinery purchase[*3]

Source: Reorganized by author with the results of Ohara et al. (2021) and the survey in 2018 and 2019.
*Remarks) *1: KDML105 and RD6 are the name of rice variety. KDML105 is non-glutinous variety, and the variety is labeled "Jasmin rice" in market. RD6 is glutinous variety which is popularly eaten in Northeastern Thailand.*
**2: "Running cost" include maintenance of machinery, petrol, wedge for driver and miscellaneous expenses.*
**3: Group D purchased 9 drill seeders with their own fund in 2017.*

Simulation of Revolving Joint-Use Fund on Lending Combine Harvesters

We simulated revolving joint-use fund with the experience of lending combine harvester in one LLPR case (group A) and showed the path to accumulate joint-use resource enough to provide services for all members. The reasons why we choose LLPR as the case of this simulation include: LLPRs focus on joint-use of production resources, but CRSCs' main purpose is self-supply of rice seeds and LLPR program was started later than CRSC, we could collect the detailed information about initiation of revolving joint-use fund. The information was useful for simulating from the point of receiving subsidies. Among four cases of LLPRs, we could get detailed account data just from group A; in the cases of group B, C and D, we could not collect it because of missing some important records of bookkeeping.

Table 4 Simulation of revolving joint-use fund based on the case of group A

Items (Unit from (1) to (8): THB[*1])	1st year[*2]	2nd year	3rd year	4th year	5th year
Number of operated combine harvesters	2	2	3	4	5
Harvested paddy area by group's combine harvester[*3]	400	400	600	800	1,000
Unit: rai (% in 1,000 rai[*1] = total registered area)	(40%)	(40%)	(60%)	(80%)	(100%)
(1) Total income	324,550	284,550	386,825	489,100	611,375
Rice sales[*4]	60,000	40,000	20,000	0	0
Investment from member	20,000	0	0	0	0
Revenue of lending combine harvester[*5]	244,550	244,550	366,825	489,100	611,375
(2) Total cost	96,728	96,728	133,516	170,305	207,094
Running cost for lending combine harvester[*5]	73,577	73,577	110,365	147,154	183,943
Reward for committee members	15,400	15,400	15,400	15,400	15,400
Meeting	5,193	5,193	5,193	5,193	5,193
Miscellaneous expenses	2,558	2,558	2,558	2,558	2,558
(3) Dividend for shareholders[*6]	29,400	29,400	46,662	63,759	80,856
(4) Benefit: (1) – (2) – (3)	198,422	158,422	206,647	255,036	323,425
(5) Amount of fund at the beginning of FY	0	198,422	106,844	63,491	68,527
(6) Amount of fund at the end of operation: (4) + (5)	198,422	356,844	313,491	318,527	391,952
(7) Cost for purchasing combine harvester	0	250,000	250,000	250,000	0
(8) Balance of fund at the end of FY[*7]: (6) - (7)	198,422	106,844	63,491	68,527	391,952

Source: Reorganized by author with the results of the survey in 2018 and 2019.

*Remarks) *1: 1 THB = 0.031 US$ (average in 2021). 1 rai = 0.16 ha.*

**2: 1st year's data is based on the actual account information of group A in 2017/18. The cost-benefit data from 2nd to 5th year is estimated based on the data of 1st year.*

**3: On the simulation, volatility of harvested area caused by disasters or/and crop failures is not considered. Average area of each registered plot is 5 rai and most of them are a part of each member's operated paddy. In case member's total harvested area is diminished because of disasters or/and crop failures, The area rolled by group's combine harvesters is supposed not to be affected since members can use the harvesters for their paddy plots other than registered one.*

**4: The government provide LLPRs rice seed for 3 years and the amount is gradually decrease. On the simulation, it is assumed that the group gets rice for sale from members as the return for providing rice seed provided by the government. Therefore, the amount of "Rice sales" gradually decreases from 1st to 3rd year and does not account from 4th year.*

**5: Regarding "Revenue of lending combine harvester" and "Running cost for lending combine harvester", the amount is assumed to change proportionately to "Harvester paddy area by group's combine harvester" based on the 1st year's data. The value rates are as follows; "Revenue of lending combine harvester": 611 THB/rai, and "Running cost for lending combine harvester": 183 THB/rai (including petrol cost, wage for operator, insurance, and maintenance fee). Both of values were actual data of group A in 2017/18.*

**6: "Dividend for shareholders" is estimated based on the following calculation. When the group established, all members purchased 1 share (100 THB / share) and they receive dividend form the group's revenue equally. The amount of dividend was 20 % of the balance between "Revenue of lending combine harvester" and "Total cost" = (2).*

**7: "Balance of fund at the end of FY" = (8) is entirely carried forward as "Amount of und at the beginning of FY" = (5).*

As shown in Table 4, group A had 200 members and 1,000 rai registered paddy field (5 rai for each member). Each combine harvester assumed to roll 200 rai in one fiscal year and the cost of purchasing one combine harvester was set 250,000 THB. If the fund accumulated more than 250,000 THB, the group shall purchase an additional combine harvester. The goal of this

simulation is to prepare the number of combine harvesters which is enough to harvest on all registered paddies. Based on the above assumptions, the group can independently continue its function after the withdrawal of government supports. The group purchased combine harvester and expanded its business from third fiscal year. When the number of combine harvester reach to five, the group achieved to prepare enough number of combine harvesters for providing all members with a lending service.

Conceptual model of Joint-Use Fund Management in Rice Farmers-group

Based on the observation of actual cases and the simulation of revolving joint-use fund, we induced a conceptual model of joint-use fund accumulation by rice farmer-group (Fig. 2).

This model was formed on the precondition which farmer-group receive an initial provision of goods (e.g., free lease of machinery, rice seed, fertilizer) from the government. Group members bring in-cash and in-kind inputs as investments (share purchase or membership fee) and charge of services (machinery charge or in-kind return for seed provision). Accumulated capital on the fund is used for providing returns to members (lending machinery, joint procurement of rice seed, dividend for members who hold shares).Through this input-use cycle, the group keeps enlarging their fund even after finishing the 3 years provision of materials from the government and success to accumulate enough amount of fund (including cash and fixed assets) to provide sufficient returns for all members.

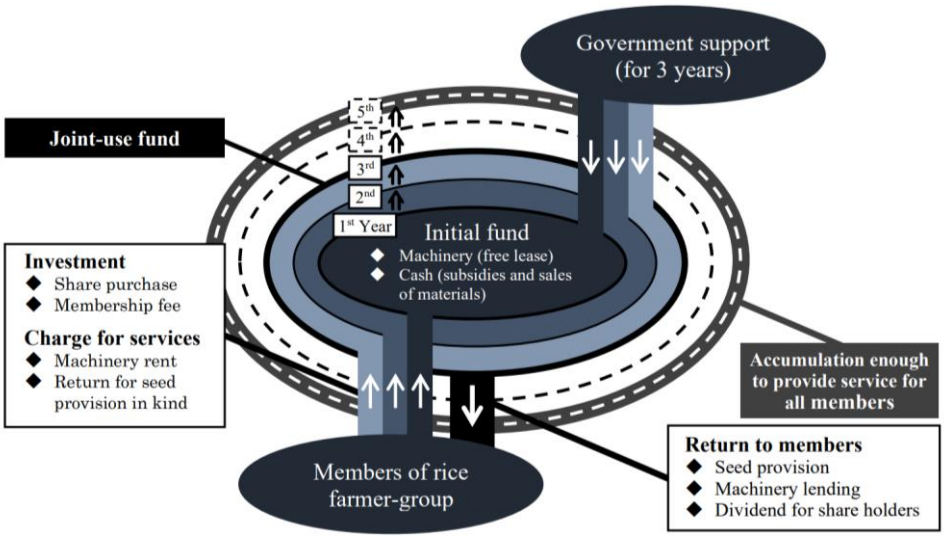

Fig. 2 Conceptual model of revolving joint-use fund by rice farmer-group

CONCLUSION

The aim of this study is to simulate a model for the joint-use fund management using cases of rice farmer-groups located in Northeastern Thailand.

We found both of rice farmer-group (CRSCs and LLPRs) managed joint-use fund through the cycle of input/use. The groups provided services to members with the resources provided by the government and investments from members. A revenue generated by the group was accumulated as a joint-use fund and used for dividend to members, running cost, and capital investment. We simulated this management cycle of joint-use fund with the account information of one LLPR group in 2017. The result of the simulation showed that the group can increase the amount of joint-use fund and the scale of operation in terms of machinery rental service to members. From the third year, the group became to keep running their operation without government support, and in the fifth year, the group can scale-up their operation enough to provide service for all members.

From the simulated result, we depicted a conceptual model of joint-use fund management on rice farmer-group. The figure showed that farmer-groups form an initial fund with resources provide by government. Through revolving the input-use cycle with the initial fund, the groups keep enlarging the size of join-use fund even after reducing government support and achieve to accumulate joint-use fund enough to provide sufficient service for all members. This discussion showed the potential path in which famer-groups could become independent from government support through voluntary joint resource management.

However, the result should be refered with a limitation in mind. In this study, the sample size was not enough to represent the whole situation of rice farmers groups. In addition, simulating revolving joint-use fund was just conducted with regard to lending service of combine harvester. The simulation also had the limitation related to a reliability of result because the conditions were assumed based on just one case of LLPRs. From the above, the conceptual model still stands on many assumptions.Therefore, further studies are required considering more cases of rice farmer-group on top of including other activities contributing for accumulation of joint-use fund.

ACKNOWLEDGEMENT

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Research article

Product and Market Diversification Trends: The Case of Horticulture Exports in Kenya

JANE GITHIGA*
Graduate School of Sustainability Science, Tottori University, Tottori City, Japan
Email: githigajane@gmail.com

ASRES ELIAS
Faculty of Agriculture, Tottori University, Tottori City, Japan

KUMI YASUNOBU
Faculty of Agriculture, Tottori University, Tottori City, Japan

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Abstract One of the major successes of trade liberalization in Kenya was promotion of horticultural exports. This was aimed at reducing export earnings instability that resulted from declining commodity prices of tea and coffee. The export promotion programs put in place in the 90s paid off and horticultural exports was able to record its strongest period of growth in the 2000s. In this period the major horticulture export product was French beans in which the EU was the primarily market. However, the global markets have been changing posing new challenges of increased competition and regulatory standards which could threaten the survival and sustained participation of Kenyan horticultural exports. At the same time creating opportunities to increase export products and expand market access through transfer of knowledge, skills, and technology. For many developing countries diversification into new products and markets has been encouraged by development platforms to deal with trade related shocks that emanates from reliance of one market and a narrow range of products. Therefore, the objective of this study was to analyze the trends of product and market diversification of horticulture exports in the periods 2002 to 2019 in Kenya using UNComtrade data. We employed the Hirschman-Herfindahl index to measure product and market diversification. The study finds that the horticultural products are less diversified while the index for the market diversification showed are more diversified markets access. This shows that horticultural products have not increased instead concentrated into the same products while widening market access to other regions despite the EU markets controlling the largest share of exports. The results highlight the need to increase the export products and take advantage of untapped potential markets.

Keywords diversification, horticulture, exports, Hirschman-Herfindahl index

INTRODUCTION

Dependence on the EU market has been a striking feature for Kenyan horticultural exports sector since the 1990's when it became a major supplier of French beans and other Asian vegetables (Jaffee, 2003). Despite the stiff competition, the exports have continued to grow both in volume and value. In 2019 the sector gained over 1.07 billion USD by exporting over 328.3 thousand metric tonnes of cut flowers, vegetables, and fruits. It is the second largest foreign exchange earner after tea contributing 19% of total exports in 2019, and a major employer providing 350,000 jobs directly and supporting over 6 million livelihoods (KNBS, 2020). Horticulture exports are critical for rural development because of the commercialization of small-scale farming opportunities it provides through contract farming. (Jaffee, 2003) found that 50% of the vegetables and 85% of fruits total exports were supplied by small scale farmers while Kazimierczuk (2018) found that 5% of cut flowers were from small-scale farmers.

From trade-led development perspective, participation in global export markets over a period often initiate innovation and expansion in terms of market access and products exported. This can happen in two ways; first, from market related challenges resulting from competition, changes in consumer needs, instability in the partner markets among others. This manifested in the rapid transformations of the EU markets in the last two decades resulting to changes in governance of the supply chain and the way of doing business (Jaffee, 2003). It started with the evolution of Sanitary and Phyto sanitary (SPS) standards that aimed at enhancing product safety and food quality (Jaffee and Henson, 2004). This was extensively debated by researchers who raised concern on the market entry barriers and threatened participation of exporters particularly from developing countries who lack infrastructure, technology and other trade related costs required to meet these standards (Jaffe and Masakure, 2005). Consequently, in response to changing regulatory environment, the EU market supply chain changed from previously wholesale markets to tightly integrated buyer-driven supermarkets. (Jaffee, 2003). These supermarkets enforced their own standards too, posing further challenges especially for small-scale farmers.

Secondly, there is opportunity by developing countries in participating in high value global markets. Studies have found that through knowledge and skills transfer farmers develop capacity to produce and export different varieties and use this knowledge to produce for different markets therefore increasing market access (Jaffe and Masakure, 2005). Nevertheless, literature tend to agree that participants of horticultural exports must reorient towards meeting the changing global markets and embracing opportunities through product and market diversification (Shepherd and Wilson, 2013). Samen (2010) defines diversification as increasing the number of export products and partner markets. Through diversifications commodity exporters can navigate through changing market environments and market externalities resulting from dependence on a single market. The welfare of millions the sector support depends on its ability to adapt to a highly dynamic market and seek ways of spreading risks through diversification.

Two decades later, Kenyan horticultural exports have been increasing both in volume and value in a highly dynamic global market. We therefore seek to determine to what extent has the Kenyan horticultural exports diversification trends changed over time in terms of product exported and market access.

METHODOLOGY

The data use in the study was obtained from UNComtrade Data, aggregated in World Trade organisation (WTO) harmonised system (HS). The horticulture products in this study will be defined as cut flowers, vegetables and fruits categorised by WTO HS codes. HS 06, HS 07, and HS 08 respectively. There are different methods used different studies to measure export diversification. These methods include the Hirschman- Herfindahl index, entropy index, concentration ratio and the ogive index (Samen, 2010). For our study based on available data we use the Herfindahl-Hirschman Index (HHI), a commonly used measure by policy makers to give summary of diversification. The HHI is the sum of squared export product or markets shares of country *i* at a given time t. HHI index ranges from 0 to 1 and the closer the index to 0 (=diversified) while the closer the index to 1 (= less diversified). If the HHI index is 1, it means either a country *i* is exporting only one product or it is the only exporter in that market.

The HHI index for product diversification was calculated by following equation.

$$HHI = \sqrt{\frac{\sum_{x-1}^{n}\left(\frac{x_i}{X}\right) - \sqrt{\frac{1}{n}}}{1 - \sqrt{\frac{1}{n}}}} \quad (1)$$

While market diversification HHI was calculated by Eq. (2).

$$H = \sum_{i-1}^{N} s_i^2 \quad (2)$$

Where is the S_i is the Share of the country *i* in the market, and N is the number of countries.

$$X = \sum_{i-1}^{n} x_1 \quad (3)$$

RESULTS AND DISCUSSION

General Trends of Horticultural Exports Growth

Farmers are likely to venture into new products and market when there's growth in income which is evident of increasing growth in value of horticultural exports over the period as shown in Fig. 1.

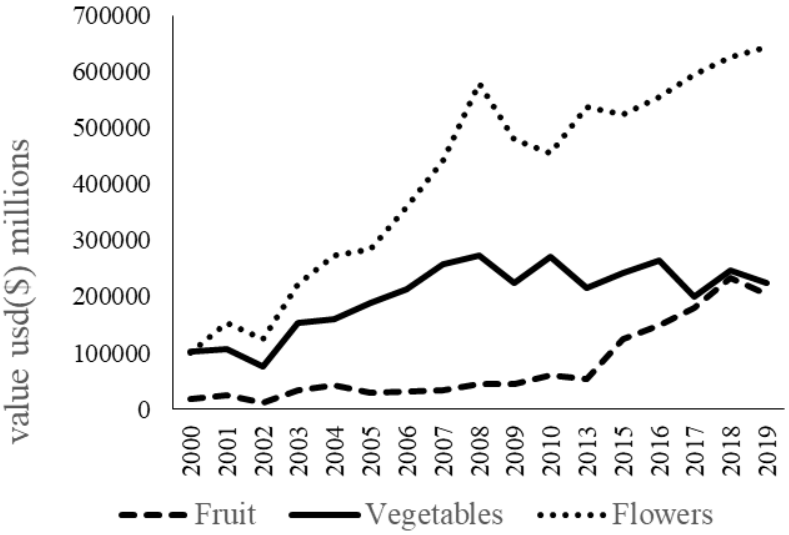

Fig. 1 Trends in value for horticulture exports
Source: Own calculations using UNComtrade

The highest growth being experienced between 2002 and 2007, a period of strong macroeconomic stability owing to President Kibaki acceded to power in 2002. The growth however slows down after 2008 which can be attributed to both domestic and market factors. Domestically, the major horticulture producing areas were affected by 2007 post-election violence followed by a widespread drought in 2009 which affected production (Tyce, 2020). As for market factors, the global economic crisis in 2008 affected major export markets (Heher and Steenberg, 2021). Further, delays and cancellation of flights to Europe due to Icelandic ash in April 2010 and heavy snow in December the same year. The exchange rate volatility especially in 2016 when the Euro/USD exchange rate dropped from 120 to 100, or delays in the signing of EPA agreement between East African community and EU in 2015. Vegetables exports have shown more erratic in growth compared to fruits and cut flowers. Moran (2018) found that vegetables are losing popularity due to a stringent market and some exporters are moving to cut flowers which contributes to the highest share of horticulture exports.

Market Access General Trends

The EU market still controls the largest share of total horticulture exports although other markets have showed potential as shown in Fig. 2. The EU controlled over 90% of total exports in 2000 which has reduced to 71% by 2019. The market with the highest potential is the Middle East which can be attributed to the proximity it is from Nairobi as found by Irandu (2019), the closer the partner market the higher the likelihood of trade. Although the EU controls the larger share of the exports, other markets have experienced higher average growth (Table 1).

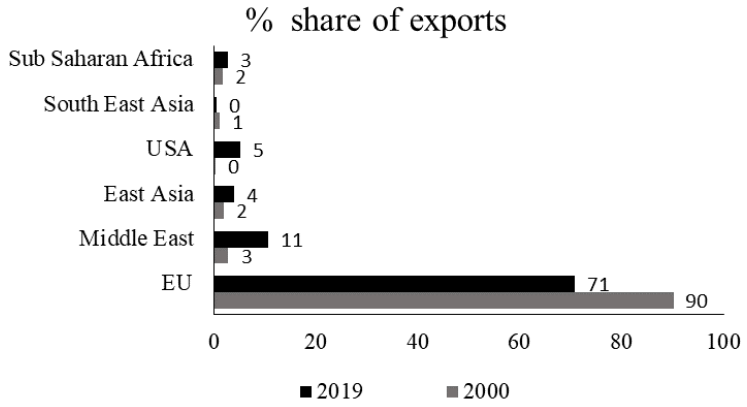

Fig. 2 Share of total horticulture exports according to markets
Source: Own calculations using UNComtrade data

Table 1 Average growth in % of major horticulture markets

Market	Average growth 2001-2010	Average growth 2010-2019
EU	15%	3%
Middle East	29%	28%
USA	37%	4%
East Asia	21%	155%
Southeast Asia	175%	79%
Sub-Saharan Africa	61%	26%

Source: author calculation based on UNComtrade data.
Average growth was calculated using the average yearly change in percentage of total exports value. The markets were defined used the United Nations defined regions. The United Kingdom is still included in the EU in this analysis.

Product Diversification Trends

The objective of the study is to determine to what extent have horticultural products have diversified. This was achieved by the change in the HHI index between 2002 to 2018, if the trend tends towards 1 (=less diversified) and if the trend tends towards 0 (= more diversified).

The study found that in all three categories of horticulture exports, the index is less than 1, meaning that the farmers are already exporting a number of products. As shown in Fig. 3, HHI index for combined horticulture products were 0.28 in 2002 has since rose to 0.31 meaning that the horticultural products are less diversified and there's no evidence of increase in additional products in the specified period. However, if we consider the different products individually, we observed a change of pattern in vegetable category after 2012. At first the Index rises from 0.34 in 2002 to 0.38 in 2012. Then falls to 0.21 in 2018. The HHI index in the flowers category was 0.71 in 2002 and rose to 0.81 in 2018. The high index in indicates that there were only a few products exported in this category which have continued to intensify over time while fruits HHI index rise from 0.31 in 2002 and 0.39 in 2018.

The evolution of SPS standards had a higher impact on vegetable exports compared to fruits and flowers. This came as a challenge and opportunity, with Global GAP (formally EUREPGAP) being rolled out in 2007, many farmers were in the process of compliance. However, there was a widespread product interception and banning of some vegetable products by the EU for failure to meet maximum residue limits (MRL) in 2012. Farmers took this opportunity to add value to the previously bulk unprocessed vegetable exports and diversified into semi-processed vegetables prepack Asian vegetables (karella, chillies, aubergines and okra) (Herher and Steenbergen, 2021). Which could explain the HHI index for vegetable categories started falling after 2012 as an indication of additional products in the export baskets.

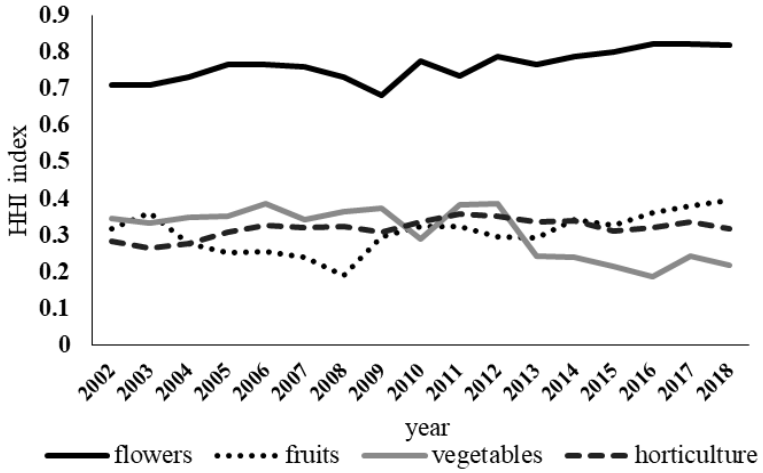

Fig. 3 Product diversification trends

Source: Own calculations using UNComtrade data

The role of governance of the horticultural supply chain as a possible explanation of less diversified products. The "buyer -driven" supply chain where supermarkets in the EU dictate what products to produce, the packaging characteristics and quality of products (Jaffe, 2003) is likely to affect innovation and addition of new products. Similarly, small scale farmers on contract can only produce what is provided the contractors. This unbalanced power dynamic observed in the export business could hinder diversification. The same phenomenon is observed in cut flowers which has the highest HHI index, where breeders and propagators determine what, when and how the planting materials are distributed (Kazimierczuk et al., 2018; Tyce, 2020).

Finally, an increasing HHI index could be explained by difficulty in access to approved planting materials especially in cut flowers exports which is associated with high cost of investment that is why 95% of the farms are owned by large scale farmers and multinational companies. High cost of royalty's payments for the planting materials, propagating, research, and development of new varieties often locks out resource poor farmers who only produce low value summer flowers (Kazimierczuk et al., 2018).

Market Diversification Trends

HHI index for market diversification in horticulture dropped (Fig. 4) from 0.27 in 2002 to 0.18 in 2019, with vegetables showing higher market diversification where the index dropped from 0.49 in 2002 to 0.18 in 2019. Fruits HHI index dropped from 0.18 in 2002 to 0.13 in 2019 while flowers index dropped from 0.37 in 2002 to 0.27 in 2019. The index has a slight increase between 2008 and 2012, which can be explained by market factors discussed in Fig. 1 above i.e the global economic crisis in 2008, the flight cancellations in EU markets due to weather.

The EU markets still controls the largest share of exports (Fig. 2) as discussed above which can be explained. First, the evolution of SPS standards did not deter exporters from the EU markets, instead most farmers embraced the compliance (Jaffee and Henson 2004). Second, the presence the foreign direct investment (FDI) coming from the EU along the supply chain such as exporters, breeders & propagators and cool chain management and inputs (Irandu, 2019). Third, the established ties in the EU supermarkets could hinder further market diversification, highly perishable products rely on trusted relationships and cost of diversion of products from one market to another is high (Dennis and Shepherd, 2007). Fourth, availability of flights to EU that can deliver the highly perishable products in short time. Fifth, growth and advancement in Kenyan airfreight and tourism has also aided delivery of highly perishable products in multiple destination within a limited time. Finally Kenyan export's ability to meet year-round demand that can supplement their production in winter.

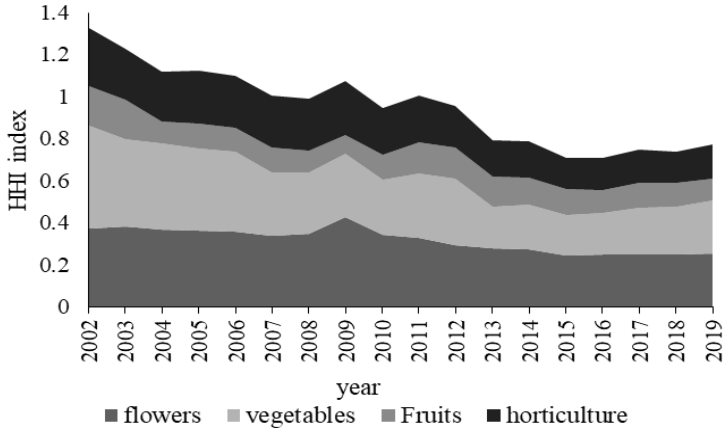

Fig. 4 Market diversification trends

Source: Own calculations using UNComtrade data

There is opportunity in participation in the EU market, Kenyan horticultural exports have widened their market access as indicated by falling HHI index both regionally and beyond (Fig. 3). Krishna (2018) found that emergence of regional value chains has provided exporters a venue to channel excess spillovers that don't make it to the main markets. The experience gained from the EU markets has equipped farmers in supplying horticultural products in multiple markets governed by different regimes. However, there is still potential in untapped markets.

CONCLUSION

The aim of the study was to determine the diversification trends of Kenyan horticultural exports this was based on the hypothesis that continued participation of farmers in a highly dynamic global markets is likely to initiate diversification. Our results confirmed that horticultural exports are more diversified in terms of markets access as evidenced by a falling HHI index. On the other hand, we found that the products to be less diversified meaning there is no evidence of any significant change in number of products exported over time as evidenced by an increasing HHI index. We further found that the EU still controls the largest share of horticulture exports. Finally, we found that other markets have shown great potential in terms of growth despite controlling a small share of exports. Trade facilitation by the government could help farmers tap into those markets and increase new products.

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Research article

Impact Assessment of System of Rice Intensification Adoption - Case from Madagascar -

MASATO KISHIMOTO*
Construction and Technology Institution, Tokyo, Japan
Email: seatma92@gmail.com

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

TAKESHI SAKURAI
School of Agricultural and Life Sciences, The University of Tokyo , Japan

Received 31 January 2022 Accepted 23 April 2022 (*Corresponding Author)

Abstract The System of Rice Intensification (SRI) is expected to improve rice yield with minimal impact on harming environment. While many studies have confirmed that the yield increases with adopting SRI by field surveys, the impact of SRI on household income is still debatable because SRI is a labor demanding method and may cause labor redistribution within a household. This study assesses the impact of SRI on the yield, household income, expenditure and caloric consumption in Madagascar, taking into account the endogeneity between farmer's capacity and adapting technologies. The authors collect the data for small-scale rice producing households in Alaotra-Mangoro region on Madagascar central highland in 2014 and 2017 by a face-to-face questionnaire survey. The authors find that the adoption of at least one component of SRI has no significant impact on the rice yield, income, expenditure and caloric consumption of households on average compared with them that adopt none of the SRI components, taking account of the endogeneity of technology adoption. This study applies Propensity Score Matching (PSM) to take account of the endogeneity. Then, comparing mean variables with using fertilizer by using PSM, the authors confirm the positive impact on yield by plot level. However, because households can't adopt both SRI and the use of fertilizers for all plots, no significant difference is observed in household income and expenditure. The findings suggest that a combination of SRI with fertilizer inputs may increase yield significantly, if more farmers in the area start using fertilizers in the future. Provision of technical SRI training alongside sales of fertilizers is crucial. However, it is needed to conduct further research in our study site to explore the impact on the household adopted all four of the SRI components which is more effective, and long-term effects of SRI.

Keywords system of rice intensification (SRI), Madagascar, propensity score matching (PSM), impact assessment, technology adoption, small-scale rice farmers

INTRODUCTION

Sustainable agriculture that reduces environmental load and increases food production has been attracting attention in recent years. System of Rice Intensification (SRI) is one of such a sustainable agriculture that has been drawing attention. This study focuses on the impact brought about by the use of SRI in the Republic of Madagascar, the birthplace of SRI.

Madagascar is in Sub-Saharan Africa where population is growing rapidly, and is a major producer of rice, its staple food. While most of its citizens engage in agricultural activities, the country suffers from low rice productivity and depends on imports for approximately 10% of its consumption. Poverty rate in rural areas is quite high at 78%. Improved rice productivity is considered to be a contributing factor towards poverty reduction in Madagascar.

SRI is a rice cultivation method developed in 1993 by Father Laulanié and is based on his observations of local farming methods as well as his own cultivation experiments (Stoop et al., 2002). SRI is practiced in many countries, particularly developing countries, thanks to dissemination activities led by Norman Uphoff and others.

SRI is not a single package but rather a system that combines principles for transplantation as well as soil and water management, does not require fertilizers and other exogenous inputs, and is expected to promote tillering in rice plants and increase yield. The following four practices are considered to be central principles of SRI in many areas where SRI is practiced (Noltz et al., 2012):

(1) The use of young seedlings: transplanted within 15 days after germination (care must be taken to ensure roots are not damaged), (2) Single seedling transplanting: A single seedling is transplanted per hill, (3) Planting at wider spacing: planting at 20cm × 20 cm spacing, (4) Intermittent irrigation: dry the soil moderately instead of ponding at all times. However, ensure that soil remains moistened.

While income from rice cultivation due to improved productivity is expected to increase, results vary by regions in terms of the impact of SRI on household income of farmers (Berkhout et al., 2015).

In East Timor, impact of SRI is observed with endogeneity of the adoption of agricultural technology taken into account. As a result of taking endogeneity into account, SRI was found to have an effect on the yield increase, but the difference in income between farmers who adopted SRI and farmers who did not was quite small (Noltze et al., 2012). Similarly, a study that considered endogeneity in Indonesia found that SRI increased yield but did not affect the income of farmers. This was because the time previously spent by farmers to earn non-agricultural income was now being spent on the labor required for rice cultivation. (Takahashi and Barret, 2013). Another study found that SRI increases yield in areas without an irrigation facility but does not improve income (Alem, 2015).

The impact of SRI on yield varies by region. On the other hand, improved agricultural productivity affects household budget in various aspects. This includes an increased consumption at home by farmers and consumption of food with higher nutritional value due to improved income (Pandey et al., 2016). In India, one study has found that farmers who adopted SRI are purchasing insurance and consuming food with higher nutritional values (Singh et al., 2017). However, no study has assessed its impact on expenditures and consumption while taking endogeneity into account.

Madagascar is the origin of SRI, and previous studies have attempted to find a correlation between SRI and rice yield as well as identify components of SRI that are crucial in increasing the yield (Barison and Uphoff, 2011; Tsujimoto et al., 2009). Another study has investigated determining factors that leads to the adoption of SRI as well as inhibiting factors (Moser and Barrett, 2003). On-site surveys have shown that SRI is effective in improving yield compared to a conventional farming method (Barrett et al., 2004, Barison and Uphoff, 2011).

While several studies have investigated factors associated with an adoption of SRI and factors that cause an increase in yield, few studies have focused on the impact of adoption of SRI on farmers in Madagascar, and as far as the author is aware, a study on such an impact that takes endogeneity of the technical adoption into account is particularly lacking.

OBJECTIVE

The objective of this study was to estimate the impact of SRI on the improvement of productivity and livelihood of farmers in central highlands of Madagascar. Impact of SRI on the welfare of a household is elucidated through a survey on the household income of farmers as well as their expenditure and food consumption.

METHODOLOGY

Two communes, Ampitatsimo and Ilafy, located in Ambatondrazaka District in the Alaotra-Mangoro Region of Madagascar, were chosen as study sites. Irrigated area by Lake Alaotra is located 240km northeast of the capital Antananarivo at 800m above sea level, and its climate is a tropical highland climate. Rice cultivation and zebu cattle grazing have been practiced in the region since the 19th Century (Yokoyama and Sakurai, 2014). Rice production in Lake Alaotra Region is among the largest in the country and includes District PC15, one of the large-scale irrigated rice cultivation districts from the French colonial era (Fujiki, 2015). Rice cultivation period is long and lasts five to six months, and rice is usually grown once a year.

Fukuda (2015) investigated characteristics of SRI farmers in Ambatondrazaka District. Farmers in this area combined technologies per plot with respect to varieties, transplantation, and SRI. SRI was utilized in combination with the conventional practice. Risk preference also influenced the decision of technologies. Risk-loving husband were more likely to adopt SRI. On the other hand, more risk-aversive wives tended to choose conventional varieties and sort seeds.

Survey on an Introduction of SRI

A team led by Professor Sakurai of the University of Tokyo conducted a survey of Ambatondrazaka District in 2014. Survey method is discussed below (Fukuda, 2015). Ampitatsimo consists of eight villages (fokontany), and Ilafy consists of twelve villages. Average population per village was calculated by dividing the total population of the commune by the number of villages, and four villages were selected from Ampitatsimo and six from Ilafy. 40 rice farmer households were randomly selected from each village (for a total of 400 households), with whom a face-to-face questionnaire survey was conducted. The survey covered a broad range of topics including socioeconomic attributes, income, food expenditures of farmers, the use of inputs at a plot level, adoption of the technology, and yield, and it was conducted twice from May to June in 2014 and again August 2014.

Number of plots managed by farmers totaled 1,337 plots, of which 732 plots were rice paddies where rice was being cultivated. Surveyed farmers also participated in risk experiment in order to measure their risk preference.

335 households and 646 plots were used as survey data after removing missing values and outlier data. Data from farmers who could not respond during the second survey period, farmers whose responses were insufficient, and farmers whose number of cultivated plots increased between the first and second survey periods were removed.

Survey on Knowledge on SRI and Decision on Its Implementation

Additional survey was conducted in December 2017 to clarify the path of SRI dissemination and the state of its implementation. A semi-structured interview was conducted with eighteen farmer households that has partially adopted SRI components, nine households who has not adopted any SRI components from the previous survey. Additionally, the interview was conducted with two agricultural bureau staff at the surveyed district, one head of the irrigation association, and one Japanese specialist staff.

Analysis Framework and Method

Average treatment effect on the treated (ATT) is used to measure the difference of the average between SRI farmers (i.e. treated group) and non-SRI farmers (non-SRI group) (Wooldridge, 2010).

$$ATT = E(yi1|Di = 1) - E(yoi|Di = 1) \quad (1)$$

Where yi1 shows the results for treated group, and *y0i* shows the results for control group. In

this study, *y* is defined as the income of an SRI farmer or a yield from an SRI plot. Additionally, *i* is the identification number assigned to each farmer. Technology is adopted when Di=1 and technology is not adopted when *Di*=0. Since *yi1* and *y0i* cannot be measured at the same time against *i-th* farmer, *E(y0i ∣ Di=1)* is replaced with measurable data from a non-SRI farmer. Typically, a difference in farm management capability and motivation is assumed between SRI farmers and non-SRI farmers, and such a difference causes bias in the results. Propensity Score Matching (PSM) is used to address the bias from replacement (Rosenbaum and Rubin, 1983).

PSM assumes that an adoption of SRI is determined by an observable variable. If the adoption is determined by an observable variable, the following equation can be derived.

$$E(y0i|Di = 1, p(xi)) = E(y0i|Di = 0, p(xi)) \quad (2)$$

Where p(xi) shows a probability that SRI is used under observable variable x.

$$Pr(Di = 1|xi) \equiv p(xi) \quad (3)$$

PSM requires another assumption. Covariance of SRI farmers and non-SRI farmers need to greatly overlap. In another words, $0<p(xi)<1$ needs to be satisfied. The following equation is derived from Equation (1).

$$ATT(psm) = E(yi|Di\ 1, p(xi)) - E(y0i|Di = 1, p(xi)) \quad (4)$$

From the above equation, the impact of SRI can be evaluated while taking endogeneity into account. However, in order to minimize the estimation error of PSM, inclusion of every variable associated with SRI adoption is recommended. If a variable that is not observed affects the adoption of SRI, a bias may exist in the ATT result as well. Methods for matching treatment group and control group includes nearest-neighbor matching, stratification matching, radius matching, and kernel matching, among others (Wooldridge, 2010). A matching method that minimizes the pseudo-coefficient of determination and error after estimation was chosen.

Factors that determine SRI adoption were analyzed in order to calculate aforementioned propensity scores. Farmers presumably combine agricultural technologies independently for each plot. Therefore, propensity scores were calculated for each plot. Logistic regression was used to calculate propensity scores.

$$Pr(Y = 1|X1, X2, \dots, Xk) = F(\beta 0 + \beta 1X1 + \cdots + \beta kXk) \quad (5)$$

Where *y* is adoption of the technology (*y*＝1: SRI plot, *y*＝0: others), *β0* is slices, and *xk* is variable pertaining to adoption.

Hypotheses

This study asks two research questions: "How does SRI technology affect rice yield" and "how does SRI affect farmers?".

A pair of hypotheses are validated. First, fields where SRI is implemented produce greater yields compared to non-SRI fields. Second, an increase in rice yield leads to an increase in rice income, resulting in an overall increase in income for the household of the farmer. Over the course of validating hypotheses, any changes in expenditure and personal caloric consumption are also noted even when the income of farmers who has adopted SRI has not increased.

RESULTS AND DISCUSSION

Results of Introducing SRI

For analysis, an SRI plot is defined as a plot where at least one of the components ((1) Use of young seedlings within 14 days after sowing, (2) Single seedling transplanting, (3) Transplanting by spacing of at least 20cm, (4) Intermittent irrigation) is adopted because farmer adapting all component is very few. A farmer is identified as an SRI farmer if the household practices SRI in at least one of its cultivated plots.

Table 1 The results of a comparison based on whether SRI adaptation by plot level

Variable	SRI ave.	Non-SRI ave.	Total ave.	SRI-Non-SRI diff.
Cultivated area (ha)	0.60	0.75	0.72	-0.15
Dummy for PC15	0.35	0.14	0.18	0.20***
Presence of an irrigation facility	0.58	0.64	0.63	-0.055
Dummy for land ownership	0.64	0.64	0.64	0.0018
Dummy for land fertility	0.10	0.15	0.14	-0.052
Weeding frequency	1.06	0.86	0.89	0.21***
Dummy for transplantation	0.96	0.61	0.67	0.35***
Dummy for the use of commercial varieties	0.71	0.78	0.77	-0.68
Seed usage (kg/ha)	147	158	156	-12
Total chemical fertilizer usage (kg/ha)	1.20	1.17	1.17	0.033
Total organic fertilizer usage (kg/ha)	1,149	734	810	415*
Distance to the plot (min)	24.1	40.5	37.6	-16.4**
Yield (t/ha)	2.91	2.34	2.44	0.57***
Rice productivity per person (kg/person)	19.3	28.5	26.9	-9.23
Revenue from rice (1,000Ar/ha) …A	2,120	1,703	1,777	417***
Fertilizer cost (1,000Ar/ha)	51.6	36.9	39.5	14.7
Pesticide cost (1,000Ar/ha)	6.01	4.25	4.57	1.76*
Herbicide cost (1,000Ar/ha)	6.677	6.675	6.676	0.002
Seeds cost (1,000Ar/ha)	111	103	104	8.32
Land improvement cost (1,000Ar/ha)	61.4	47.6	50.0	13.8
Hired labor cost (1,000Ar/ha)	272	172	190	100***
# non-hired laborers (man-days/ha)	289	190	207	99**
Cost of rice cultivation (1,000Ar/ha) …B	509	371	395	139***
Cost incl. non-hired labor (1,000Ar/ha) …B'	1,379	942	1,019	437***
Income from rice (1,000Ar/ha)… (C = A – B)	1,611	1,333	1,382	278*
Profit from rice (1,000Ar/ha) … (D = A - B')	742	762	758	-20.2
Observed	112	521	633	

*Note: *** p<0.01, ** p<0.05, * p<0.1*

Table 1 shows the results of a comparison based on whether SRI is adopted or not at a plot level. Significant differences between SRI plots and non-SRI plots were observed for presence of PC15, weeding frequency, transplantation, amount of organic fertilizer used, distance from home to plots, cost of hired labor, and number of labor days worked by non-hired laborers.

Ratio of transplantation is higher among SRI plots since three of the SRI components (excluding intermittent irrigation) are techniques related to transplantation. Intermittent irrigation requires an irrigation facility, and the ratio of intermittent irrigation and the ratio of District PC15 was greater for SRI plots. Weeding work was performed more often in SRI plots due to intermittent irrigation. Greater number of organic fertilizers used in SRI plots was due to recommendations being made towards the use of organic fertilizers at the time of SRI adaptation. Greater hired and non-hired labor in SRI plots was also consistent with previous studies, which confirmed the possibility that SRI is a more labor-intensive farming method.

Yield increased by 0.57 (t/ha) in SRI plots. At the same time, cost incurred by rice cultivation also increased. Based on the market price for Alaotra-Mangoro Region from 2014, price per kg of rice was assumed to be 728 (Ar/kg). Rice income per ha was greater in SRI plots at 10% significance level. Cost of non-hired labor was calculated by assuming the mode of hired labor cost as the employment wage within the area. Significant difference was not observed in profit calculated after including a non-hired labor cost. Significant difference was not observed for rice productivity per person (kg/person), and the adoption of SRI in the area has not improved labor efficiency. Additionally, farmers who adopted SRI were accounted for 23% of the total households, and average yield was 2.32 (t/ha).

Impact of Each Variable on the Adoption of SRI

The impact of each variable on the adoption of SRI at a plot level, calculated by using a logit model which can estimates probability to adapt the SRI. Variables that had a negative impact on the adoption of SRI were cultivated area, number of family members, female family head, distance from home to the field, and the commune in which the farmer lives. Variables that had a positive impact on the adoption of SRI were availability of irrigation, PC15 dummy, number of years of education, number of traders the farmer knows, and knowledge on intermittent irrigation.

Estimated ATT

Table 2 shows the estimated ATT. At a plot level, yield was greater in SRI plots than non-SRI plots and income, but its difference was not significant. Both hired and non-hired labor were greater in SRI plots. In particular, non-hired labor was 113 (man-days/ha), which was significantly larger at 10% significance level and showed a much greater need for labor in SRI plots. No significant differences were observed for other variables, which show that technologies other than adopted SRI (e.g. fertilizer inputs) do not make a difference between SRI and non-SRI plots. At a household level, no significant difference was observed in yield between SRI and non-SRI farmers. Income from rice and income for the entire household were greater among SRI farmers, but no significant differences were observed. Income by means other than labor was the only variable where a significant difference was observed between SRI and non-SRI farmers; SRI farmers were generating a greater amount of income through remittance and land lease. These results indicate that the adoption of SRI has not had an impact on yield and income in the area at a household level.

Table 2 Estimated results by ATT

Plot level		
Variable	ATT result (SRI plots - non-SRI plots)	Standard error
Yield (t/ha)	0.37	-0.32
Cost of rice cultivation (1,000Ar/ha)	29.2	-65
Income from rice (1,000Ar/ha)	243	-153
Profit from rice (1,000Ar/ha)	-95.4	-212
# non-hired laborers (man-days/ha)	113*	-70.0
Hired labor cost (1,000Ar/ha)	44.4	-43
Total chemical fertilizer usage (kg/ha)	-2.05	-2.48
Total organic fertilizer usage (kg/ha)	113	-338
Seed usage (kg/ha)	-9.59	-17.2
Observed	630	-
Household level		
Variable	ATT result (SRI farmers -non-SRI farmers)	Standard error
Average yield for a household (t/ha)	0.39	0.39
Household income (1,000Ar)	601	609
Income per person (1,000Ar/person)	77.8	126
Income from rice cultivation (1,000Ar)	244	472
Income from crops excl. rice (1,000Ar)	-36.9	104
Income from self-employment (1,000Ar)	-14.3	184
Non-agricultural income (1,000Ar)	-1.99	122
Income from livestock (1,000Ar)	101	87
Non-labor income (1,000Ar)	309***	130
Food expenditure (1,000Ar / week)	1.16	2,41
Total expenditure (1,000Ar/ month)	12.4	24,7
Calorie consumption per person (kcal/day)	-30.2	173.3
Observed	325	-

*Note: *** p<0.01, ** p<0.05, * p<0.1*
Plot level uses Kernel matching was used as a matching method. Bandwidth was 0.01, and resampling was iterated 900 times by bootstrap method to obtain a standard error.
Household level uses Radius matching was used as a matching method. Radius was 0.06.
Observed number is different from Table1 because some date is not suitable due to missing parameter.

Knowledge on SRI and Decision on its Implementation

Fig. 1 shows the timing in which farmers became aware of SRI, and shows components regarded as a part of SRI technology in the studied area. While there were some differences in terms of the recognized techniques that constitute SRI, all 27 farmer households interviewed knew about SRI.

Diverse timing in which farmers became aware of SRI and various paths through which SRI disseminated indicate that the word "SRI" itself is widely known in the studied area. However, institutions such as JICA and the local agricultural bureau have also disseminated other technologies, and it is quite possible that farmers confuse these technologies with SRI.

Highest number of farmers that learned about SRI was recorded in 2000, a year in which extension workers of an NGO have disseminated the SRI technology in several communes. Importance of water management was recognized in many households. Many farmers also felt the importance of using relatively innovative technologies, including the use of chemical fertilizers and pesticides and the use of a rotary weeder. While many farmers said that regular planting and row planting are important, only three respondents saw increased spacing between rows (a unique feature of SRI) as important, four saw single seedling transplanting as important, and two saw the use of young seedlings as important.

Results suggest that farmers in this area may be recognizing new technologies also as "SRI", in spite of the fact that they are not a part of the four major components that constitute SRI.

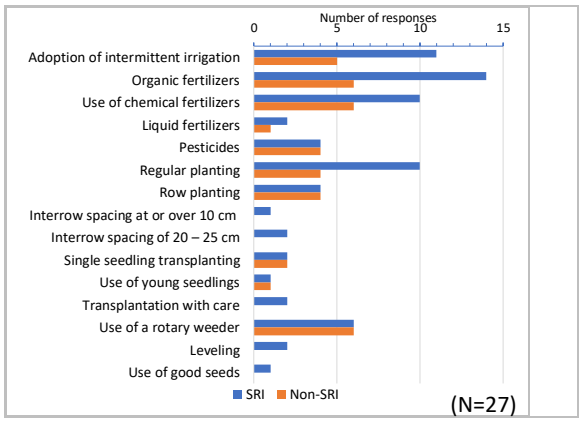

Fig. 1 Component techniques of SRI

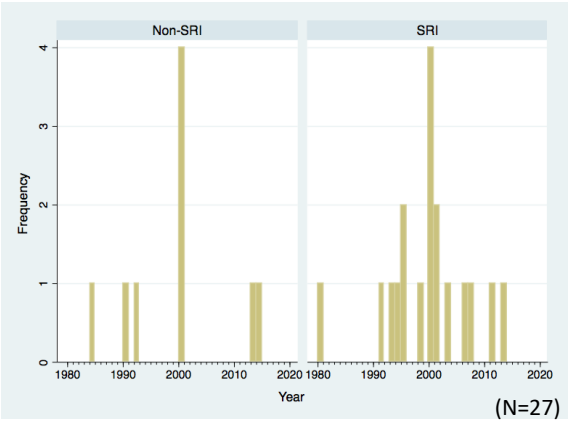

Fig. 2 Period in which farmers know about SRI

Impact of Fertilizer Inputs

Soil fertility in the studied area is low, and phosphorus deficiency is particularly evident (JICA, 2017). For this reason, widening the spacing between seedlings only widens the space and is likely to reduce yield. In the farmer's interview, some farmers indicated that farmers also viewed the relationship between land fertility and seedling spacing as important. Fertilizer inputs itself is assumed to contribute greatly to yield improvement. In addition, if seedlings are planted at wider spacing while fertilizers are applied, merits of SRI such as seed savings and an increase in the number of tillers can be expected.

Therefore, differences in yield and income due to whether fertilizer are applied or not as well as a combination of fertilizer inputs and SRI were verified using data from 2014.

Table 3 shows the results. Estimation after matching shows an increase in average yield due to fertilizer inputs. However, a significant difference in income was not observed due to an increase in fertilizer cost and hired labor cost. When fertilizer inputs were combined with SRI, yield increased by 0.61 (t/ha). While the cost of rice cultivation increased, income per ha also increased due to a significant increase in yield. However, income did not increase when non-hired labor was converted to cost due to an increase in the amount of non-hired labor. At a household level, no significant differences were observed in rice yield and thus income from rice cultivation, and no significant differences were also observed in other incomes.

Table 3 Impact of fertilizer inputs

by plot	Estimation by ATT	
Variable	Fertilizer (Fertilizer = 297)	Fertilizer + SRI (Fertilizer + SRI = 61)
Yield (t/ha)	0.37**	0.61***
Cost of rice cultivation (1,000Ar/ha)	130***	145***
Income from rice (1,000Ar/ha)	138	302**
Profit from rice (1,000Ar/ha)	53.0	66.1
Seed usage (kg/ha)	20.1*	20.1
Cost of hired labor (1,000Ar/ha)	36.7**	86.0***
# non-hired laborers (man-days/ha)	28.4	78.6*
Observed	630	630
per household	Estimation by ATT	
Variable	Fertilizer (Fertilizer = 181)	Fertilizer + SRI (Fertilizer + SRI = 50)
Household income (1,000Ar)	82.6	588
Income per person (1,000Ar/capita)	5.29	136
Income from rice cultivation (1,000Ar)	197	416
Average yield for a household (t/ha)	0.26	0.33
Income from crops excl. rice (1,000Ar)	11.0	34.0
Income from self-employment (1,000Ar)	-123	-112
Non-agricultural income (1,000Ar)	28.9	47.8
Income from livestock (1,000Ar)	0.875	91.1
Non-labor income (1,000Ar)	-31.5	111
Food expenditure (1,000Ar / 1 wk)	-0.361	-0.098
Total expenditure (1,000Ar/ month)	16.9	-16.8
Calorie consumption per person (kcal/day)	17	-37
Observed	325	325

*Note: *** p<0.01, ** p<0.05, * p<0.1*
By plot level uses radius in radius matching for fertilizer use was 0.04, and radius for fertilizer + SRI was 0.01
Per household level uses radius in radius matching for fertilizer use was 0.05, and radius for fertilizer + SRI was 0.06.

As a result, the difference in household income due to fertilizer inputs was not significant. This result was also the same for a case in which the use of fertilizers and SRI were combined. Lack of difference in yield and income at the household level may be due to the fact that the technologies were not being applied across all cultivating plots.

Comparison of average yield difference between years 2016/2017 and 2013/2014 showed a reduction in average yield for 2017 by 0.68 t/ha. This is likely due to a dearth of rainfall in 2016/2017, which led to a poor harvest for the year with a significant reduction in average yield. Weather conditions such as rainfall were not controlled, but they suggested that an increase in yield between 2014 and 2017 was unlikely.

CONCLUSION

This study investigated the impact of SRI on yield and living expense among rice farmers in two communes in Ambatondrazaka District of Madagascar. In the analysis, yield, household income, and expenditure were compared by using data obtained by on-site surveys. PSM was used to account for selection bias and compare average yield between SRI and non-SRI plots, which showed that yield was greater in SRI plots but without a significant difference. Improvement in rice income due to an adoption of SRI was not observed. While the household income was greater for SRI farmers, there were no significant differences between two groups. Differences due to SRI adoption were not observed with regards to a week's worth of food expenditure and expenditure per month by the farmer. Similarly, consumed calories were calculated based on food consumption by farmers, but no difference due to the adoption of SRI was observed.

Interview results from 2017 showed that the term "SRI" is widely known among farmers. However, details of the technology recognized by farmers varied greatly, which implied that SRI is a technology whose name is well-known, but its details are not accurately known.

Considering low soil fertility of the studied area, wider spacing between seedlings may reduce yield. On the other hand, high yield may be achieved by improving soil fertility through fertilizer

inputs and adoption of SRI. Survey results from 2014 also confirmed that yield increases when SRI is combined with fertilizer inputs. In this case, cost incurred to cultivate rice increased at a plot level, but income also increased, thereby indicating the importance of combining fertilizer inputs with SRI components. Even in this case however, because households were unable to adopt both SRI and the use of fertilizers for all plots, no significant difference was observed in income from rice cultivation and household income.

In the future, a combination of SRI with fertilizer inputs may increase yield significantly, if more farmers in the area start using fertilizers. Provision of technical SRI training alongside sales of fertilizers is crucial.

Future Research

Among farmers surveyed in this study, only one household adopted all four of the SRI components. In the analysis, farmers who have adopted some of the SRI components were defined as farmers who have adopted SRI. SRI is considered to be most effective when all of the components are adopted (J-SRI, 2011). For this reason, any area nearby the site for this study where SRI is widely practiced may have adopted all components of SRI and thus increased the yield. In addition, comparison per SRI component was not possible due to the sample size, and an identification of component(s) that is important for the study site could not be conducted.

This study did not consider the number of years through which SRI is continually practiced. One study has suggested that farmers who have continued to practice SRI for a number of years are accustomed to the technology and thus able to improve their productivity (Moser and Barrett 2003). An analysis that accounts for the number of continuously practiced years would be important in measuring long-term effects of SRI.

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Research article

Effects of Lead and Other Metals from Historical Smelting on Sustainable Fruit and Vegetable Cultivation

BARRY NOLLER*
The University of Queensland, St Lucia, Australia
Email: b.noller@uq.edu.au

FIONA HENDERSON
The University of Queensland, St Lucia, Australia

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Abstract Wollongong, located in the Illawarra region of NSW Australia, contains the industrial complex of Port Kembla. Lead in Port Kembla soils, ~2.5 km from a former copper smelter (1908-2003), have exceeded soil contamination guidelines for human health (HIL) and ecological (EIL) investigation levels. Previous studies regarding heavy metal contamination from the industrial complex, do not include comparisons to HIL and EIL guidelines. This study re-examines the risk of legacy (historic) heavy metals in urban soils to residents in proximity to the Port Kembla industrial complex. This was accomplished by reviewing: (i) resolution of heavy metal dispersion data from the copper smelter, in historic soil concentration data (n=95 top soil samples) collected by Jafari (2009) and reviewed by Noller (2020a); (ii) providing a new comparison of historic percentile data to current Australian soil contamination guidelines (NEPC, 2013) and German atmospheric pollutant guidelines; and (iii) re-evaluating treatments to soil data by Jafari (2009), in the context of bioaccessibility and bioavailability to humans and plants. At 75th percentile, arsenic, cadmium, copper, lead and zinc concentrations exceeded HIL Level A guidelines. When detection limit values (52 out of 95) were removed (n=22 samples), median cadmium concentrations exceeded HIL Level A guidelines. Dietary exposure to cadmium, lead, zinc and copper is a risk to residents through the consumption of vegetables grown in urban gardens in proximity to the Port Kembla industrial complex. Copper in vegetables sampled from soils in the vicinity of the Port Kembla copper smelter was greater in comparison to sampling completed at other smelter sites. Port Kembla urban garden vegetables showed exceedance of food guidelines for both cadmium and lead, highlighting the health risks of growing vegetables in proximity to industrial areas.

Keywords heavy metals, arsenic, smelting, sustainable, fruit and vegetable cultivation

INTRODUCTION

The Wollongong local government area (LAG) is located in the Illawarra region of New South Wales (NSW), Australia (Fig. 1), 80 km south of Sydney. The Wollongong LAG contains the industrial complex at Port Kembla; a feature which has remained in place for over 100 years (Chiaradia et al., 1997; Jafari, 2009). A copper smelter, formerly Southern Copper ERS Ltd (SC in Fig. 1), commenced operations at Port Kembla (1908-2003) and demolished in 2014. A considerable body of literature exists on the nature, extent and distribution of heavy metals and arsenic in soils in Wollongong and Port Kembla (Noller, 2020a). The current Australian guidelines for human health (HIL) and ecological (EIL) investigative levels are risk-based approaches used to examine and interpret soil, air, water and food environmental data. Existing guidelines (HIL and EIL) had yet to be implemented at the time of previous data collection and analysis (Noller, 2020a). Previously, lead (Pb) was mainly investigated at Port Kembla, yet cadmium (Cd), zinc (Zn), copper (Cu), and arsenic (As) also exceeded Australian National soil contamination guidelines (HIL and EIL) (NEPC, 2013; Noller, 2020b). In the absence of Australian air pollutant guidelines, German

air pollutant controls (TA LUFT standards) for metal fallout were used (TA LUFT, 1990, 1999; Noller, 2020b).

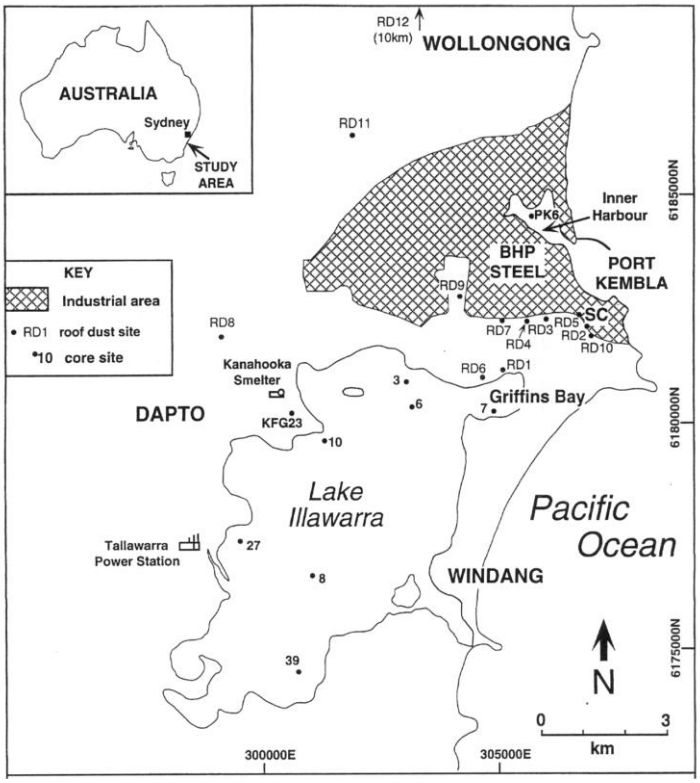

Fig. 1 Location of the historical Port Kembla industrial complex, including the southern copper smelter (SC) and other sampling sites (Chiaradia et al., 1997)

OBJECTIVE

The objectives of this study are to re-examine and evaluate the human-health risks to residents in the proximity to the Port Kembla industrial complex, based on historic heavy metal and As concentrations in soil.

METHODOLOGY

This study aims to follow three methods of re-examination and analysis: (i) to review the resolution of heavy metal and As dispersion data from the copper smelter, in historic soil concentration data (n=95 top soil samples) collected by Jafari (2009) and reviewed by Noller (2020a); (ii) to provide a new comparison of historic percentile data to current Australian soil contamination guidelines (NEPC, 2013) and TA LUFT (1990, 1999) German atmospheric fallout standards; and (iii) to re-evaluate treatments to soil data by Jafari (2009), in the context of bioaccessibility and bioavailability to humans and plants.

The Jafari (2009) study measured the total concentration of 37 elements in soil samples (n=95) by XRF-spectrometry. Soil samples were treated with 0.1M hydrochloric acid extraction and ethylenediamine tetra acetic acid (EDTA). Data from Jafari (2009) was not previously evaluated for human health or ecological risks, however extraction methods in Jafari (2009) are an analog to reflect human bioaccessibility of metals and As in soils (HCl acid extract similar to stomach acid) and indicate plant uptake (EDTA extract). The detection limit for Cd was 10-20 mg/kg (Jafari, 2009) resulting in only high values of Cd being compared with guidelines (Noller, 2020a). This study re-examines data from Jafari (2009) and Noller (2020a) and compares percentile values of As, Cd, Cu,

Pb and Zn against soil guidelines (NEPC, 2013), to inform a risk assessment of potential resident exposure from historic smelter emissions.

RESULTS AND DISCUSSION

Summary results are given in percentile values in Table 1 for metals and As in soil (mg/kg), and Table 2 for mean percent extractable metals and arsenic in soil at Port Kembla.

Table 1 Percentile values for metals and arsenic in soil (mg/kg) at Port Kembla

Metal/ metalloid (n=95)	No.< Values	Mean (SD)	Median	75th percentile	Maximum	HIL[a] Level A	EIL[b] Urban-residential
Copper	0	556±1246	161	535	1999	1000	30-230
Zinc	2	373 ±417	220	432	2833	7000	25-1300
Arsenic	1	14 ±24	7	12	183	100	50-100
Cadmium	52	89 ±189	29	39	840	20	-
Lead	3	178 ±479	64	126	667	300	270-1100

Source a. HIL Level A is for urban residential with garden (Noller,2020b); and b. EIL Urban-residential includes public open spaces for both invertebrate and plant species protection level of 80% (approximated using 75% data) with upper and lower levels combining added contaminant limit with background concentration. The EIL for Cd is not available. Site specific measurements can be undertaken to derive a Cd EIL (NEPC, 2013; Noller, 2020b), but not for this study.

Examination of percentile values (Table 1) shows that concentrations of As, Cd, Cu, Pb and Zn exceeding HIL Level A investigation levels for residential soils are all greater than 75th percentile values. When the detection limit values of Cd (52 out of 95) were removed, 22 soil concentrations exceeded HIL Level A at their median (50th percentile) value.

Jafari (2009) noted a positive correlation between Cu ($P < 0.001$), As ($P < 0.001$), Pb ($P < 0.001$) and Zn ($P < 0.01$) concentrations and distance from the smelter stack. Concentrations in soil in proximity (< 1.5 km) to the smelter stack contained higher amounts of total Cu (>1500 mg/kg) and As (> 10-15mg/kg), Pb (> 150-200mg/kg) and Zn (> 400-600mg/kg) (Jafari, 2009). Highest concentrations of As, Cd, Cu, Pb, and Zn were attributed to samples from slag heaps (Jafari, 2009). Contamination of heavy metals and As in soils surrounding the Port Kembla smelter, range at a distance of 1-4km, but higher concentrations are observed <1km from the smelter stack.

Percentile values depicted in Table 1, shows that except for Cu, 75th percentile values for metals and As do not exceed EIL standards. Readers should note that there is no current EIL guideline for Cd. Some effects on terrestrial species in garden soil from Cu may be expected as the EIL urban-residential guideline is exceeded for concentrations greater than median (Table 1).

Single extraction technique data used to determine 0.1M Hydrochloric acid and 0.05M EDTA concentrations of elements (Table 2) show that Cu, Pb and Zn concentrations decreased with increasing distance from the stack (Noller, 2020a). The heavy metal and As extraction technique of 0.1M hydrochloric acid, can be utilized as a gastro-intestinal simulation, to predict human bioavailability (Table 2). More accurately, 0.1M hydrochloric acid extractable metals and arsenic provides an indication of their bioavailability during the gastric phase (Table 2); however, this method likely overestimates their bioaccessibility, as the intestinal phase (functions at ~ pH 7 conditions) is not considered (Noller, et al. 2017). It is important to distinguish that the human intestine is where heavy metal and As absorption takes place, while the stomach (gastric phase) is where solubilization of food (heavy metals and As) occurs. The 0.05M EDTA extractable concentrations of heavy metal and As represent the relevant concentrations of plant uptake from soil (Table 2).

Table 2 Mean percent extractable metals and arsenic in soil at Port Kembla

Extractant	Arsenic (%)	Copper (%)	Lead (%)	Zinc (%)	Cadmium (%)
0.1M HCl	35.7	22	28	43	4.27
0.05M EDTA	42.9	32	37	33	4.5

The mean 0.1M hydrochloric acid extractable Pb concentration (Table 2) of 28.0% in Wollongong soil indicates that bioaccessibility is low (compared with < 100%). This bioaccessibility (BAc) level is similar to soil at other mining centres in Australia (Noller et al., 2017). The HIL Level A 300 mg/kg for Pb and 0.1M hydrochloric acid extractable Pb is equivalent to a site-specific level of 1,071 mg/kg (BAc-adjusted site-specific concentration = HIL A (300 mg/kg) / 0.28), i.e., by assuming that the bioaccessibility is conservatively 28.0%. The HIL Level A 100 mg/kg for As and 0.1M hydrochloric acid extractable As is equivalent to a site specific level of 280 mg/kg (BAc-adjusted site specific concentration = HIL A 100 mg/kg/ 0.36); The HIL Level A 6000 mg/kg for Cu and 0.1M hydrochloric acid extractable Cu is equivalent to a site specific level of 27,300 mg/kg (BAc-adjusted site specific concentration = HIL A 6000 mg/kg/ 0.22), i.e. assuming BAc is 22.0%. If 'bioaccessibility-adjusted' concentration is utilized, no exceedances of HIL A from metals and As in soil occurs. The HIL Level A 20 mg/kg for Cd and 0.1M hydrochloric acid extractable Cd is equivalent to a site-specific level of 468 mg/kg (bioaccessibility-adjusted), assuming bioaccessibility is 4.27%. This shows 'BAc-adjusted' concentrations (n=22) do not exceed HIL A for Cd.

Table 3 summarizes and compares historical Pb and Cd (μg/m^2.day) fall-out data at Port Kembla and other Wollongong sites, with fallout data from the electrolytic refinery site at Hobart, Tasmania (located 1600 km south of Sydney, NSW; Fig. 1). Converting the measured fall-out in units of μg/cm^2.year to μg/m^2.day (Table 3) enabled a comparison of historical data for Pb and Cd with current German dust metal and metalloid deposition guidelines (TA LUFT, 1990 and1991). A retrospective evaluation of fallout data compared to German guidelines informs on the significance of historical Pb and Cd deposition in soil. Data in Table 3 shows: (i) Lead at sites near Port Kembla smelters exceed TA LUFT 'protection of human health and crop land integrity' and 'Grassland integrity' (May 1981) for fallout monitoring during the 1970s - 1980s; and (ii) Cadmium, at all sites at Port Kembla, exceed TA LUFT 'Protection of human health' guideline by 47 times at a value of 94μg/m^2.day except when <5.5μg/m^2.day. Contour diagrams of dust fall-out in Archibold and Crisp (1983) showed that Pb deposition extended across the north central part of the Wollongong study area in September 1980, with peak fallout occurring at the smelter, which subsequently decreased in April 1981. Table 3 shows the residents at this time could have been exposed (ingestion) to elevated Cd and Pb from fall-out.

Cd and Pb uptake from atmospheric fall-out, could have occurred in vegetable gardens, 1-2 km from smelter locations. Although current emission of Pb is not an issue in Wollongong for human health exposure from inhalation, it is possible that remobilization of Pb or Cd from surface soil is an ingestion issue today, particularly for children. The historical record of Cd and Pb fallout from the Port Kembla copper smelter and steelworks indicates the extent of dispersion of Cd and Pb was real and likely resulted in direct exposure to residents or due to ingestion of garden vegetables.

For ecological conditions soil organisms can be affected. Comparison of fallout levels of Cd and Pb in Hobart suburbs from the electrolytic zinc refinery (Table 3) show emissions were lower than for Port Kembla, but similar to Wollongong suburbs. Dietary exposure to Cd, Pb, Zn, Cu, and As is a risk to human health through consumption of vegetables, especially in urban-residential areas. The extent of Cu uptake in vegetables sampled from soils in the vicinity of the smelter at Port Kembla was greater than at other smelter sites (Kachenko and Singh, 2006). Both Cd and Pb in vegetables at Port Kembla exceeded Australian Food Standards maximum level (ML both 0.1 mg/kg fresh weight for Cd and Pb; (FSANZ 2016; Kachenko and Singh, 2006). This highlights the importance of historical investigations and retrospective evaluations. This study reveals the risk of heavy metal persistence in urban-residential soils near historic smelter operations. Local residents

may be at risk from growing vegetables in soils not completely rehabilitated following decommissioning of smelters.

Table 3 Summary of historical air fallout data for lead and cadmium at Port Kembla and Wollongong, NSW and Hobart, Tasmania

Site (n)	Cadmium Mean±se ($\mu g/m^2.day$)	Lead Mean±se ($\mu g/m^2.day$)	Reference
Wollongong suburbs			
Wollongong suburbs (2)	<5.5	71.2 ±27.4	Beavington (1977)
September 1980 (13)	-	185 ±36.8	Crisp et al., (1984)
October 1980 (4)	-	725 ±323	Crisp et al., (1984)
November 1980 (9)	-	183 ±44	Crisp et al., (1984)
Port Kembla			
Port Kembla smelter/ works (5)	26.3 ±9.7	568 ±230	Beavington (1977)
September 1980(1)	-	1040	Crisp et al., (1984)
October 1980(1)	-	4870	Crisp et al., (1984)
May 1981(7)	94 ±3.0	3760 ±109	Archibold and Crisp (1983)
Rural site			
56km from SC smelter (1)	<5.5	24.7	Beavington (1977)
Hobart suburbs			
Hobart suburbs (11)	1.70 ±0.60	40 ±14	Ayling and Bloom (1976)
Electrolytic zinc refinery site (7)	6.0 ±5.0	173 ±100	Ayling and Bloom (1976)
Dust Deposition Guidelines			
Cadmium[a]	2		TA LUFT (1990, 1999)
Lead[a]			
Protection of human health[b]		100	
Protection of crop land integrity[c]		185	
Protection of grassland integrity[c]		1900	

Source a. Averaging Period 1 year; *b .TA LUFT (1990); and c. TA LUFT (1999).*

CONCLUSION

The total concentrations of heavy metals and As in 95 surface soil samples collected in 2009 as percentile values provided better resolution of dispersion distance from the copper smelter at Port Kembla. The comprehensive treatment of existing data by comparing historical data against current guidelines was not previously possible until this study. Historical fallout data compared against current heavy metal fall-out guidelines predicts past smelter emissions build-up in soil suggesting potential risks to residents ingesting vegetables grown from contaminated urban soils.

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Research article

Utilizing Lead Isotope Tracing to Investigate Sustainable Agriculture Practice in the Burdekin Catchment, Australia

FIONA HENDERSON*
The University of Queensland, St Lucia, Australia
Email: uqfhend1@uq.edu.au

BARRY NOLLER
The University of Queensland, St Lucia, Australia

TATIANA KOMAROVA
Queensland Health Forensic Scientific Services, Brisbane, Australia

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Abstract The Burdekin delta is the largest sugarcane producing region in Australia (85,000 ha) and a major coastal output to the Great Barrier Reef (GBR). Run-off from cultivation areas contain heavy metals from fertilizers, contributing to elevated Cd, Hg, and Pb in waterways. Validating the efficacy of sustainable agriculture practice is necessary to determine if current strategies protect ecosystems and uphold environmental standards. The objective of this study is to utilize Pb isotope tracing ($^{207/206}$Pb and $^{208/206}$Pb) and elevated trace-elements (Cd, Hg, and Pb) as a monitoring tool, to detect residual heavy metals from fertilizers and alternative pollutant sources in the Burdekin catchment. Lead-isotope ratios from dry-season samples of embankment soils/sediment (n=15, 2016, 2019) and water (n=35, 2016-2020), reveals sources of natural forest soils, cane soils (fertilizer enriched), ambient dust, and historic coal fly-ash (Collinsville Power Station). Pb isotope compositions and low levels of heavy metals (soil/sediment: TCd 0.11 mg/kg, THg 0.03 mg/kg and TPb 11.02 mg/kg; estuary: THg 0.011 µg/L and TPb 4.99 µg/L) indicate that fertilizers applied to soils have minimal impact on Burdekin waterways during the dry-season, suggesting effective agricultural practice and sustainable irrigation control.

Keywords agriculture, sustainability, sustainable practice, lead isotope, source-tracing

INTRODUCTION

The GBR is the largest reef ecosystem on the planet (344,400 km^2) and a World Heritage site located off the coast of Queensland (QLD), Australia (Coggan et al., 2021). Land-runoff from coastal catchments can adversely impact the GBR (Lewis et al., 2021). Agricultural mismanagement, (i.e. fertilizer overuse and uncontrolled irrigation run-off) contributes to water quality risk through the accumulation of heavy metals in soil and remobilization to waterways (Table 1; Alengebawy et al., 2021; Coggan et al., 2021). In literature, research has conventionally used elevated heavy metals to establish pollutant presence and Pb-isotopes to trace pollutant source by providing a measure of geologic age (Table 1; Diaz-somoano et al., 2009; Lottermoser, 2009; Alengebawy et al., 2021). Following ~10 years of sugarcane cropping, Rayment (2007) noted Cd and Hg were elevated in QLD cane soils. Davis, et al. (2008) detected sugarcane pesticides in Burdekin waterways. Extended fertilizer use is known to degrade soil fertility and productivity (Ping et al., 2020). Fertilizer overuse burdens the environment, economic and social value of both the GBR and the sugarcane industry (DAE, 2017). Sugarcane production is $1.33 billion AUD (gross); the Burdekin represents 31% or $4.12 million AUD (DAE, 2017). Aboriginal and Torres Strait Islanders have maintained cultural ties to the GBR for ~ 60,000 years. There are over 70 identified clans in the GBR; 16 of which reside in the Burdekin (DAE, 2017). Coastal communities

with high fish intake risk methyl-Hg and Cd (neurotoxins) exposure; illustrating community dependence upon ecosystem health (Haswell-Elkins et al., 2006; Russell et al., 2015).

Table 1 Summary of mean cadmium, mercury and lead concentrations (mg/kg) in contaminated soils, fertilizers, sugar cane soil, and sugarcane by-products loading to soil

Description	Cd (mg/kg)	Hg (mg/kg)	Pb (mg/kg)	Reference
Fertilizer Derailment				
Contaminated soil (n=7)	4.21	n.a.	53.7	Noller, 2021
Contaminated soil (max)	45	n.a.	790	Noller, 2021
Fertilizer type (N-K-P)				
0-9-0, (n=4)	22	0.5	5.43	Lottermoser, 2009
TSP, 0-21-0	6.67	0.5	6.68	Lottermoser, 2009
DAP, 18-20-0 (n=3)	1.18	0.5	0.33	Lottermoser, 2009
13-14-12 plus	0.85	0.5	132	Lottermoser, 2009
Sugarcane soil (± SD)	0.05	0.069	27	Rayment, 2007; 2011
Sugarcane by-product	Cd (kg/ha)	Hg (kg/ha)	Pb (kg/ha)	
Filter Mud	0.011	n.a.	n.a.	Rayment, 2011
Mill Ash	0.003	n.a.	n.a.	Rayment, 2011
Biosolids	0.11	n.a.	n.a.	Rayment, 2011
Soil loading limits	2	n.a.	260	NWQMS, 2000

Note: N-K-P nitrogen, potassium, and phosphorus; SP, superphosphate; TSP, triple superphosphate; DAP, Di-ammonium phosphate; sugarcane by-products load to soil (0-10 cm depth).

OBJECTIVE

This study investigates utilizing analytical indicators (Pb isotopes: $^{207/206}$Pb and $^{208/206}$Pb and heavy metals: Cd, Pb, and Hg) to monitor sustainable agricultural practice and identify impacts of fertilizer to Burdekin waterways. Alternative pollutant sources are also investigated. In this study, appropriate fertilizer use and irrigation run-off control defines sustainable agricultural practice.

METHODOLOGY

The Burdekin catchment (area ~130,400 km^2) resides in the seasonally dry tropics of NE QLD (Fig. 1). The Upper Burdekin is bordered by coastal ranges (750-1070 m height) < 50 km from the coastline and feeds into the largest dammed catchment in QLD, Lake Dalrymple, impounded by the Burdekin Falls Dam (BFD). In the dry-season, lower catchment flow is driven by allocated releases from the BFD (mean ($\bar{x}$) minimum flow volume ± standard error (±se): 4715 ±406 ML/month) and uncontrolled irrigation run-off (QLD Government, 2017). Approximately 75% of surface water diversion schemes go to irrigation of sugarcane agriculture (Lewis et al., 2021). Monsoonal rains govern flow volumes during the wet season ($\bar{x}$ ±se: 1535476 ML ±255826). Extreme flooding events occur annually, resulting in overspill at BFD, dislodging fertilized material, and dispersing heavy metals to waterways. Monitoring of Burdekin River environment health is carried out during the dry season (May-November $\bar{x}$ ±se:101672 ML ±36104) when vehicle access is possible, and samples are safe to collect. Wet season volumes also cause dilution ($\bar{x}$:15 times, 1986-2021) often resulting in undetectable heavy metal concentrations (WMIP, 2022). As a consequence, heavy metal concentrations from the run-off events are likely to pose greatest environmental risk during the dry-season, when perennial river volumes have returned to "steady-state" flows. Embankment soils/sediments (n=15, 0-100 mm depth, 2016, 2019) and water (n=35, unfiltered, 2016, 2018, 2019 and 2020) were sampled in the Upper and Lower (estuary) sub-catchments of the Burdekin watershed during the dry season. Water and sediment samples in 2016 and 2018 (Fig. 1) were collected in June and July to demonstrate dry-season sources of heavy metals, and input of soil seepage, representing concentrations coinciding with fall of the hydrographic curve. Samples in

2019 and 2020 were collected in late November and early December (increase in hydrographic curve). Thus, sample collections in 2019 and 2020 (Fig. 1) captured first flush and post run-off heavy metal concentrations from the start of the wet-season, including any input from agricultural fertilizers.

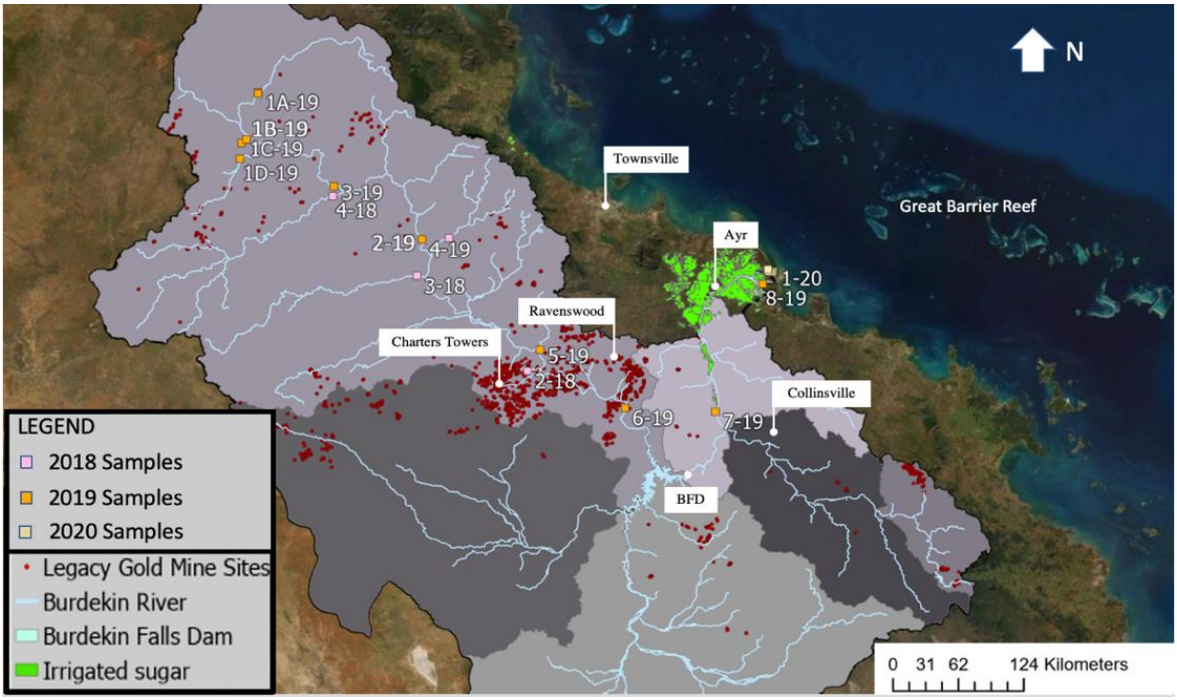

Fig. 1 Study area and sample site location map

Water and soil/sediment were analyzed at the NATA accredited laboratory (ISO/IEC 17025, 2017) Inorganic Chemistry, Queensland Health and Forensic Scientific Services, Coopers Plains, QLD 4108, Australia. Agilent 8800 triple quadrupole inductively coupled plasma mass spectrometer (ICP-QQQ; Agilent Technologies, Santa Clara, CA, USA) measured heavy metal concentrations. Internal standards, spikes and certified reference materials (CRM, TM-28) were used for quality assurance and quality control (QA/QC). QC for Hg analysis used 5% Hg (v/v) HNO_3 solution (SRM ID 3133, SRM Lot # 060204; High Purity Standards, Charleston, SC 29423, USA). Pb isotope ratios ($^{207/206}$Pb and $^{208/206}$Pb) in water, soil and sediment digests were determined by Agilent 8800 ICP-QQQ (CRMs: GXR-1, JG-2, JR-1, JSD-1, JSD-2). Soil/sediment (including CRMs) were prepared following the standard operating procedure (SOP 18191). Water samples were analyzed directly after addition of 0.2 mL High Purity HNO_3 to total 10mL. Pb isotope stock standard solution was used from Choice Analytical and prepared via serial dilution. Ratios were calculated using instrument software. Blank corrections were made with 0.5mL High Purity HNO_3 in 10mL of deionized water. The ICP-QQQ is tuned following manufactures recommendations (Ref 11.3) and QIS: 30638 Operational Guidelines – ICP-MS. Total Hg measurements in soil were analyzed by National Measurement Institute Department of Industry, Innovation and Science, Sydney, Australia.

RESULTS AND DISCUSSION

Mean ±se of total (T) Hg (0.016 ±0.002 µg/L) and TPb (0.15 ±0.02 µg/L) in freshwater remain below ANZG (2018) default guideline values (DGVs) (Table 2). Mercury ($\bar{x}$ ±se: 0.011 ± 0.001) in the estuary are below marine DGVs. In one estuary sample, TPb (4.99 µg/L) is above a marine DGV of 4.4 µg/L (Table 2). At < 2 mm size fraction, embankment soil/sediment samples reflect $\bar{x}$ ±se of TCd (0.11 ±0.10 mg/kg), THg (0.03 ±0.004 mg/kg) and TPb (11.02 ±1.65 mg/kg), all

below soil and sediment DGVs throughout the upper and lower catchments (Table 3). The majority of Burdekin soils/sediments (80%) and water (72%) samples, reflect isotopic compositions of cane soil (fertilizer enriched) and natural forest soils (Lottermoser, 2009; Fig. 2A and B). Isotope tracing also suggests TPb Burdekin soils/sediments and waters are reflective of residual coal fly ash and ambient-background dust (Turull et al., 2018). NSW coal fly ash signatures (Fig. 2; Diaz-somoana et al., 2009) identified in Burdekin samples likely reflect historic contributions from a nearby powerplant. A nearby coal-electricity generation station is the Collinsville Power Plant (Fig. 1). Based on current flow statistics, the Burdekin River is highly variable, considerably influencing annual sediment and nutrient loads (Brodie and Bainbridge, 2008). This is apparent in Pb isotope compositions that vary with sample years (Fig. 2B). In 2016, isotope ratios trend toward phosphate-fertilizers and are very similar to ratios found in fertilizer-enriched cultivation areas of the Tully catchment (QLD; Turull et al., 2018). In 2018 and 2019, ratios in fresh and estuarian waters reflect a mixture of sources: NSW coal fly ash, dust, natural forest soils and leaded petrol (1996) (Fig. 2 B).

Table 2 Total Hg and Pb (µg/L) in the Burdekin River from 2016, 2018, 2019, and 2020.

Freshwater	THg (µg/L)	TPb (µg/L)	Saltwater	THg* (µg/L)	TPb (µg/L)
N	24	24	N	11	1
Mean	0.016	0.146	Mean	0.011	4.99
SD	0.01	0.079	SD	0.004	n.a.
SE	0.002	0.018	SEM	0.001	n.a.
Min	0.005	0.053	Min	0.004	n.a.
Median	0.013	0.111	Median	0.011	n.a.
80 percentile	0.022	0.149	80 percentile	0.011	n.a.
95 percentile	0.027	0.204	95 percentile	0.015	n.a.
99 percentile	0.044	0.372	99 percentile	0.018	n.a.
Max	0.048	0.414	Max	0.019	n.a.
Toxicant DGV	0.06[a]	3.4[b]	Toxicant DGV	0.1[a]	4.4[b]

*Note: N, count; SD, standard deviation; SE, standard error, *Collected in 2019 and 2020 n=11,*
[a] 99% level of protection for Hg. [b] 95 % level of protection of species for Pb (ANZG-water, 2018)

Table 3 Total Cd, Hg and Pb (mg/kg), <2mm size fraction soil/sediment from 2016 and 2019

Summary	TCd (mg/kg)	THg (mg/kg)	TPb (mg/kg)
n	14	15	14
No < values	4	9	0
Mean	0.11	0.03	11.02
SD	0.37	0.01	6.16
SE	0.10	0.004	1.65
Min	0.00	0.02	2.40
Median	0.02	0.03	9.13
80 percentile	0.04	0.04	16.00
95 percentile	0.53	0.05	21.10
99 percentile	1.23	0.05	24.22
Max	1.40	0.05	25.00
Toxicant DGV*	1.5	0.15	50

*Note: * No defined level of protection available (ANZG-sediment, 2018)*

BFD stores are replenished during the wet-season from moonsoonal rains (cf. Townsville rainwater $\bar{x}$ ±se: pH 6 ±0.1; Na 1 ± 4 mg/L, Cl 17 ±7 mg/L, from seawater) and released in the dry season for irrigation (Crosbie et al., 2012). Site 7-19 samples, taken below BFD, captures wet-season water stores from dam releases. This is evident in 7-19 water characteristics, where pH and electrical conductivity (EC) are influenced by wet-season rains ($\bar{x}$ ±se pH 7.4 ±0.01, EC: 193 ±1.1 µS/cm). Upstream (dry season) waters ($\bar{x}$ ±se pH 8.5 ±0.02, EC: 558 ±21.1 µS/cm) have higher

alkalinity/hardness and EC demonstrating differences between wet/dry waters. In the dry season, heavy metal re-mobilization from sugarcane areas has low environmental, economic and social risk; with one sample, TPb of 4.99 µg/L (2019), above DGVs of 4.4 µg/L (Table 2). Isotope tracing reveals that fertilizer signals remain low throughout the catchment, suggesting sustainble irrigtion practice and run-off control. The impact of fertilizer use in this study is likely minimized due to a delayed start to the wet season in 2019 and 2020 resulting in reduced rainfall run-off events. It is recommended that on-land investigations should be carried out to further inform on fertilizer rates.

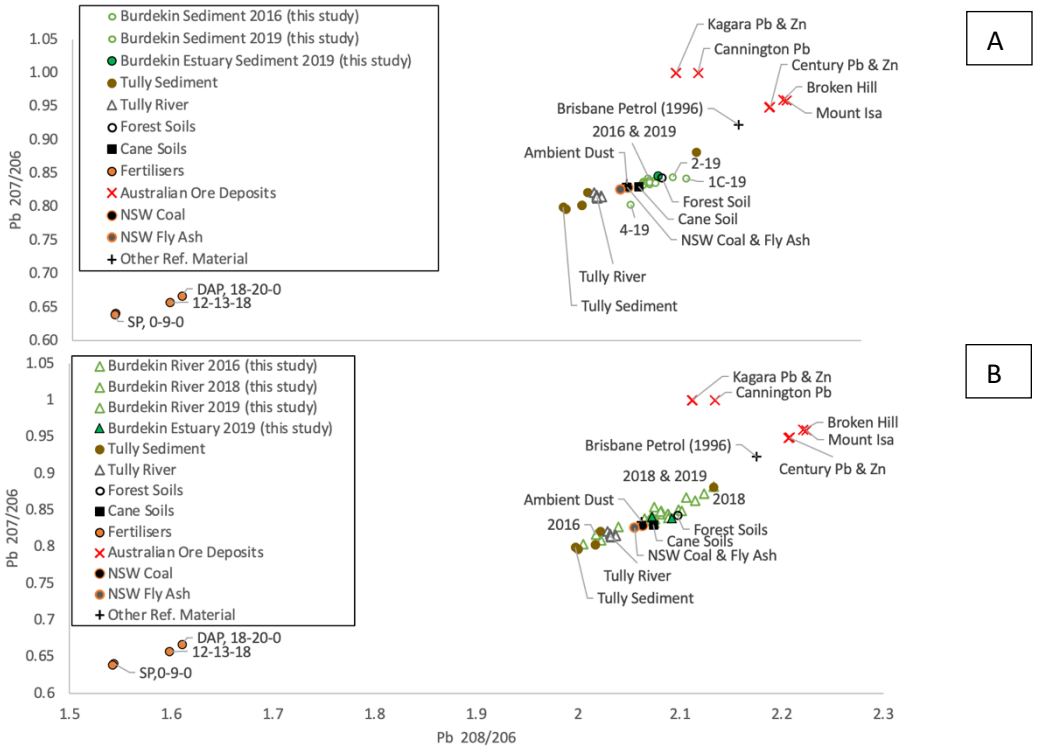

Fig. 2 Pb isotope ratios, $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$, suggest natural and anthropogenic sources (A) soil/sediment (2016 and 2019) and (B) water (2016, 2018 and 2019)

CONCLUSION

This study informed on baseline heavy metal concentrations and provides new insights of alternative anthropogenic sources impacting Burdekin River water quality (i.e. Collinsville Power Plant). Pb isotope tracing and elevated trace elements is effective at monitoring irrigation control. Fertilizer use has no impact on the Burdekin River in the dry season, suggesting low environmental, economic and social risk. Future land-based investigations could further inform on fertilization rates and impact.

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Research article

Enhancement of Carbon Fiber Electrode Performance using Lactic Acid Bacteria and Steelmaking Slag

NARONG TOUCH*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan
Email: nt207118@nodai.ac.jp

TADASHI HIBINO
Graduate School of Advanced Science and Engineering, Hiroshima University, Japan

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Abstract Microbial fuel cell technology (MFCT) provides many benefits to rural regions, such as organic waste disposal and renewable energy recovery. However, its performance is low and must be improved for practical uses. Mixing steelmaking slag (SS) and lactic acid bacteria (LAB) with sediment can enhance the MFCT performance owing to LAB and iron ions dissolved from SS attaching to the electrode surface. This study proposes a simple method for attaching LAB and iron ions on carbon fiber electrode and subsequently evaluating its performance. A carbon fiber electrode was placed in a bottle containing tap water, SS, LAB, and bamboo powder (as nutrients for bacteria) for 7 days to allow LAB and iron ions to adhere to its surface. The electrode was then used as the cathode of MFCT. Results showed a decrease in the electrode potential and a consequent reduction in MFCT performance owing to the attached LAB and iron ions. The performance improved after the electrode was oxidized, suggesting that aeration is required during attachment to prevent the decrease in electrode potential. After 1 month of electricity generation, the electrode with the attachment produced high electrical current and exhibited low decrease in MFCT performance owing to electricity generation. Therefore, attaching LAB and iron ions on the electrode surface can improve the electrode performance and prevent performance degradation owing to electricity generation.

Keywords microbial fuel cell, performance, electrode potential, attachment, steelmaking slag, lactic acid bacteria

INTRODUCTION

Microbial fuel cell technology (MFCT) offers many benefits for rural regions, particularly in developing countries. For example, this method can be used to treat agricultural wastewater, household sewage, and organic waste, provide electricity to households, and recycle resources to farmlands (Touch et al., 2020). However, the performance of MFCT remains low and must be improved for practical uses. MFCT efficiency depends on the cathode and anode. A low electrode performance will restrain the overall performance of MFCT. According to Yamasaki et al. (2018), various types of potential losses occur during electron flow to an electrode. One of which is activation loss that strongly influences electrode performance. Activation loss should be minimized via pretreating the electrode to obtain a high MFCT performance. Furthermore, this loss increases during electricity generation owing to the crystallization of ions present in water on the electrode surface. Thus, a method for minimizing the performance reduction owing to electricity generation is necessary.

Adsorption of bacteria or metal ions on the electrode surface is a method for improving the electrode performance. Wang et al. (2009) successfully enhanced electrode performance by activating the bacteria at the electrode and consequently reducing potential losses. The boosted electrode performance through bacterial attachment and biofilm formation has been widely studied using the cyclic voltammetry measurement (Carmona-Martinez et al., 2011; Kang et al., 2012).

Electrode performance can also be improved via coating a catalyst on the electrode surface. Many types of catalyst have been used in chemical reactions, such as iron ions. Nishimura, et al. (2018) reported that ferric ions dissolved from steelmaking slag (SS) improve sediment microbial fuel cell (SMFC) performance. Using SS and lactic acid bacteria (LAB) in the anode of SMFC can also enhance its performance (Touch et al., 2020). On this basis, the attachment of iron ions and LAB on the electrode surface can increase the electrode performance.

OBJECTIVE

This study proposed a simple method for attaching LAB and iron ions dissolved from SS on carbon fiber electrode. Changes in electrode potential and electricity generation (electrode performance) owing to the attachment were subsequently investigated via measuring the polarization (current-voltage relation) of electrode to determine changes in potential loss and examining the current to detect alterations in MFCT performance when the electrode is used as the cathode. The effects of the attachment on MFCT performance reduction owing to electricity generation were also discussed.

METHODOLOGY

Experimental Materials and Procedures

Dip-coating and electrodeposition are used to attach metal oxides on an electrode surface. For practicality, a simple attachment process should be considered. Iron ions dissolved from SS are adsorbed on the cathode of MFCT during long-term electricity generation (more than 6 months). This study focuses on how to attach iron ions dissolved from SS to a carbon fiber electrode in a short span (1 week).

Cylindrical bottles (120-mm inner diameter and 150-mm height) were filled with 500-mL tap water. Some bottles contained 20-mm depth of SS and 20-mL lactic fermenting beverage, as shown in Fig. 1. Bamboo powder (5 g) was then added to the bottles and reduced the solution pH because of its fermentation. This process facilitates the dissolution of iron from SS. Furthermore, nutrients from bamboo powder can activate LAB. Therefore, iron ions and LAB can attach to the electrode surface in a short span.

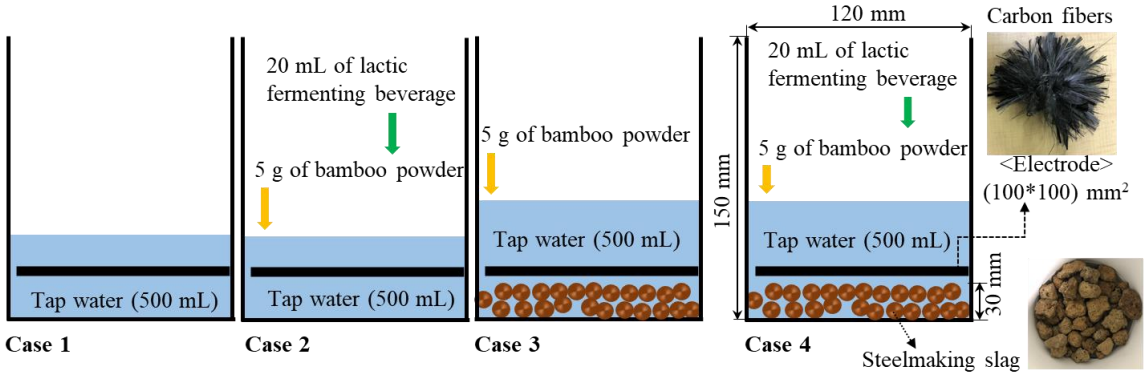


Fig. 1 Experimental devices and materials

The electrode material was carbon cloth (News Company, PL200-E), preheated at 500°C for 1 h to improve its performance (Nagatsu, et al. 2014). The heated carbon cloth with a 100-mm width and length was separated into fibers to form a brush-type electrode (photo in Fig. 1), which was then placed in the bottle for 7 days during bamboo powder fermentation.

Operations and Measurements

Experiments were conducted following the procedures in Fig. 2. The electrodes were placed in the solution for 7 days and then extracted from the bottle to measure their polarization using the circuit in Fig. 2a. In particular, the anode potential was fixed at −0.64 V to display a clear variation of the cathode (the electrode taken from the bottle) performance. An external resistance with 2.2 Ω–10 kΩ was loaded between the anode and cathode. Cell voltage was recorded 1 min after loading each external resistance and used to calculate the current according to the Ohm's law: $I = U/R_{ex}$, where U [V] is the voltage, I [A] is the current, and R_{ex} [Ω] is the external resistance. Power P was calculated according to $P = IU$. Current and power densities were obtained by dividing these values by the surface area of the electrode, i.e., 0.01 m^2.

After polarization measurements, the electrodes were placed in the bottle filled with tap water near the water surface for 7 days to examine the effects of oxidation on the electrode performance. The polarization of each electrode was remeasured after oxidation. The electrode was used as the cathode of SMFC (Fig. 2b) for 1-month electricity generation to examine its long-term performance. For electrical current generation, an external resistance of 2.2 Ω was loaded between the anode and cathode. Although different SMFCs were used for each case, the initial anode potential of each SMFC was the same order of magnitude.

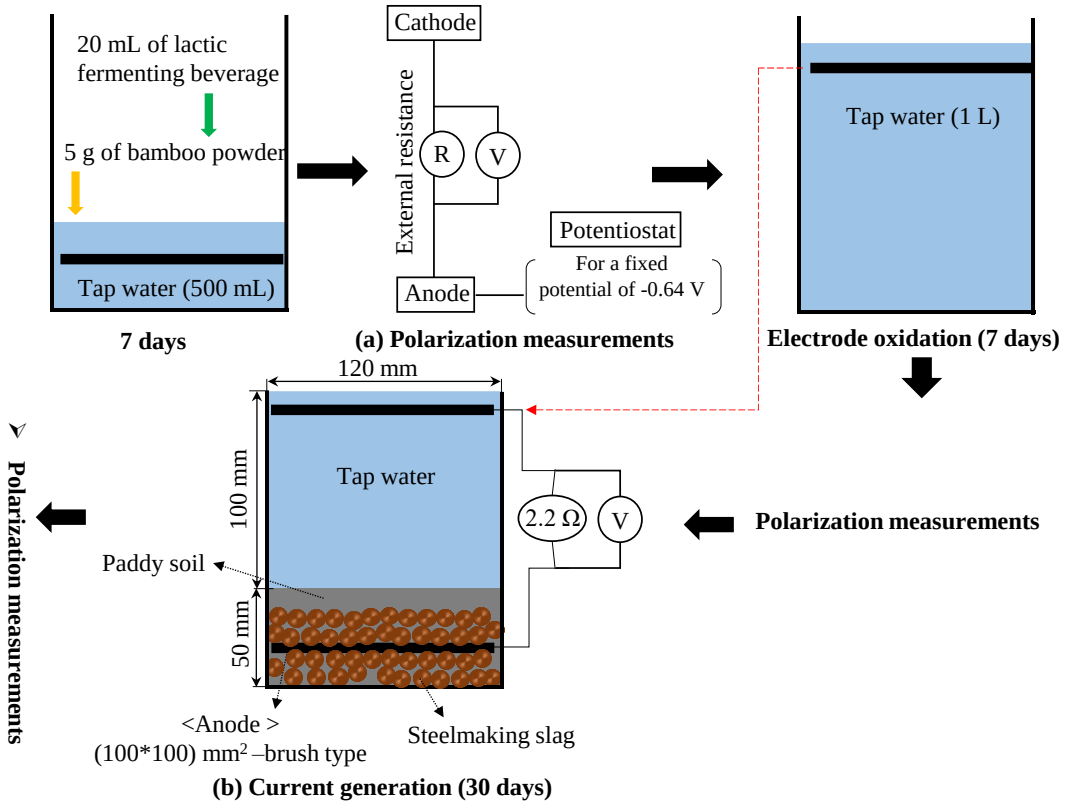


Fig. 2 Operations and measurement methods

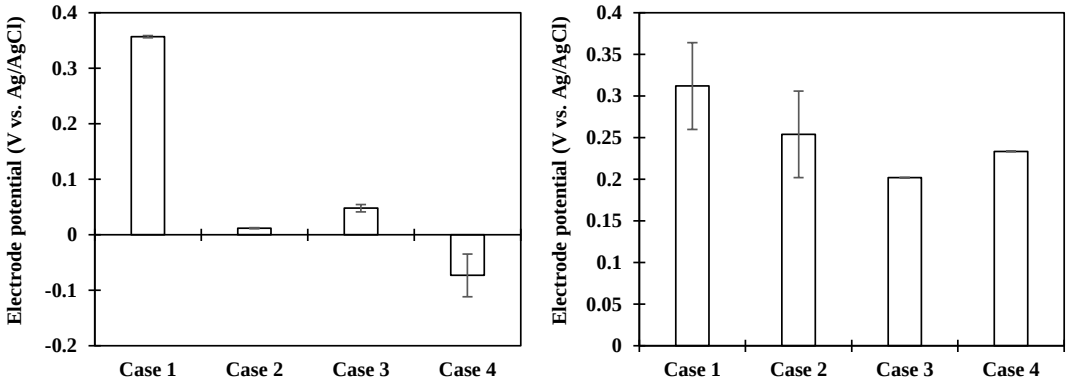
After electricity generation, polarization and exchange current density were measured to examine the effects of electricity generation on the electrode performance. Exchange current density is an index for evaluating activation losses at the electrode surface, that is, a high exchange current indicates a small potential loss, i.e., a high electrode performance. Exchange current density was determined using the method noted in the study by Nagatsu et al. (2014).

RESULTS AND DISCUSSION

Effects of LAB and Iron Ion Attachment on the Electrode Performance

After fermentation and when each electrode was place in tap water, the electrode potential was measured to examine the effects of LAB and iron ion attachment on the electrode performance. Comparison of electrode potential is shown in Fig. 3. The electrode potential largely decreased from 0.36 V (Case 1) to 0.01 V (Case 2) owing to LAB adsorption, to 0.06 V (Case 3) owing to iron ion adsorption, and to -0.11 V (Case 4) owing to LAB and iron ions adsorption (Fig. 3a). After the electrode was oxidized for 7 days (Fig. 3b), the electrode potential (Cases 2-4) largely increased (from 0.20 V to 0.25V).

These results indicate that the proposed method can attach LAB and iron ions dissolved from SS to the carbon fiber electrode. However, the attachment decreases the electrode potential. Consequently, the MFCT performance is reduced when the electrode is used immediately after the attachment. Given that electrode oxidation increases its potential, oxidizing the electrode with the attachment should be conducted before its usage in MFCT. Aeration should be performed during attachment to prevent the decrease in the electrode potential.

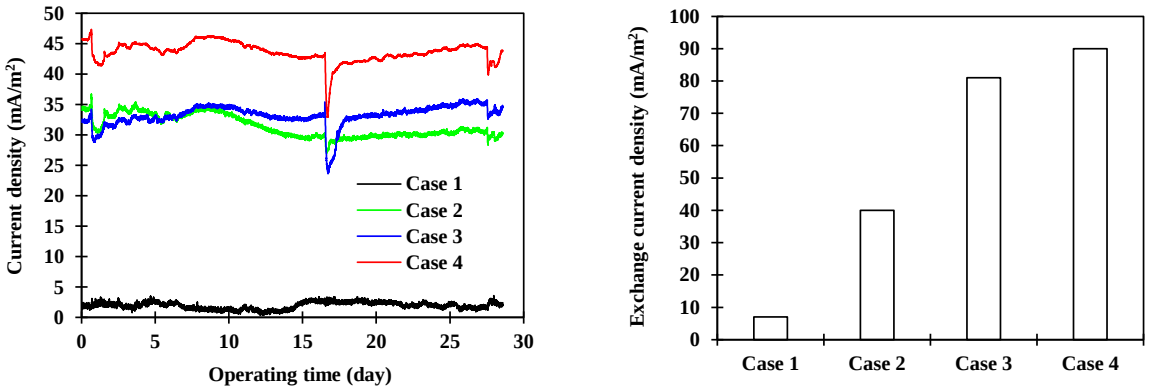


(a) after attachment (b) after electrode oxidation

Fig. 3 Comparison of electrode potential at different conditions

Changes in Electrode Performance Owing to the Attachment of LAB and Iron Ions

Fig. 4 compares of the electrode performance of each condition. The electrode without attachment (Case 1) produced only approximately 3 mA/m^2 of current density. Meanwhile, the electrode attached to either LAB (Case 2) or iron ions (Case 3) generated 30–35 mA/m^2, a 10-fold increases (Fig. 4a). These results indicate the improved electrode performance can be attributed to the adsorption of LAB or iron ions on the electrode surface. A further increase in current density was also observed when LAB and iron ions were attached to the electrode (Fig. 4a, Case 4). Therefore, irons ions aid LAB to transfer electrons to electrode.



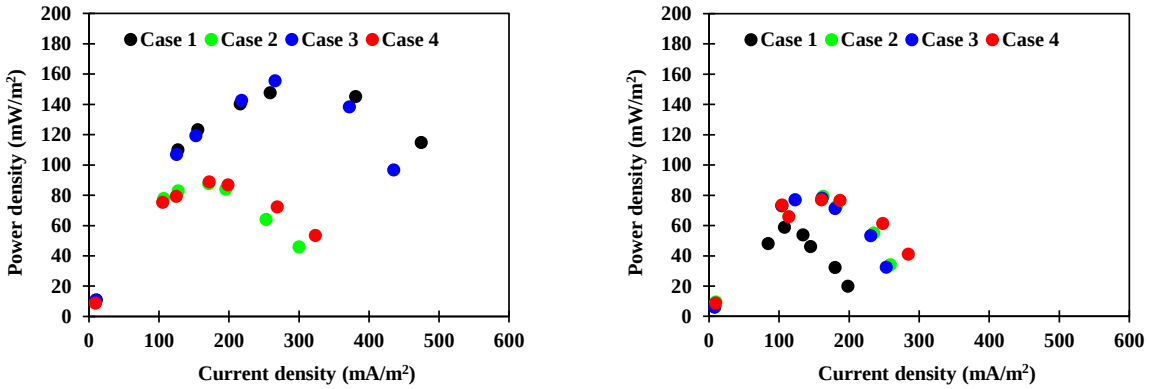
(a) temporal change of current density (b) exchange current density after current generation

Fig. 4 Comparison of the electrode performance of each condition

The exchange current density of each case was compared in Fig. 4b. As shown in Fig. 4b, the exchange current density increased after the attachment of either LAB or iron ions on the electrode surface. This finding indicates that the potential loss at the electrode surface is reduced owing to the attachment, i.e., electrons are easily transferred to electrode via LAB or iron ions. In addition, the exchange current density of the electrode with iron ions attached (Case 3) was 80 mA/m^2 which was two-fold higher than that of the electrode with attached LAB (Case 2, 40 mA/m^2). Iron ion attachment provides a better performance than LAB attachment. However, the combination of LAB and iron ions exhibits a higher performance than the use of each component alone.

Reducing the Performance Decrease Owing to Electricity Generation by LAB and Iron ions

Figures 5a and 5b depict the comparison of performance (current and power density relationship) for electrodes with and without electricity generation. Power density and current density decreased owing to electricity generation. In the experiments, crystallized compounds were observed on the electrode surface and can contribute to the decrease in performance.



(a) without electricity generation (b) with electricity generation

Fig. 5 Comparison of performance for electrodes with and without electricity generation

An 80-mW/m^2 reduction in power density was observed for the electrode without attachment (Case 1) and 70-mW/m^2 reduction for the electrode with iron ion attachment (Case 3). Only 12-mW/m^2 reduction in power density was observed when LAB attached to the electrode surface with and without iron ions (Cases 2 and 4). Therefore, LAB attachment on electrode surface effectively improves the reduced performance owing to electricity generation. Crystallization cannot occur on the electrode surface with LAB.

CONCLUSIONS

Laboratory experiments were conducted to verify the efficiency of the proposed simple method for attaching LAB and iron ions on a carbon fiber-electrode and to examine the effects of attachment on the electrode performance. Approximately 300-mV reduction in electrode potential was observed owing to the attachment. Nevertheless, the electrode potential recovered almost to the initial state after oxidizing the electrode by placing it in tap water near the water surface for 7 days. Thus, aeration should be conducted during attachment to prevent the decrease in the electrode potential. A 10-fold increase in current density was observed for the electrode attached with either LAB or iron ions. A high increase in current density was obtained when LAB and iron ions were attached to the electrode. On the basis of the increase in exchange current density owing to the attachment, the potential loss at the electrode surface is reduced owing to the attachment, i.e., electrons are easily transferred to electrode via LAB or iron ions. Finally, the performance decrease owing to electricity generation was largely (88%) reduced for the electrode attached to LAB. Therefore, the attachment of LAB on the electrode surface can restrain the formation of crystallized compounds.

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Research article

Characteristics of Ion Components of Clearwater Stream Watershed in an Agricultural Area with Multivariate Analysis

YURI YAMAZAKI*
Tokyo University of Agriculture, Tokyo, Japan
Email: yy206792@nodai.ac.jp

TOSHIMI MUNEOKA
Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan

CHIE MATSUDA
Zukosha Co., Ltd., Hokkaido, Japan

MASATO KIMURA
Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan

OSAMU TSUJI
Zukosha Co., Ltd. / Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan

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Abstract Restoring the clear-stream environment that once existed in agricultural areas is one of the major challenges for the development of sustainable agriculture. Therefore, we analyzed the ionic components of the Rekifune and Satsunai River basins, which are regarded as clear-water basins in the Tokachi region of Hokkaido, using principal component analysis and cluster analysis based on surveys conducted in June and September 2014. The results showed that most of the sampling points in the Rekifune and Satsunai drainages were comparable to the average values of water quality assessed as clear-streams in Japan. However, in the tributaries of the Rekifune River, since Cl^- and Na^+ increased characteristically, the water quality was degraded by anthropogenic pollution sources such as domestic wastewater. In the Satsunai River, the water quality of the downstream tributaries was degraded due to agriculture. In addition, in one of the tributaries, deterioration of water quality was observed only in September, and the water quality of the main river immediately after the inflow of this tributary was also affected. These results indicate that the water quality in the two basins in the predominantly agricultural area is generally good. Still, it is necessary to identify the source of pollution in some areas and take countermeasures.

Keywords river water quality, agricultural area, principal component analysis, cluster analysis

INTRODUCTION

Historically, rivers flowing through rural areas in Japan had clear water and were home to various aquatic life. However, modern agricultural land-use changes and river alterations have resulted in the disappearance of the 'clear water' environment in rural areas. This water pollution caused by modern agriculture has become a global problem. We now understand the need to conserve intact rivers in agricultural areas and restore altered river ecosystems to meet the global challenge of more sustainable agriculture.

The term “clearwater stream” generally refers to uncontaminated rivers-however, no scientific definition in Japan. For example, the Japanese government publicizes river rankings based on water quality measurements, particularly biochemical oxygen demand (BOD). Therefore, any river ranked highly in the river-ranking program is defined as a clearwater stream. Also, rivers selected as “100 clearest streams in Japan” by the Ministry of the Environment are evaluated as clearwater streams.

The Tokachi region of Japan, which has an essential role in Japan’s food supply, has two clearwater streams: the Rekifune and Satsunai rivers. Both had been ranked high in the government's river-ranking program in prior years, and both had low BOD values. In a questionnaire provided to Hokkaido residents to rank clearwater streams, the Rekifune River ranked second, and the Satsunai River ranked 5th place (Shimatani et al., 1996). Therefore, it is clear that both rivers are recognized as being clearwater streams in Hokkaido. However, ever since large-scale agriculture commenced in the watershed of the Rekifune and Satsunai drainage basins, water pollution caused by these agricultural activities has become a concern. In 2008, for example, water quality studies of the Rekifune and Satsunai rivers had shown elevated nitrogen concentrations in river water caused by agricultural runoff (Yamazaki et al., 2017).

OBJECTIVE

This study evaluated ion components of river water and all water quality factors using multivariate analysis in clear stream watersheds at a large agricultural area to develop guidelines for preserving river environments.

MATERIALS AND METHODOLOGY

Study Sites

This investigation examined two clearwater stream drainages in the Tokachi region in eastern Hokkaido, Japan: the Rekifune and Satsunai drainages. Both rivers supply irrigation and tap water to the residents in the Tokachi region. Also, the Rekifune and Satsunai watersheds are geographically adjacent to one another in their headwaters. The catchment areas are similar, and the primary land use of the region is agriculture and forest.

The primary land use in the Satsunai drainage is agricultural cropland (30% of total area), including wheat, potato, sugar beet, and beans. Both chemical and organic fertilizers (livestock manure) are applied to croplands. In the Rekifune drainage, pasture and forage crops are produced, constituting 17% of the total land area.

Water Quality Investigation

We selected fourteen water quality sampling stations in the Rekifune drainage and 21 points in the Satsunai drainage; these stations were sampled once per month in June and September 2014 during normal water levels; a total of 42 and 63 samples were collected from the Rekifune and Satsunai River drainages respectively (Fig. 1). The sampling points were located on the main stems (Stations A-F on the Rekifune River and Stations 1-11 on the Satsunai River) and downstream along tributaries (Stations G–N on the Rekifune River and Stations 12-21 on Satsunai River).

Electrical conductivity and water temperature were measured using a digital conductivity meter (DKK TOA Corporation; 592896; Japan). We analyzed the following ion components in each sample: Cl^{-}, NO_3^{-}, NO^{2-}, SO_4^{2-}, Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+} using liquid chromatography.

Multivariate Aalysis

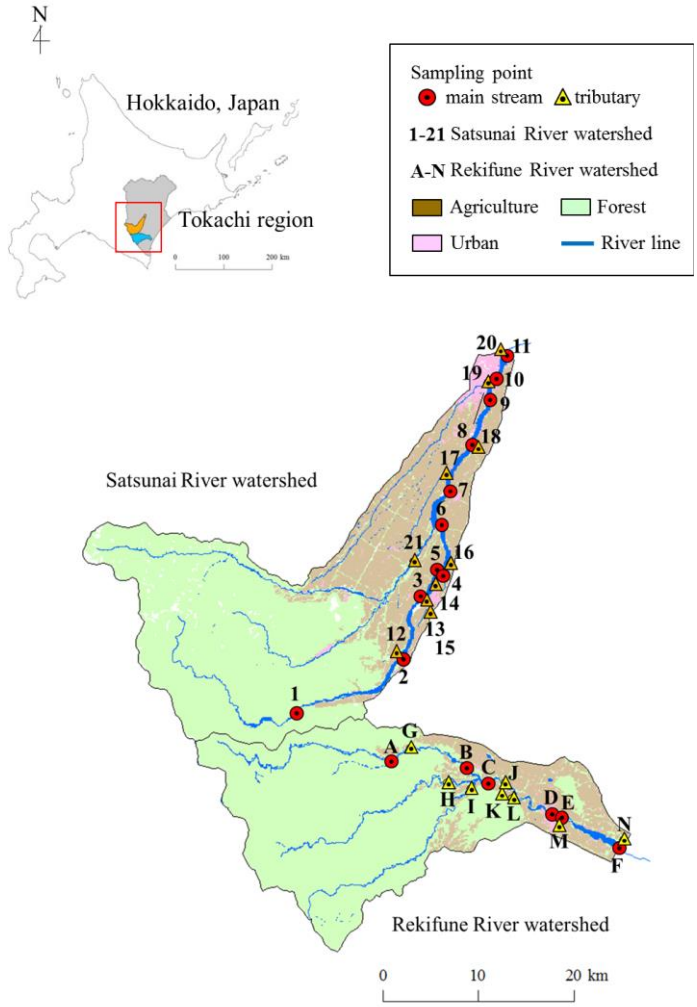

Fig. 1 Land use and sampling stations of the Rekifune and Satsunai River drainages

We used the R package (R Foundation for Statistical Computing; Ver. 3.0.3; Austria) for cluster and principal component analyses. The ion components (Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, Ca^{2+}, and Mg^{2+}) were used as input variables. Cluster analysis and principal component analysis are both types of multivariate techniques. We applied Ward's method to the cluster analysis. Principal component analysis (PCA) was derived using the "princomp" algorithm of the R package.

RESULTS AND DISCUSSION

Cluster Aalysis and Pincipal Cmponent Aalysis of the Rver Water Qality

Cluster and principal component analysis using correlation matrix were carried out for seven variables: ion concentrations (Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, Ca^{2+}, and Mg^{2+}) at 35 sampling stations in the Rekifune and Satsunai drainages. We compared water quality between the mean ion concentration of river water and groundwater from "100 clearest streams in Japan" of 1985 and 2008 (Yabuzaki et al., 2009) as a reference. These analyses were performed for the July and September observations in the Rekifune and Sastunai drainages, respectively.

Table 1 shows the cluster analysis results and PCA score of PC1 and PC2 of the July and the September observations, respectively. First, the "100 clearest streams in Japan" of 1985 and 2008 were classified as Cluster1 and Cluster2, respectively, in the July observation data. Also, twenty-eight sampling stations (11 stations of the Rekifune and 17 stations in the Satsunai) were classified

into Cluster1 and Cluster2. Therefore, most of the main stems and the tributaries of the Rekifune and the Satsunai drainages have the same level of water quality concentration as the “100 clearest streams in Japan”. However, three tributaries of the Rekifune and four of Satsunai drainages, classified as Cluster3 to Cluster5, show a different trend from the “100 clearest streams in Japan”.

Next, in the September observation data, the “100 clearest streams in Japan” of 1985 and 2008 were classified as Cluster1. Also, twenty-four sampling stations (11 stations of the Rekifune and 13 stations in the Satsunai) were classified into Cluster1. The results of the Rekifune River were like those of the July cluster analysis, while the Satsunai River showed a different trend. Particularly, Stations 5 and 14 in the Satsunai River were classified as Cluster5.

Table 1 Results of cluster analysis and PCA score

ID	June			September			ID	June			September		
	PC1	PC2	Cluster ID	PC1	PC2	Cluster ID		PC1	PC2	Cluster ID	PC1	PC2	Cluster ID
1985	-0.53	0.07	Cluster 1	-0.77	0.21	Cluster 1	1	-1.81	0.22	Cluster 1	-1.98	0.21	Cluster 1
2008	0.37	-0.54	Cluster 2	0.04	-0.30	Cluster 1	2	-1.73	0.23	Cluster 1	-1.83	0.17	Cluster 1
							3	-1.37	0.20	Cluster 1	-1.40	0.04	Cluster 1
A	-1.56	0.15	Cluster 1	-1.69	0.07	Cluster 1	4	-1.36	0.22	Cluster 1	-1.44	0.04	Cluster 1
B	-1.12	-0.02	Cluster 1	-1.37	-0.08	Cluster 1	5	-1.07	0.30	Cluster 1	3.99	0.79	Clsuter 5
C	-1.15	0.04	Cluster 1	-1.39	0.02	Cluster 1	6	-1.17	0.33	Cluster 1	-0.75	0.27	Cluster 1
D	-0.91	-0.01	Cluster 1	-1.17	-0.05	Cluster 1	7	-0.93	0.09	Cluster 1	-0.99	0.01	Cluster 1
E	-0.87	0.00	Cluster 1	-1.17	-0.05	Cluster 1	8	-0.78	0.03	Cluster 1	-0.76	-0.13	Cluster 1
F	-0.68	0.05	Cluster 1	-0.96	-0.01	Cluster 1	9	-0.60	-0.02	Cluster 1	-0.72	-0.14	Cluster 1
G	-0.71	-0.26	Cluster 1	-1.18	-0.09	Cluster 1	10	-0.61	0.01	Cluster 1	-0.72	-0.13	Cluster 1
H	-1.32	0.11	Cluster 1	-1.52	0.04	Cluster 1	11	-0.35	-0.10	Cluster 1	-0.36	-0.26	Cluster 1
I	-1.31	0.09	Cluster 1	-1.56	0.15	Cluster 1	12	-1.01	0.07	Cluster 1	-1.36	0.17	Cluster 1
J	0.84	-0.56	Clsuter 4	0.86	-0.17	Clsuter 3	13	-0.95	0.02	Cluster 1	-0.40	-0.38	Clsuter 3
K	0.80	-0.63	Cluster 2	-0.08	-0.13	Cluster 1	14	-0.63	0.51	Cluster 1	5.86	1.44	Clsuter 5
L	0.11	-0.48	Cluster 2	-0.59	-0.08	Cluster 1	15	-1.44	0.23	Cluster 1	-1.51	0.04	Cluster 1
M	5.51	8.13	Cluster 5	3.15	5.73	Cluster 4	16	-0.28	0.05	Cluster 1	-0.34	-0.24	Clsuter 3
N	2.37	-1.14	Clsuter 4	2.10	-0.72	Clsuter 3	17	-0.90	-0.17	Cluster 1	-1.29	-0.03	Cluster 1
							18	5.74	-3.57	Cluster 3	4.54	-2.92	Cluster 2
							19	3.80	-1.49	Cluster 3	3.20	-1.51	Cluster 2
							20	5.41	-2.14	Cluster 3	4.49	-1.99	Cluster 2
							21	2.19	-0.02	Clsuter 4	1.08	0.03	Clsuter 3

Fig. 2 shows the eigenvector of PC1 and PC2, also Fig. 3 shows the results of the principal component analysis, color-coded into clusters 1 to 5 as described above. The x-axis is the first principal component (PC1), and the y-axis is the second principal component (PC2).

The cumulative contribution of the principal component analysis was 95% and 82% from the first to the second principal components in July and September observations, respectively, indicating that the characteristics of river water quality in the Rekifune and Satsunai River drainages can be summarized by two principal components. The eigenvectors of the first and second principal components showed a similar trend in both July and September. First, the eigenvectors of PC1 were positive for all items. PC1 indicates the overall characteristics of the river water quality, and the larger the positive value of PC1 is, the worse the river water quality is. The eigenvectors of PC2 showed positive values for Cl^-, Na^+, and K^+, and negative values for NO_3^-, SO_4^{2-}, Ca^{2+}, and Mg^{2+}. The negative values of PC2 indicate that the components are contained in fertilizer, so it can be inferred that when PC2 is large with negative values, the influence of agriculture is significant. On the other hand, for the item with a positive PC2, the increase in Cl^-, and Na^+ concentrations in river water due to the inflow of domestic wastewater was reported in the suburbs of urban areas (Taniguchi et al., 2004; Hirata et al., 1999), which may reflect anthropogenic influences other than agriculture.

Cluster1 and Cluster2 in July, and Cluster1 in September, show the range of -1.9 to 0.8 for PC1 and the content of -0.6 to 0.5 for PC2. The main stems and most of the tributaries of the Rekifune and Satsunai Rivers are comparable to those of the “100 clearest streams in Japan”.

On the other hand, the three sites in the tributaries of the Satsunai River, classified as Cluster3 in July and Cluster2 in September, showed positively large values of PC1 and negative values of PC2 in both July and September. The tributaries located in the lower reaches of the Satsunai River

are affected by agriculture. Although the water quality is worse than "100 clearest streams in Japan", it does not significantly affect the water quality of the main river of the Satsunai River.

In addition, Cluster4 in July and Cluster3 in September have a larger PC1 than the "100 clearest streams in Japan". Therefore, the water quality tends to deteriorate, although not as markedly as the tributaries in the lower reaches of the Satsunai River.

One tributary station of the Rekifune River, classified as Cluster5 in July and Cluster4 in September, showed large positive results for both PC1 and PC2. The water quality at station M of the Rekifune River is degraded by anthropogenic influences other than agricultural influences in the period of July to September at least.

Finally, one station in the main stem of the Satsunai River and one station in a tributary classified as Cluster 5 in September were both classified as Cluster 1 in July, and the river water quality in July was good. However, in September, PC1 became larger with positive values, and the water quality deteriorated. On the other hand, PC2 is positive, ranging from 0.8 to 1.4. Therefore, although it is not as pronounced as station M in the Rekifune River, it is considered that the river is affected by anthropogenic factors other than agriculture only in September. Since station 5 of the main stem of the Satsunai River is just after the inflow of the tributary of station14, it is considered that there is a pollution source around station 14, which deteriorates the river water quality of the main stem around station5.

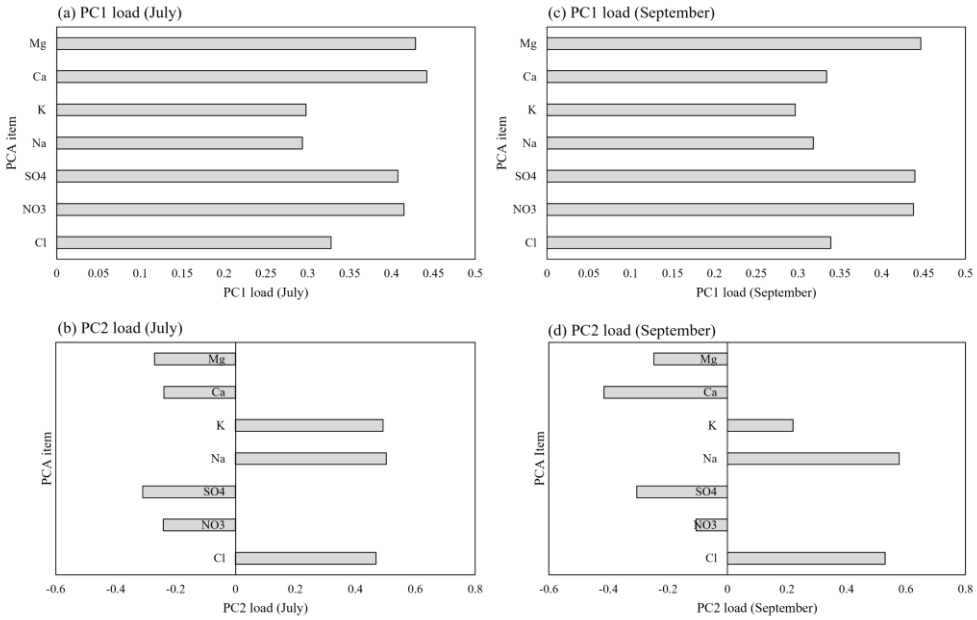

Fig. 2 Eigenvector of PC1 and PC2

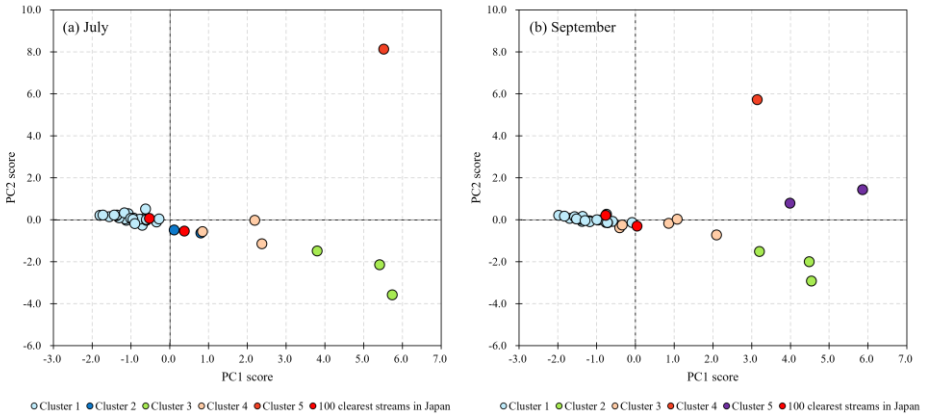

Fig. 3 Relationships between PC1 and PC2

CONCLUSION

In this study, we investigated the water quality of the Rekifune and the Satsunai drainages, which are in a large agricultural area and are regarded as clear streams. We compared them with the "100 clearest streams in Japan" results using multivariate analysis. As a result, the water quality of both rivers is comparable to that of the “100 clearest streams in Japan” and can be evaluated as a good water quality environment. However, the Rekifune River deteriorated at one station due to anthropogenic influences such as domestic wastewater. Furthermore, there is a concern about pollution sources operating at different times in the Satsunai River. Although the effects of these pollution sources have not had a significant impact on the main rivers of both the Rekifune and the Satsunai Rivers, it is necessary to identify these pollution sources and take measures to ensure sustainable conservation in the future.

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Research article

Evaluating Ion Exchange Capacity of Molten Slag for Hydroponic System

ANTONIO PEREZ FUENTES
Graduate School of Agro-Environmental Science, Tokyo University of Agriculture, Tokyo, Japan

SARVESH MASKEY
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

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

YURI YAMAZAKI
Faculty of Agriculture, Tottori University, Tottori, Japan

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

TOSHIMITSU ASAI
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

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Abstract Hydroponic farming promotes high-efficiency water, fertilizers, and high productivity under a controlled environment. However, the use of this system needs consistent application of fertilizers, increasing the cost of operations. Molten Slag (MS), a waste from the Municipal Solid Waste Incineration has essential nutrients that can be used as fertilizer. The objective of this study was to clarify the releasing process of nutrients by molten slag to be applied as a substrate in hydroponic system. For this, anion and cation contents of three varieties of Molten Slag (MS1, MS2, MS3) were determined in the laboratory by a shaking method. The nutrient content, P_2O_5, K_2O, MgO and CaO were in MS1, MS3 and MS2. The quantification ion released was performed at 1, 6, 12 and 24 hours. It was observed that MS3 had performed the best condition in the releasing process of K^+, Mg^+, SO_4^{2-} and Cl^-. Although MS1 had higher nutrient content, MS3 released higher contents of those minerals among the samples. According to the result of this study, it was confirmed that MS3 has a high potential for hydroponic farming.

Keywords molten slag, hydroponic system, ion exchange capacity, releasing nutrients

INTRODUCTION

Around 200 billion tons of fertilizers are produced annually for agricultural purposes (FAOSTAT, 2021). The use of these fertilizers and water supply tends to increase to provide food safety for 9 million people toward 2050. The benefit of fertilizers in agricultural production is remarkable since it improves yields and keeps fertile soil. On the other hand, the constant use of fertilizers not only increase the costs but hazard the ecological balance with releasing of greenhouse gases and eutrophication to water bodies (Sedlacek et al., 2020).

Molten Slag (MS) is a by-product of the Municipal Solid Waste Incineration -MSWI- process (Fig. 1). The process to generate molten slag starts with the addition of wastes inside a furnace, this waste can be paper, plastic, glass, steel, aluminum, food waste/raw garbage, waste oil, among others. After burning most of the organic wastes, the residues are separated as ferrous materials (aluminum, steel, incombustibles), vitreous material and molten slag. The gas generated in those

furnaces goes through a chamber for purification and generation of energy, and the fly ash is also collected for future processing. The composition of molten slag varies according to the diverse wastes in every municipality and the type of furnace in which they are processed (Czop and Łaz´niewska-Piekarczyk, 2020). Molten slag shares similarities to the slag generated by the iron and steelmaking process, and they have been tested for correct use as a cement aggregate, road building and for soil correction (Dubey et al., 2019; Zeng et al., 2020; Devnita et al., 2021). Altland, et al. (2015) described the possibility of up taking micro-nutrients from these types of slag and the spontaneous vegetation in landfills where molten slag is storage (Gomes et al., 2016) opens to discussion if the contents of Ca, K, Mg, and Na, from molten slag can be a good source of nutrients for plants. Molten slag collected from MSWI has not been used in agriculture and recent studies (Kobayashi et al., 2004; Sekito et al., 2014) found that there was not leaching of heavy metals in several samples analyzed. As the generation of wastes increases around the world, this study reveals the possibility to release beneficial ions to assess the growth of crops with this material.

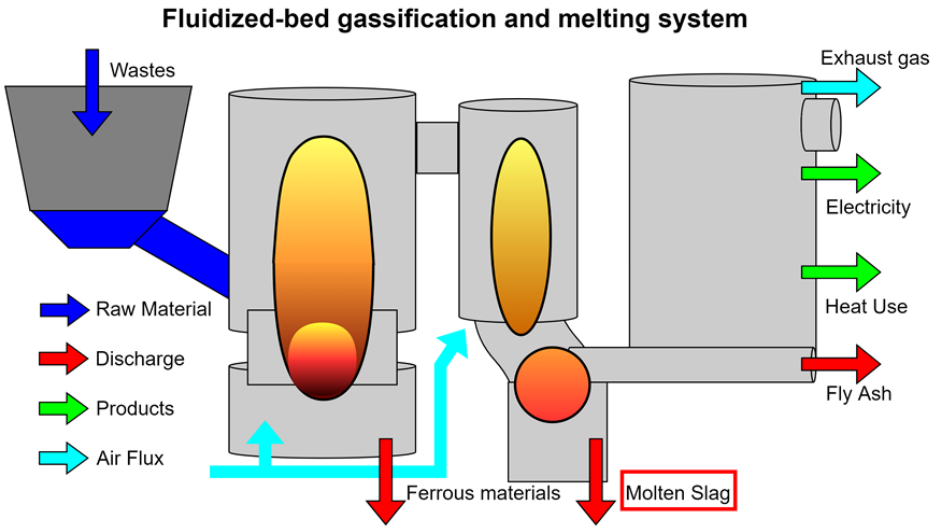

Fig. 1 Municipal solid waste incineration process

OBJECTIVE

The objective of this study was to quantify and record the releasing process of nutrients released and retained by three types of molten slag from the Kanto region in Japan and estimate the availability of those nutrients for crop production under hydroponic conditions.

METHODOLOGY

We collected three types of molten slag from Kofu (MS1), Kamiina (MS2) and Nishi-Akikawa (MS3), the dried content of CaO, MgO, K_2O and P_2O_5 was determined in principle, then the analysis of releasing those minerals was carried out. First, we prepared 10 g of every sample inside a bottle with 50 mL of Ultra-Pure Water and two replicates. The samples were shaken at 180 rpm for 1, 6, 12 and 24 hours. Electrical conductivity (EC), pH and anion/cation contents were measured. Anion and cation contents in the water samples, which were filtered by membrane filter with a diameter of 0.45 μm, were measured by a spectrometric method using Ion analyzer (IA-300, HORIBA). Only seven ions were involved in the discussion, considering plant growth, and the concentration is given in mg/L. ANOVA and T-test were applied to find any significant difference among the samples.

RESULTS AND DISCUSSION

Chemical Properties of Molten Slag

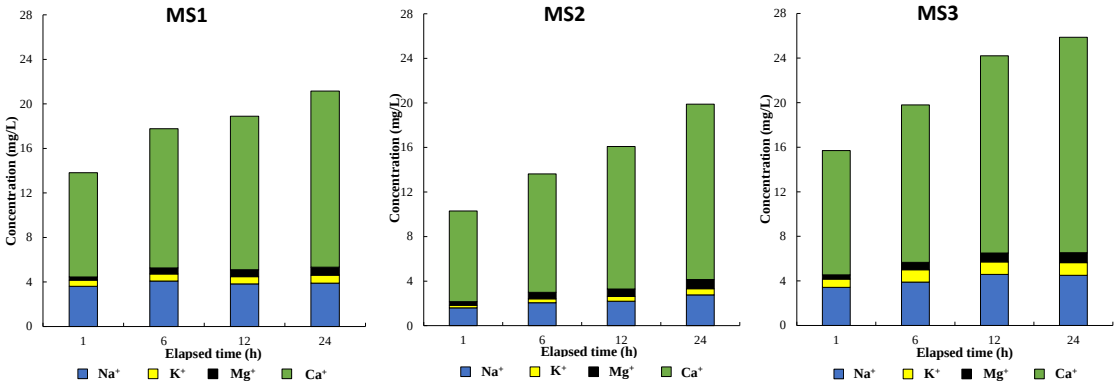

Fig. 2 Amount of cation released by every type of slag along 1, 6, 12 and 24 hours of shaking treatment

Table 1 Chemical properties of three varieties of molten slag

	Per Wind Dried Material				Per Dried Material								
	pH	EC	CEC	Bulk density	NH_4-N	Inorg. N	P_2O_5	K_2O	MgO	CaO	Zn	Cu	Fe
Units		mS/cm	meq/100g	kg/m^3	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g	mg/kg	mg/kg	mg/kg
MS1	7.17	0.04	ND	1.58	0.6	0.6	21	2.6	8.6	142	48	208	34.7
MS2	7.78	0.04	ND	1.59	0.9	0.9	12	1.6	6.2	42	34	106	12.9
MS3	7.84	0.06	0.1	1.51	0.6	0.6	7	2.2	5.3	103	102	182	40.7

Obtained by dry method in Katakura Co Op Agri Labs *ND: Not Detected*

MS1 has higher content of P_2O_5, K_2O, MgO, CaO, and Cu as shown in Table 1. On the other hand, MS2 has the lowest nutrient content in all aspects, except for P_2O_5 and MgO, including the highest density.

Releasing of Cations by Molten Slag

During the test, pH values did not raise levels higher than nine, but this value is still considered high for crop development. It was expected that MS1 would have the largest EC due to the significant amounts of CaO, MgO and K_2O, however, after 24 hours none of those ions tend to increase in this material. The leachate of calcium explains the peak values observed at 6 hours of shaking into the water, producing carbonation's reaction (Huntzinger et al., 2009).

K^+ plays a significant role in many synthetic, physiological and biochemical processes in plants. This element is present in the soil in low concentrations, from 0.2% to 3.3% of the total soil mass (Barker and Pilbeam 2015). Although a low value of K^+ was found in this releasing process of molten slag, the concentrations in the dried material are acceptable. The range goes from 0.0011 to 0.0028 mg/g in MS2 and from 0.0037 to 0.0057 mg/g in MS3. At least 16%, 21% and 31% were released from the MS1, MS2 and MS3, respectively. MS3 is the most suitable supplying more K^+ into the water.

Even though MS1 has more significant amounts of MgO than MS3, it was observed that the percentage of Mg^+ released by MS1 is lower compared to MS3, producing almost the double amount of Mg^+ released in the same period. In comparison, MS2 has around 0.062 mg/g and released 0.0068 mg/g. It is only about 10% of MgO.

For the efficient process to obtain better gas in the incineration process, calcium oxide is added to clean the impurities (Zheng et al., 2018), this component remains in the slag and becomes the most abundant next to the silicates. MS1 was the material with the highest content in many

compounds, having values of Ca^{2+} superior to 1.4 mg/g; moreover, after 24 hours in the shaking process, it was determined that the values of the Ca^{2+} released are still low compared to 26% released from the MS2. Calcium is not an essential nutrient for plants, but it is a requirement. An excessive amount of Ca^{2+} can result in plants toxicity. Plants can allocate around 100 mg/g per dry matter (Römheld, 2012; White and Brown, 2010). When the delivery of Ca^{2+} to the soil exceeds the plant's uptake capacity, there is a risk of accumulation of Ca^{2+} at the surface of the roots and most of the time to the precipitation as $CaCO_3$, $CaSO_4$, or Ca oxalate in rhizocylinders around the roots induced by P deficiency (Newman and Römheld, 1998; Marschner and Rengel, 2012). Ca^{2+} released by MS3 ranges between 7.5 and 13%, meanwhile in MS1 and MS2, it goes from 4.6 to 7.7% and from 13.5 until 26%, respectively.

The primary function of Na^+ seems to be to maintain osmolality in the plant tissues of the halophyte seepweed under NaCl conditions (Mori et al., 2010). However, Na^+ is not considered a nutrient for most plant species. Subbarao et al. (1999) showed that it could be a substitute for potassium in *Beta sp*. to a large extent and, it has been accepted as a micronutrient in some C4 plants that require Na^+ for cotransport. Although Na^+ values were not obtained in the dried content analysis of the samples, it was observed that there was a leaching of sodium along with the shaking test, there was not a variation among the shaking period, but there is a significant difference among the three samples. Assuming that the contents of sodium in MS2 are also lower than the following two samples as occur for the minerals, this is the reason why this sample had the lowest trend, as observed in Fig. 2. High Na/Ca ratios may lead to a deficiency of Ca^{2+} in Sodic or saline soils due to the excess of Na^+ in the soils (White, 2015) that's why it is important to consider that ratios of Na/Ca are also balanced. The ratio of Na/Ca of Molten slag goes from 0.03 to 0.05 in all the samples with contents from 0.020 mg/g in MS1, 0.011 mg/g in MS2 and 0.022 mg/g in MS3.

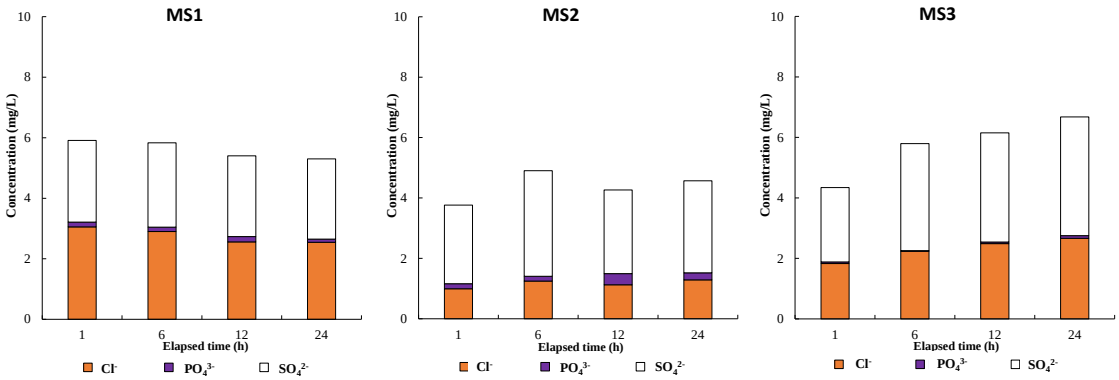

Fig. 3 Anion released by every type of slag along 1, 6, 12 and 24 hours

Anion Concentration

From the three samples analyzed in this study, only MS2 showed a small fraction of PO_4^{2-} released; it is possible to say that 0.3 mg of PO_4^{2-} are available in the water to be taken by the plants from this material. The range of PO_4^{2-} in MS2 goes from 0.0008 mg/g to 0.0018 and finally to 0.0012 mg along the treatment. Only MS2 could perform this condition from the three samples since MS1 and MS3 didn't show great changes during the same period.

SO_4^{2-} is an important nutrient that acts as a major structural component of proteins, also participates in several processes like photosynthesis, N_2 fixation, chlorophyll production, and catalytic activities of many enzymes (Mills and Jones, 1996; Hawkesford, 2010). An unbalanced application of N fertilizers with low or lack of sulfur can indicate the plant's sulfur deficiency. In principle, the samples of molten slag released around 0.013 mg/g of SO_4^{2-} at the first hour, but after 24 hours, it was only MS3 which increased to 0.019 mg/g. Since the molten slag can't provide nitrogen such as NH_4^+ or NO_3^-, the sufficiency of sulfates in agricultural systems will be directly related to the content from an external nitrogen source. Although molten slag can provide few SO_4^{2-} to crops systems, this quantity is not enough to accomplish the plant requirements.

Cl^- concentrations up to 500 mg/L have been supplied in sweet onion and demonstrated that the requirement of chlorides is only exceeded by N, P and K (Randle, 2005). Furthermore, the concentration observed in the releasing process from the three types of molten slag doesn't exceed more than 3 mg/L by 200 g of MS. Therefore, this amount of Cl^- found doesn't represent a hazard for crop growth but enriches the micronutrients uptake by plants in the water content.

It was observed that MS1 is the material with the highest content of nutrients per dried soil. This condition does not guarantee that the releasing amounts of nutrients from molten slag is related to the mineral content in every type. Although MS2 does not have great amounts of nutrients, it was observed that EC increased due to high amounts of Ca^{2+} released.

CONCLUSION

In this study, three varieties of molten slag under releasing treatment of nutrients for crop system proved a remarkable difference among the quantities of nutrients released by every type of slag analyzed. MS3 had performed the highest amounts of nutrients released by g of sample, finding that the percentage of K^+ available for plants is higher in MS3 than MS1 and MS2. Even when the content of Ca^{2+} is lower in MS2, the final concentration in the water was higher than the following two samples, which can increase pH levels due to the chemical reactions of Ca^{2+} when it contacts water. It was indeed MS3 that released more Mg^+ ions into the water and SO_4^{2-} that can make a difference in plant nutrition. Certainly, PO_4^{2-} is one of the major important anions for crop development yet low concentrations were found in this experiment: therefore, deep analysis and a different methodology should be considered to set the availability of this nutrient in crop systems. It is expected that MS3 will perform better plant growth as it promises essential nutrients for plant development. Since the melting furnace is feed by same type of raw material, a comprehensive study will be focused on the differences of every of system combined with analysis switching sampling periods to confirm the releasing process.

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Research article

Some Physico-Chemical Characteristics of Surface Water in Mining Areas in the Lao PDR

SANTI KONGMANY*
Center of Excellence in Environment, Research and Academic Service Office, National University of Laos, Vientiane Capital, Lao PDR
Email: s.kongmany@nuol.edu.la

VANSENG CHOUNLAMANY
Faculty of Natural Sciences, National University of Laos, Vientiane Capital, Lao PDR

PHETYASONE XAYPANYA
Faculty of Water Resources, National University of Laos, Vientiane Capital, Lao PDR

OULAY PHOUPASONG
Faculty of Environmental Sciences, National University of Laos, Vientiane Capital, Lao PDR

BOUNTHOB PRAXAYSOMBATH
Faculty of Natural Sciences, National University of Laos, Vientiane Capital, Lao PDR

SINDAVANH PHENGTHAVANH
Information Compilation Division, Department of Mining Management, Ministry of Energy and Mines, Vientiane Capital, Lao PDR

Received 22 February 2022 Accepted 25 April 2022 (*Corresponding Author)

Abstract Lao People's Democratic Republic (the Lao PDR), is naturally enriched with mineral resources having been the important potential in the country socio-economic development. Mining activities for utilizing such resource is expected to bring not only benefit but also environmental problems such as deforestation due to land opening, surface water quality decline. The objective of this study was to initially investigate the surface water quality of the two main rivers (Namkok and NamMo) near two mining areas (Sepon and PhuBia) in Savannakhet and Xaysomboun provinces, respectively. Water samples from 5 sampling sites on each river were analyzed for physical (pH, EC, temperature, turbidity, TDS,) and chemical (alkalinity, DO, COD, inorganic cations and anions, and some heavy metals) characteristics in two sampling times (May and July) in 2021. The finding results unveiled that the water of the two rivers had temperature of 23-32ºC, DO 8-16 mg/L and COD 1.8-64 mg/L. The water pH, EC, and alkalinity were found at values of 7-8, 83-576 µS/cm, and 48-174 mg-$CaCO_3$/L ranges, respectively. In contrast, the amount of TDS in the both rivers were 53-369 mg/L. The detected dominant cations were Na^+, Ca^{2+} and Mg^{2+} and their concentration was in a concentration range of 0.5-34 mg/L, while main anions were F^-, Cl^- and SO_4^{2-} (3-9 mg/L). The particulate matter content in the water in the form of TSS (67-372 mg/L) were observed. The presence of both TDS and TSS might lead to the water turbidity of as low as 5 NTU or as high as 200 NTU. The investigated heavy metal concentration was typically low. Based on the findings, the water quality of the two rivers at the time of investigation was not beyond the Lao national environmental quality criteria.

Keywords physico-chemical characteristics, surface water, mining areas, the Lao PDR

INTRODUCTION

Lao People's Democratic Republic (Lao PDR or Laos), a country in Indochina peninsula, has an outstanding abundance of natural resources such as densely forest for reserving the water resources

and its quality, nutrient-rich abundance for agriculture, streams for agricultural irrigation, human-being livelihood and water resources for hydropower development, precious minerals, charm and beautiful tourist sites (Kiprop, 2019). If well managed and used, the natural resources wealth contribute to the national development and bring benefit to Lao people (Vostroknutova, 2010). Depositing in many parts of Laos, it has identified that more than 570 mining areas where gold, copper, zinc and lead covered around 47%, which are the socio-economic development potentials of Laos (Kyophilvong, 2009). Two main mining companies in Laos are Lanxang Mineral Company which have been operating at Vilabuly district of Savannakhet province since 1993, and PhuBia Mining Company Limited which have been operating at Anuvong district of Xaysomboun province since 1994 (Shibata, 2008).

The environmental impacts from mining is diverse, and various tools are needed for monitoring and assessing the impacts (Islam et al., 2020). Physical, biological and chemical properties are the main components of water quality for assessing the mining caused impacts to the water sources environment (Amin et al., 2016; Hirwa et al., 2019). The water quality assessment could provide important information for protecting environment and people living downstream of the mining areas (Gerhardt et al., 2004). However, the mostly concerned river water pollution caused by mining is the presence of heavy metals of which their concentration and distribution in the surface water are dominated by the geochemical situation and the pollution source, but seriously affected by mining leachate and chemical wastewater discharge (Liang et al., 2011). Therefore, the inspection of mining companies which must follow the environmental standard criteria and the participation of the publics in the water quality monitoring (WQM) might have challenges beyond the environmental responsibility of the authorities: (1) scientific soundness, (2) political relevance and (3) harmonization in WQM implementation (Mercado-Garcia et al., 2019).

OBJECTIVE

The objective of this study was to investigate the physico-chemical characteristics of the main rivers – NamKok and NamMo rivers near the two gold-copper mining areas in Vilabuly and Anuvong districts of Savannakhet and Xaysomboun provinces, respectively.

METHODOLOGY

Sampling Sites and Times

The physico-chemical characteristics of NamKok and NamMo were investigated in two sampling times – one in May and another in July as a representative of dry and rainy season in 2021. The typical maps of the two mining areas where 5 selected sampling sites were marked are shown in Fig. 1. The selected sampling sites are the same places where the water quality was also monitored by the companies' environmental monitoring units.

Sampling and Analytical Method

The water samples collected by grabbing method were either preserved or non-reserved and stored in plastic sample bottles according to the parameters - alkalinity, hardness, chemical oxygen demand (COD), inorganic cations and anions, and heavy metals for being analyzed in a laboratory. During transportation to the laboratory, the all sample in the bottles were kept in an ice box with cooling packs. The electrical conductivity (EC), pH, dissolved oxygen (DO), temperature and turbidity of water samples was measured at the sampling sites using portable multi-parameter water quality meter and turbidity meter. Total dissolved solids (TDS) was estimated from EC, while total suspended solid (TSS) was determined by Standard Methods 2540 D (dried at 103-105°C), alkalinity, hardness by titrimetric method, COD by potassium dichromate method, inorganic cations and anions by ion chromatographic method, heavy metals (Cu, Pb, Cr, As, Hg, Zn, Cd, Ni, Fe) by atomic absorption spectrometric method (APHA et al., 2017).

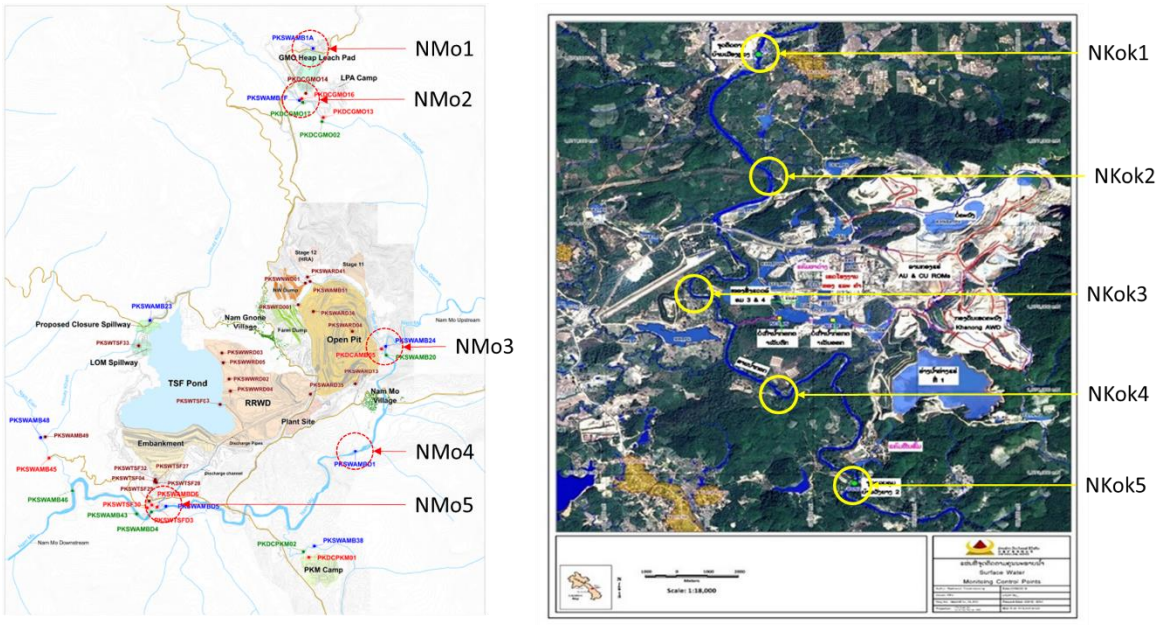

Fig. 1 A typical topographic maps of 5 sampling sites in NamMo (NMo1-5) and NamKok (NKok1-5) in PhuBia and Sepon Mining Areas

RESULTS AND DISCUSSION

Temperature, pH, DO and Alkalinity

The comparison of temperature, pH, DO and Alkalinity for the two rivers (NamMo and NamKok) are shown in Fig. 2. The temperature and pH characteristics of them were similar. In contrast, NamKok's DO and alkalinity was somehow higher than those of NamMo. The difference in the river's alkalinity in May and July would be due to their seasonal hydrological and geographical characteristics. High alkalinity of these rivers would be good for high buffering capacity of the water against change in pH (Weiner and Matthews, 2003), and this would be correlated to the observed pH.

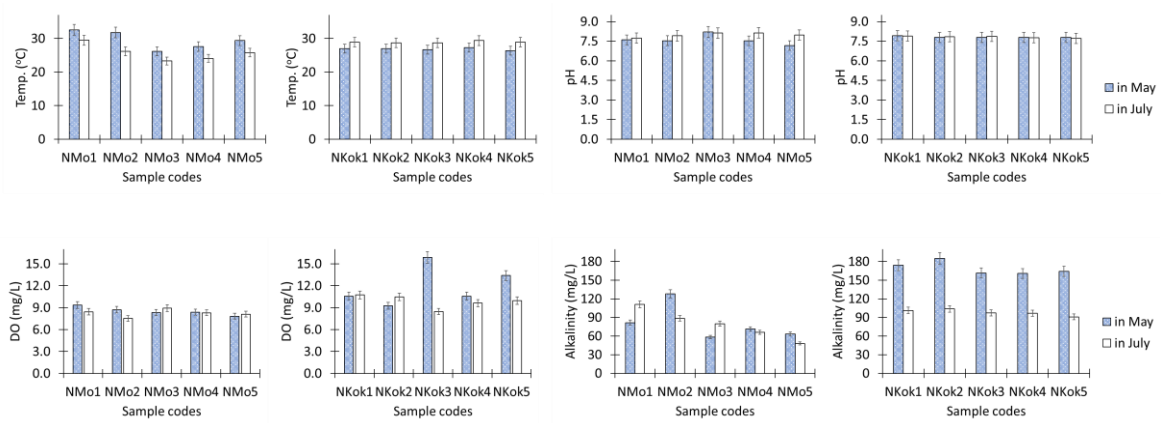

Fig. 2 Temperature, pH, DO and Alkalinity of NamMo (NMo1-5) and NamKok (NKok1-5) in May and July 2021

TDS, TSS, EC, Turbidity and COD

The analytical results of the two rivers in terms of TDS, TSS, EC, turbidity and COD are shown in Fig. 3. NamKok river showed its TDS and TSS characteristics higher than that of NamMo in May, but not much different in July, and this would lead to their similar properties on EC. For COD, both rivers showed high values in opposite month, the reason is still unclear whether by the effect of water nature dilution or anthropogenic mining activities (Xu et al., 2020).

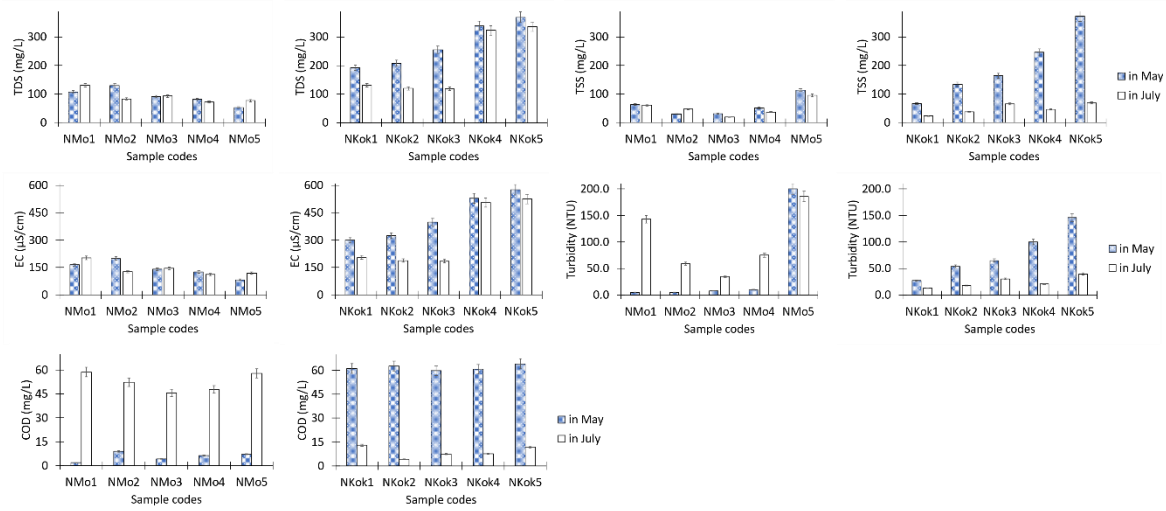

Fig. 3 TDS, TSS, EC, Turbidity and COD of NamMo (NMo1-5) and NamKok (NKok1-5) in May and July 2021

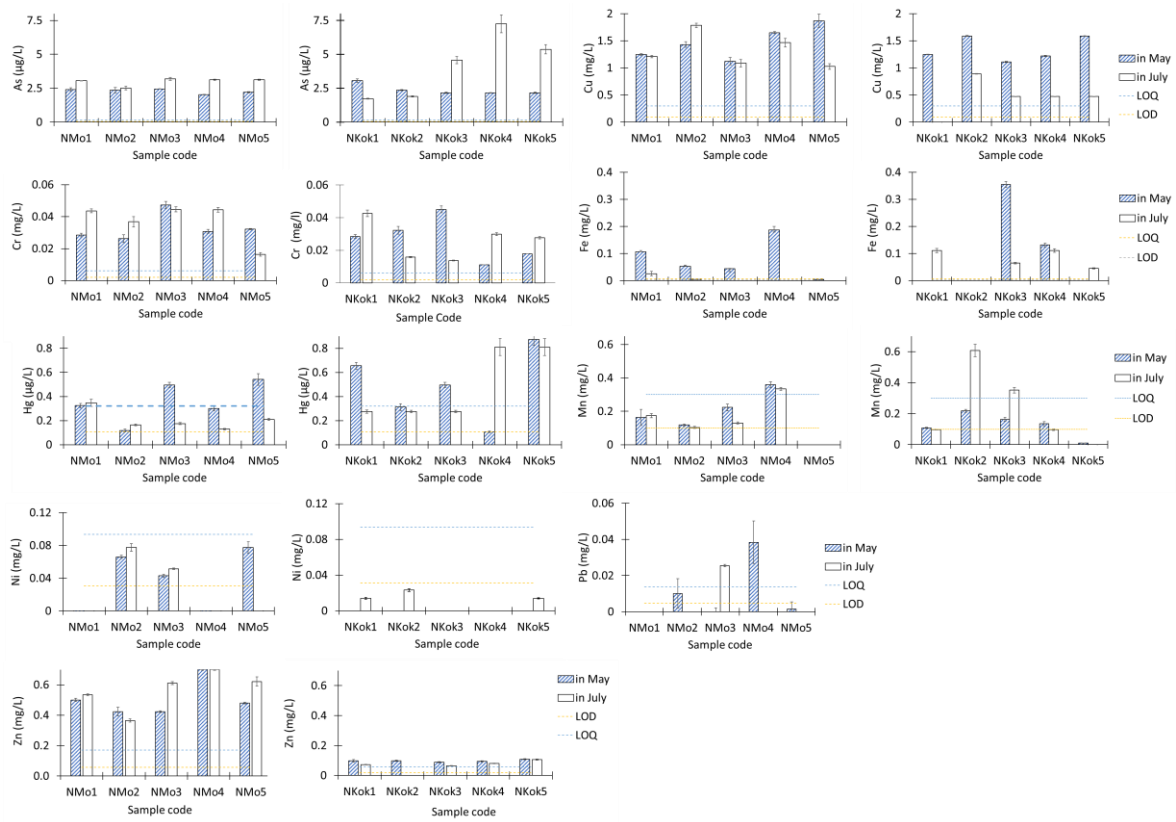

Fig. 4 Characteristics of Some heavy metals in NamMo (NMo1-5) and NamKok (NKok1-5) in May and July 2021

Characteristics of Some Heavy Metals in NamMo and NamKok

The contamination of heavy metals in water resources nearby the mining operation activities is the most concerned as most of heavy metals are toxic even at very low concentration (Fashola et al., 2016; Liang et al., 2011; Mahato et al., 2017). In this study, the presence of less toxic metals (Fe, Cu, Zn) and much toxic metals (As, Cr, Cd, Ni, Pb, Hg) in NamMo and NamKok rivers were investigated and the results are shown in Fig. 4.

The concentrations of heavy metals in NamKok river were mainly higher than those in NamMo, except Zn and Ni. The Zn concentration in NamMo river was much higher than that in NamKok and it is expected that Zn metal might be abundant in nature nearby the NamMo area. Concerning As, its concentration in NamMo river was found similar in all 5 sampling sites indicating that such presentation would occur naturally (Wurl et al., 2018).

In contrast, the presence of As in NamKok river in July in downstream was somehow higher than those in upstream, indicating that leaching As from upstream area due to runoff would be expected as the cause (Dai et al., 2013). Similarly, the concentration of Hg in water sampled at the down-stream in both rivers was higher than those at upstream. The presence of Hg in the surface water could occur through soil erosion, surface runoff, and land use in the mining areas (Dai et al., 2013). The presence of Cr in both NamMo and NamKok rivers is in similar characteristics, while the highest concentration of Cr peaked at the middle stream. Furthermore, the presence of Cr in such concentration in both rivers would be due to its natural occurrence (Chrysochoou et al., 2016; Ferronato and Torretta, 2019; Mani Tripathi and Chaurasia, 2020). The presence of Ni in both rivers was very low indicated by its concentration below the detection limit.

CONCLUSION

This study unveiled, even not completely, that the water quality of the two rivers - NamMo and NamKok in the mining operation areas at the time of our investigation is still not in serious situation according to their physico-chemical characteristics which were not beyond the limited value in comparison to the Lao national environmental standard (2017) on surface water quality. The water quality of the two rivers would be affected by the seasonal (May versus July) and geographical (upstream versus downstream) difference. The results from this study could be used as a fundamental scientific data for further study. However, it is recommended that more sampling frequency and sites should be further taken into account for future investigation so that the water characteristics would be more realistic.

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Research article

Potential Use of Predatory Bug *Eocanthecona furcellata* for Biological Control of *Plutella xylostella* in Chinese Kale Production

JUREEPORN SUKHATIPHUM
National Biological Control Research Center (NBCRC), Upper North eastern Regional Center, Khon Kaen University, Thailand

PANIDA KRUAYSAWAT
National Biological Control Research Center (NBCRC), Upper North eastern Regional Center, Khon Kaen University, Thailand

NUTCHAREE SIRI
National Biological Control Research Center (NBCRC), Upper North eastern Regional Center, Khon Kaen University, Thailand

PRAKAIJAN NIMKINGRAT
Department of Entomology and Plant Pathology, Faculty of Agriculture, Khon Kaen University, Thailand

UBON TANGKAWANIT*
Department of Entomology and Plant Pathology, Faculty of Agriculture, Khon Kaen University, Thailand
Email: ubonta@kku.ac.th

Received 30 December 2021 Accepted 2 May 2022 (*Corresponding Author)

Abstract Predatory bug *Eocanthecona furcellata* was investigated for the potential of biological control agent to *Plutella xylostella* in the laboratory and greenhouse condition. Predation rate of 3rd to 4th instar nymphs *E. furcellata* on 2nd, 3rd and 4th instar larvae *P. xylostella* were studied in the laboratory. The results showed that predation rate of 4th and 5th nymphal instars of *E. furcellata* were higher than 3rd instar. Feeding rate were greater when they feed on 2nd and 3rd instar larvae than feed on 4th instar larvae of *P. xylostella*. The efficiency of *E. furcellata* in controlling *P. xylostella* under greenhouse conditions was conducted. When *P. xylostella* population reached to economic threshold (ET), 20 of *E. furcellata* were released to chinese kale greenhouse (18 m^3), Results showed that pest population was reduced 10.32% after 5 days of release when compared to control. Additionally, percentage of plant damage from released predatory bug greenhouse was lower than non-released greenhouse. Therefore, it is possible to release the predatory bug *E. furcellata* in vegetable production as a biological control agent.

Keywords predation, biological control, diamondback moth

INTRODUCTION

Plutella xylostella (L.) is an important pest to Brassicaceae including Chinese kale (*Brassica oleracea* var. *alboglabra*). The first instar larvae feed on mesophyll tissues inside the leaf, whereas, other instar larvae are surface feeders. They consume leaves, buds, flowers, siliques, and the green outer layer of stems (Sarfraz et al., 2005). The damage varies, depending on plant growth stage, plant varieties, larval densities and size. If larvae are numerous, they can consume the entire leaf except the veins. *P. xylostella* has been a serious pest of vegetable crops for many decades. The annual cost for its global control is estimated at US$ 4-5 billion per year (Zalucki et al., 2012). The short generation time, high fecundity and broad host usage within Brassicaceae host plant of *P.*

xylostella are the important factors for insecticide resistance for example chlorantraniliprole, Spinosad, chlorfenapyr and lufenuron, an insect growth regulator (IGR) (Arruda et al., 2020).

A method to delay the evolution of insecticide resistance is to integrate the use of control methods such as chemical and biological controls (Mccord and Yu, 1987). *Eocanthecona furcellata* Wolff (Hemiptera: Pentatomidae) is a common predatory stink bug in Southeast Asia (Tuan et al., 2016). It has been mass-reared and used as a biological control agent in Thailand (Suasa-ard, 2010). It has been reported for controlling many caterpillars worm such as *Mythimna separata*, *Helicoverpa armigera*, and *Heliothis assulta* etc. Predation of *E. furcellata* gradually increased from the 2nd instar to 5th instar nymph when fed on *Maruca vitrata* (Pillai and Agnihotri, 2013) and *Spodoptera litura* (Tuan et al., 2016). Even though, there are some studies of feeding efficiency and utilization of *E. furcellata* for many insect pests, there are not many studies of *E. furcellata* fed on *P. xylostella*. Tuan et al. (2016) revealed predation rate of each stage and life table of *E. furcellata* when fed on 4th larval instar but not all stage. Therefore, this study revealed the predation rate for 3rd -5th nymphal stages of *E. furcellata* when fed on 2nd-4th larval stages of *P. xylostella* for finding suitable stages for biological control. Additionally, *E. furcellata* was evaluated for its efficiency as a biological control agent in the greenhouse.

OBJECTIVE

The objectives of this study were to examine predation rate of the *E. furcellata* in predation life stages and to evaluate its efficiency as a biological control agent in the chinese kale greenhouse.

METHODOLOGY

Insect Rearing

Plutella xylostella was collected from chinese kale production area in Khon Kaen Province, Thailand. Thirty larvae were transferred in an aluminum cage (90x 60x 60 cm) with 15 days old chinese kale in a pot inside the cage. The larvae were maintained in the cage until they became to pupae. Pupae were transferred to the mating cage (10 cm in diameter and 10 cm in height). Newly emerged adults were provided with cotton balls soaked with 20% honey water as food source. Shredded of chinese kale leaves was used as the substrate for oviposition by the diamondback moth and the F3 was then used in the experiment. *E. furcellata* were taken from a colony (10th generation) maintained at NBCRC, Upper Northeastern Regional Center. The experimental insect was maintained in the laboratory at room temperature, 28 ± 5°C, relative humidity of 60 ± 10%.

Bioassay

Laboratory: The experiment was examined in the laboratory using Completely Randomized Design (CRD) with 10 replications. A newly hatched of 3rd, 4th and 5th nymphs of *E. furcellata* were test for predation rate. One of each nymph was transferred into a container (7x 9x 4 cm) with cotton balls soaked with water, and a chinese kale leaf. Second larval instar of *P. xylostella* (n = 20) were provided daily as a food until predator change to a new nymphal stage. Then, the experiments were repeated, 3rd and 4th instar larvae of *P. xylostella* were provided instead as a pray. Predation rate were recorded every day until *E. furcellata* change to new nymphal stage. The data were statistically analyzed using Statistix 10 (Analytical software, 2013) and treatments were compared using Tukey's HSD test ($P < 0.05$).

Greenhouse: The experiment was examined in the 8 chinese kale greenhouses (18 m^3) at NBCRC. Forty pots of chinese kale were use as the experimental units for each greenhouse. The population of *P. xylostella* was artificial infestation by releasing a cluster of eggs/pot when plants were 30 days old. After eggs hatched to the larvae, the population were recorded. When the population reached to the economic threshold level (ET) (1 larva/plant), Twenty of *E. furcellata* were released into the

greenhouse. While, control greenhouse was not released. The experiment was studied with 4 replications. The data were statistically analyzed using Paired sample t-test using Statistix 10 (Analytical software, 2013). Percentage of leaf area damage was recorded in level of injury (0=no damage, 1 = < 25% damage, 2 = 25-50% damage, 3 = 50-75% damage, 4 = >75% damage). The percent reduction of *P. xylostella* was statistically calculated according to the equation of Henderson and Tilton (1955).

$$\%\ reduction = 100 \times (1 - (Ta \times Cb)/(Tb \times Ca)) \quad (1)$$

Where, Ta = population of insect counts after treatment, Cb = population of untreated insect count before treatment, Tb = population of insect counts before treatment, and Ca = population of untreated insect count after treatment.

RESULTS AND DISCUSSION

Prey consumption of *E. furcellata* fed on larvae of *P. xylostella* was significantly different. The third nymphal instar of *E. furcellata* fed on 3rd and 4th instar larvae more than 2nd instar larvae, whereas, 4th and 5th nymphal instar of *E. furcellata* fed on younger more than the older prey (Table 1). Predation rate of *E. furcellata* may involve with a prey species. Tiwari et al. (2017) revealed that when *E. furcellata* fed on *S. litura*, and *M. vitrata*, predation rate of prey consumed slightly increased with increasing prey stage. However, when *E. furcellata* fed on *Spilarctia obliqua* and *S. frugiperda* predation rate of prey consume decreased with increasing prey size (Kumar et al., 2001; Keerthi et al., 2020). Rani and Wakamura 1993 suggested that physical stimuli such as host shape or movement had no influence on acceptability of the prey to *E. furcellata*.

Table 1 Prey consumption of different stages of *Eocanthecona furcellata* fed on larvae of *Plutella xylostella*

Treatment	*P. xylostella* [1/]		
E. furcellata	2nd instar	3rd instar	4th instar
3rd nymph	28±0.50 B	65±4.50 A	50±1.91 A
4th nymph	71±5.91 A	79±4.72 A	24±0.82 B
5th nymph	71±2.65 A	60±5.35 AB	38±2.08 B
F-test	**	**	*
CV (%)	24.33	30.28	26.08

[1/]*Within each column, mean±SD followed by the same capital letter indicate no significantly different (P>0.05)*

However, Kumar et al. (2001) revealed that visualization of the predator and movement of prey increases the predation rate. In this case, the active movement of 2nd and 3rd instar larvae of *P. xylostella* may be a factor of high predation rate of 4th and 5th nymphal stage of predator. Contrast to 4th and 5th nymphal stage, 3rd nymphal stage may difficult to handle the active prey movement.

The results of laboratory experiment for predation of *E. furcellata* lead to a decision to release 3rd nymphal stage of *E. furcellata* as a biological control in chinese kale greenhouse. Twenty of 3rd nymphal stage in a bio-product were released into the greenhouse after diamond back moth reach to 1 larva/plant. The results revealed that the number of *P. xylostella* was not significant different between treatment and control (Table 2). However, population of *P. xylostella* was reduced at 3 days after *E. furcellata* released. The percent reduction of *P. xylostella* at 3-5 day after predator released were 10.32, 21.79 and 18.06%, respectively. During 1-2 days after predator released the population in treatment was not reduced. At that period, most of *P. xylostella* was 2nd instar which was not suitable for the predator stage. Two day later, most of pest population was 3rd instar, and predator was changing nymphal stage from 3rd to 4th nymph. Then the population was reduced (Percent reduction was higher). Therefore, in case of a serious outbreak, 4th nymphal stage may use

instead. Level of chinese kale leaf damage in control greenhouse increased from level 1 to level 3, whereas, level of chinese kale leaf damage in control greenhouse was level 1 and level 2.

However, applying in open field condition may have some factors such as temperature, various pests, other natural enemies and chemical insecticide which involving the efficiency of predator.

Table 2 Number of *Plutella xylostella* in chinese kale greenhouse and level of leave damage with released and non-released *Eocanthecona furcellata* as a biological control agent, and percentage reduction.

Plant age (day)	non-released		released		Reduction (%)
	Insect/plant	Level of leave damage	Insect/plant	Level of leave damage	
36[2/]	2.32±1.15a[1/]	1	1.44±0.15a	1	na
37	2.21±1.12a	1	1.42±0.14a	1	-3.52
38	2.17±1.09a	1	1.40±0.15a	1	-3.94
39	2.12±1.04a	2	1.18±0.18a	1	10.32
40	2.06±1.00a	2	1.00±0.26a	1	21.79
41	1.75±1.00a	3	0.89±0.24a	2	18.06

[1/]Within each row, mean±SD followed by the same small letter indicate no significantly different (P>0.05)
[2/] Eocanthecona furcellata was released into the greenhouse.

CONCLUSION

E. furcellata is an effective predator of *P. xylostella*, the third nymphal stage consumed 3rd and 4th larval instar than 2nd instar. In contrast, 4th and 5th nymphal stage consumed 2nd and 3rd instar more than 4th instar. *E. furcellata* is an alternative biological control agent in chinese kale green house. It can reduce pest population and level of leaf damage.

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Research article

Improving Water Quality of a University-Managed Biotope

MADOKA KUROTAKI
Graduate School of Agro-Enviromental Science, Tokyo University of Agriculture, Japan
Email:12521002@nodai.ac.jp

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

Received 16 January 2022 Accepted 2 May 2022 (*Corresponding Author)

Abstract "Biotope" was coined in Germany by combining the ancient Greek word "Bios", which refers to organisms and life, and "Topos", which refers to a place. In Germany, biotopes have been attracting attention since the 1970s, when environmental problems caused by industrialization became more serious. Since the end of the 20th century, biotopes have been created in various parts of Japan, including tidal flats, wetlands, lakes, rivers, and other water bodies, as well as forests and grasslands. It is still offered as an educational opportunity in Japan. They are prone to water pollution and need to be improved because biotopes are closed environmental water bodies. In Japan, there is no set environmental level for the water quality of biotopes. In this study, we conducted water quality measurement and purification experiments in the biotope in the campus at Tokyo University of Agriculture, Japan. This study aims to evaluate total nitrogen in a biotope. The biotope at Tokyo University of Agriculture had not been managed regularly for a long time. First, the filtration system installed in the biotope was not working, so it was fixed. For measuring water quality, water samples of the biotope at Tokyo University of Agriculture were collected twice a week in a month. And the concentrations of total nitrogen (TN) were measured by a spectrophotometer. In the biotope at Tokyo University of Agriculture, total nitrogen ranged from 1.14 to 3.76 mg/L, which is high compared to the environmental level set by the Ministry of the Environment for lakes and marshes in Japan. Through a set of field observation, this study attempted to improve the water quality the biotope at Tokyo University of Agriculture, which has been unmanaged for more than long years. Water quality measurement and purification experiment revealed that total nitrogen was improved.

Keywords biotope, water quality, filtration system, total nitrogen

INTRODUCTION

Water pollution is one of the most important environmental problems that have a wide range of effects such as the reduction of fishery resources, as well as the formation of ecosystems. Water pollution can be divided into two major categories: first, water pollution caused by toxic substances and pathogens that threaten human health. The first is water pollution caused by toxic substances and pathogens that threaten human health, such as heavy metals, cyanide, and contagious pathogens such as dysentery and cholera. Secondly, water pollution caused by excrement and organic matter discharged by people's daily activities. In addition, eutrophication caused by the runoff of phosphorus and nitrogen contained in pesticides and fossil fuels in closed environmental water bodies such as lakes and marshes result in massive algae blooms that affect many aquatic organisms and cause significant economic losses to fisheries and other human production activities.

Japan has been taking proactive measures to deal with the water quality environment since the period of high economic growth in the 1970s. As a result, the non-achievement rate of environmental standards for substances that affect the human body such as heavy metals, cyanide,

organic compounds, and pesticides (health items) in public water bodies is 0.79%, which can be said to be almost achieved.

On the other hand, however, the rate of achievement of environmental standards for living environment items such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD) has not been sufficiently achieved. The percentage of pollution load including domestic wastewater, waste, livestock wastewater, and small-scale business wastewater generated from people's production activities is still high.

Since the late 1960s, organic pollution in rivers has been improving, but the status of achievement of environmental standards for phosphorus and nitrogen in lakes and marshes remains low at around 50%, although there have been signs of improvement in recent years.

As for chemical oxygen demand (COD), one of the representative indicators of organic pollution, the rate of achievement of environmental standards in lakes and marshes in FY2039 was 50.0%, a decrease of 4.3 percentage points from the previous year. Looking at the trends since 1979, COD was almost flat in the upper half of the 3 mg/L range before 2002, but has been in the upper half of the 3 mg/L range since 2003, and was 3.3 mg/L in the first year of 2003.

As for total nitrogen and total phosphorus in lakes, the achievement rate of the environmental standard was 49.2%. This is an increase of 0.4 percentage points from the previous year. The achievement rate for total nitrogen was 21.4%, while the achievement rate for total phosphorus was 50.8%.

The environmental standard attainment rate of 50.0% for lakes is still low compared to rivers and seas. It is said that the achievement rate of closed environmental water bodies is lower than that of other water bodies due to the fact that closed environmental water bodies have a large pollution load that flows in and accumulates easily. It can be said that measures to deal with nitrogen and phosphorus in domestic wastewater, which contribute to this, are a major issue. In particular, lakes and dammed lakes are often the source of water for water supply, and this causes problems such as moldy odor, filtration problems caused by blue-green algae, and bad odor.

The main source of pollution in Japan is domestic wastewater from cooking, washing, bathing, and urination. About 60% of the pollution load flowing into closed environmental water bodies comes from domestic wastewater, and the load from domestic miscellaneous wastewater (excluding urine) is particularly large. Domestic wastewater from households, such as cooking, washing, bathing, and urination, is an important source of water pollution in public water bodies.

However, if we look at the sources of pollution in terms of nitrogen and phosphorus rather than BOD, manure accounts for a high percentage of 80% and 60%, respectively. This raises the question of the importance of countermeasures.

On the other hand, measures to deal with the pollution load discharged from a wide range of sources such as farmland and forests are also considered important. It is said that 20% of the total pollution load flowing into lakes and marshes comes from this wide area, but the priority of measures remains low due to the current high pollution load from domestic wastewater.

When we took water samples from the biotope on the university campus and measured them in a class, they did not meet the total nitrogen and total phosphorus standards of the “Environmental Standards for the Conservation of the Living Environment for Lakes and Marshes” (Ministry of the Environment). We were also interested in the water quality of closed environmental water bodies such as lakes and marshes, so we chose a biotope, which can be considered a closed environmental water body, as my target site.

The term "biotope" was coined in Germany by combining the ancient Greek words “Bios” meaning organism or life and "Topos" meaning place. In Germany, biotopes have been attracting attention since the 1970s, when environmental problems caused by industrialization became more serious. In Japan, too, biotopes have been created in various places since the end of the 20th century, including water bodies such as tidal flats, wetlands, lakes, and rivers, as well as forests and grasslands. Since biotopes are closed environmental water bodies, they are prone to water pollution and need to be improved.

OBJECTIVE

Our biotope itself was artificially created. However, because it had been neglected for many years, the surrounding vegetation had become overgrown and desolate. The filtration system itself had deteriorated and was not functioning as it should, with pumps and other equipment failing. In addition, with the construction of the surrounding facilities, the biotope itself was reduced in size, and the flow of water that should have been there was lost, resulting in the current situation

This study aims to evaluate total nitrogen of this biotope, compare it to the environmental standard and examine the filtration capacity of the filter.

METHODOLOGY

The biotope in the campus of Tokyo University of Agriculture is divided into two main areas: the Chitose Gate side is called the back and the Ichigokan side is called the front in this study.

The back of the biotope and the front of the biotope are connected by a siphon to keep the water level constant. The water supply at the back of the biotope brings in new water. In addition, a fully automatic upward-flow rapid filtration machine is installed near the back of the biotope. It operates from 8:00 a.m. to 8:00 p.m. and absorbs sludge from the back of the biotope and drains the filtered water to the back of the biotope.

Since the biotope itself had been neglected for many years and we could not even recognize its original shape, we decided to clean and repair it. We collected fallen leaves floating on the surface of the biotope and cut down the surrounding trees.

It was repaired the deteriorated fully automatic upward-flow rapid filtration system. It was repaired the malfunctioning pump, cleaned the siphon, cleaned the water intake and drainage pipes, loaded filter media, replaced the filter, and installed a filter on the water intake pipe. The work was carried out over October 16, October 26, October 30, and November 9. The normal operation of the pump was confirmed on November 9.

Water samples were taken periodically for about a month at the biotope on the campus of Tokyo University of Agriculture, the target site. Starting on October 27, water samples were taken in the morning of October 30, November 3, November 6, November 10, November 13, November 17, November 20, and November 24, and measurements were taken in the afternoon.

The water samples were placed in containers marked with the date of collection and stored in a refrigerator. The total nitrogen concentration was measured by absorption spectrophotometry using the HC-1000 eutrophotometer. The dilution ratio for total nitrogen concentration measurement was 5 times. In the alkaline potassium peroxodisulfate decomposition and UV absorption method used here, sodium hydroxide and potassium peroxodisulfate are added to the sample water, and the water is autoclaved (132℃, 30 min) to oxidize and decompose all nitrogen compounds and replace them with nitrate ions. Then, the absorbance at the wavelength targeted for nitrate ions is measured and determined as the total nitrogen concentration. For the total nitrogen concentration, the following Equation (1) was used to correct the reading value.

Total nitrogen concentration (mg/L) = reading x dilution factor x 1.2 (1)

RESULTS AND DISCUSSION

After repairing the biotope by collecting fallen leaves on the surface of the water and cutting down the surrounding trees, the water area of the biotope became clearly wider than before. Since the biotope had been neglected for many years, it was confirmed that sludge had accumulated in the biotope itself and metals had been dissolved.

In addition, shellfish and goldfish were found living in the water of the biotope. Since the biotope was artificially created, it is unlikely that shellfish and goldfish came from nature to live there. Therefore, we think it is more likely that they were introduced artificially to improve water quality. We also saw other aquatic plants that had been planted on the tires. The plastic covers that covered the pipes were also observed in the water.

Total nitrogen showed a decreasing trend after the collection of fallen leaves on the 30th of October. This is thought to be because the fallen leaves that were floating on the water surface were collected and did not accumulate on the bottom of the water without decomposing in the water. As was confirmed during the cleanup, the bottom of the biotope was filled with a sludge-like substance where fallen leaves had sunk and decomposed. We believe that these had a lot to do with the water quality of the biotope and also affected the total nitrogen value. The values were on the increase after the collection of fallen leaves once on October 30. Since it is impossible to completely remove trees and leaves, we think that fallen leaves accumulated on the water surface again, sinking and turning into sludge, which affected the values.

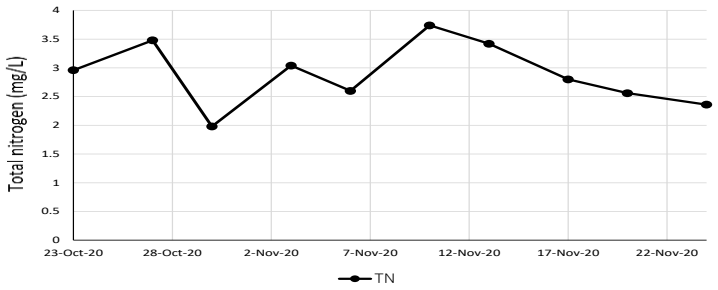

Fig. 1 Changes in total nitrogen concentration at Biotope back (Chitose Gate side)

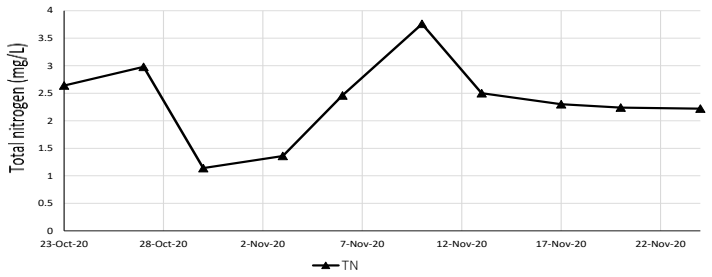

Fig. 2 Changes in total nitrogen concentration at Biotope front (Ichigokan side)

On the other hand, the values have been on a downward trend since November 9, when the pump was confirmed to be in operation. This is thought to be due to the fact that the fully-automatic upward-flow rapid filtration system works by filtering out mud and pollutants from the water, which lowers the value of total nitrogen.

The total nitrogen obtained in this study was compared with the "Environmental Standard for the Conservation of Living Environment (Lakes and Marshes)" of the Ministry of the Environment. The total nitrogen was less than 1 mg/L, which means that the item type is classified as V. In other words, it can be said that the adaptability of the purpose of use lies in industrial and agricultural water use.

However, the total nitrogen obtained in this study was very high, ranging from 2.0 to 3.0 mg/L, compared to the standard of 1 mg/L or less. We think that humus and decomposing matter are the possible causes of the high total nitrogen value in the biotope. The fact that the collection of fallen leaves on the surface of the water and the cutting down of trees had a great effect on the decrease of the total nitrogen value, and the fact that rotten fallen leaves were accumulated on the bottom of the biotope, led us to the above conclusion.

We heard that many people had dealt with the water quality improvement of biotopes as a theme for their graduation thesis or research in the past. Because of this, there were many shellfish, plants, and other things left in the biotope that would have been used for research in the past. In addition, the biotope has been reduced in size due to the construction of neighboring facilities, and the water flow that should have been there has been lost, which may have affected the water quality. In fact, by cleaning the biotope and adding new water, the water area has become much wider than before the repair.

CONCLUSION

Seeing the state of the biotope, which had been neglected to the point of changing its shape, we strongly considered the importance of maintenance and management. In this study, the fully automatic upward-flow rapid filtration machine, which had been repaired and was now working properly, can be said to have fully fulfilled its purification function and contributed to the improvement of water quality. The filter media, which is considered a consumable item, had not been replaced, and the filtration was not working because it had not been inspected or repaired. wen the future, it will be important to check and replace the filter media on a regular basis.

In this study, we thought that the total nitrogen value decreased by collecting fallen leaves. In order to prevent leaves from falling in the future, it would be a good idea to install a net. However, it is necessary to manualize and periodically repair the system, since it could be left for a long time and deteriorate, causing water pollution.

Also, it was considered that such measures for the maintenance and management of the biotope should have already been incorporated into the plan when it was artificially created. If the quality of water and the environment of the biotope is the first priority, it is necessary to clean and repair the biotope on a regular basis as we did in this study. If it is difficult to do so, we have to consider the possibility of removing them.

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Research article

Design and Experimental Analysis of Atmospheric Water Generator Based on the Climatic Conditions of Manolo Fortich, Bukidnon

TAN JERICO D.*
Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines
Email: jerico.tan@g.msuiit.edu.ph

ALBIENTO ELIZABETH EDAN M.
Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines

Received 29 January 2022 Accepted 2 May 2022 (*Corresponding Author)

Abstract Most Filipinos living in remote rural and island communities rely on unsafe drinking water sources due to a lack of reliable water supply. With this, an atmospheric water generator (AWG) can become an alternative water source by condensing and collecting water vapour present in the air. However, previous research on the design of AWG devices was conducted outside the Philippines and most studies did not design the longitudinal profile of the fins and intake fan component of the device. This study designed the longitudinal fin profile of the fins and intake fan speed based on the climatic conditions of Manolo Fortich, Bukidnon and analysed the performance of the device by conducting a field experiment. The study designed the extended fins and varied the intake fan speed by conducting a parametric analysis using existing heat and mass transfer equations. The study then conducted a field experiment of the AWG device by placing the device in a secure open space. Results of the design showed that the 9 cm fin length was optimal for the device and that higher intake fan speed were more suitable for high relative humidity (RH) and high air temperature conditions. Results from the field experiment showed that higher water productivity was observed at higher RH level compared the lower RH levels. The study concludes that a longer length of copper fins and greater magnitude of intake fan speed does not necessarily translate to higher water productivity and that higher water production rates were observed during high RH levels.

Keywords atmospheric water generator, Peltier effect, thermoelectric couple

INTRODUCTION

Potable water is a necessity for us humans to live. However, most of the river systems in the Philippines face severe problems of pollution, which resulted in the higher cost of the supply of potable water throughout the country (Rola et al., 2015). One way to obtain water cheaply and sustainably is to produce water out of air through condensation by using an atmospheric water generator technology (AWG) with the use of thermoelectric couples (TEC).

AWGs are comprised of several components. The TEC is the main cooling unit which consists of a cold surface on one side and a hot surface on the other side when an electric current is passed thru the device. Copper fins are attached to the cold side to increase the surface area of the cold surface. A fan is installed to suck in air into the device for air to come in contact with the cold copper surface making the water vapor condense in these areas. Only around 1% of the carbon dioxide (CO_2) present in the air will dissolve in condensed water vapor to form carbonic acid (H_2CO_3) making the water acidic with a pH as low as 5.5 (Bauer et al., 1980). With this, copper pitting due to carbonic acid is less likely to occur at a lower PH of water (Taxen, 2002). The study did not delve deeper in the extent of the effect of carbonic acid on the copper fins. The hot side is usually installed with an aluminum heat sink to dissipate the heat produced by the TEC. However, little work has been done on the design of two major components of the AWG namely the cold side

copper fins and the intake fan and most of the studies were designed outside the Philippines. In this study, the length of copper fins was optimized and the intake fan speed was varied based on Philippine climatic conditions and analyzed its performance in an actual field experiment.

OBJECTIVE

The main objective of this study is to optimize the design of an AWG device based on the climatic conditions of Manolo Fortich, Bukidnon. Specifically, the study will optimize the length of copper fins, identify the appropriate intake air velocity considering a maximum air velocity, fabricate the AWG prototype, and analyze the field test results of the AWG device.

METHODOLOGY

Optimization of Length of Copper Fins

The study initially acquired climatic data for Manolo Fortich, Bukidnon. The average values of the lowest, median and highest temperature and relative humidity were computed and determined the dewpoint temperatures using these values. The study then considered four different lengths of copper fins namely 8 cm, 9 cm, 10 cm and 11 cm. To maximize the amount of water generated in the device, all the surface area along the length of the copper fin should be less than the dewpoint temperature for maximum water condensation. Hence, the study performed a parametric analysis in solving the temperature distribution along the fins, using Equation 1, by using different fins lengths and different climatic conditions. The temperature distribution equation was emulated from the study of Shourideh et al. (2018) and Kilic and Onat (1981). The lengths of fin 8 cm, 9 cm, 10 cm and 11 cm that has a temperature distribution below the dewpoint at different climatic conditions were chosen as the optimized length of copper fins.

$$\frac{d^2T}{dx^2} = m^2[(T - T_a) - \frac{h_m h_{fg}^*}{hR_v T_a}(P_{v,T_a} - P_{v,T}) \quad (1)$$

Where m is fin parameter, T local fin temperature (K), T_a temperature of the surrounding air (K), h_m mass transfer coefficient (m/s), h_{fg*} modified latent heat of vaporization (J/kg), h convective heat transfer (W/m^2-K), R_v ideal gas constant (J/kg-K), T_a temperature of the surrounding air (K), $P_{v,Ta}$ partial pressure of water vapour in the surrounding air, and $P_{v,T}$ partial pressure of water vapour in the fin surface.

Also, the boundary conditions for Equation 1 were shown in Equation 2 and Equation 3.

$$T(L_f) = T_0 \quad (2)$$

$$(\frac{dT}{dx})_0 = 0 \quad (3)$$

Where L_f is length of fins (m) and T_0 initial cold side temperature of TEC (K).

Variation of Intake Air Velocity

The study also conducted a parametric analysis to compute the theoretical water generation rate by using different values of air velocity considering a maximum velocity of 4 m/s at different climatic conditions. The study utilized the equation shown in Equation 4 to compute the theoretical water generation rate. There were five cases of combinations of temperature and RH used in the analysis. The intake air velocity that gave the maximum water generation rate was chosen as the appropriate intake air velocity at that certain climatic condition.

$$V = \frac{2NbL_f m_w}{\rho l} \quad (4)$$

Where V is water generation rate (m^3/s), ρ_l the density of water (kg/m^3) and N number of fins attached to the TEC.

RESULTS AND DISCUSSION

Optimized Length of Copper Fins

Parametric analysis for the temperature distribution of the 8 cm, 9 cm, 10 cm and 11 cm lengths of copper fins for different climatic conditions were computed. Fig. 1 shows the results of the temperature distribution of each of the copper fin lengths. It can be observed in Fig. 1 (b) that the 10cm and 11cm fin lengths exceeded the dewpoint temperature at 80% percent of its length. This meant that the surface temperature beyond this point was higher compared to the dewpoint temperature at that climatic condition. Hence, the water does not condense in these regions and the copper fins can be considered as partially wet fins under these conditions since not all of its surface area can condense water.

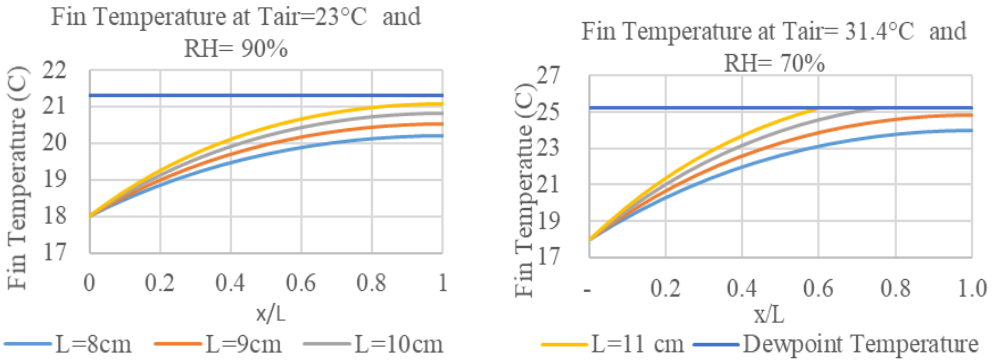

Fig. 1 Fin temperature distribution of different fin lengths at (a) T_a=23 C and RH =90%, (b) T_a=31.4 C and RH=70%

On the other hand, it can be seen in Fig. 2 that the 9 cm fin length did not reach the dewpoint temperature in all cases of climatic conditions. This meant that all the surface area of the 9 cm length copper fins can condense water vapor. Hence, the optimum length of the copper fins that was also incorporated in the design of the AWG was the 9cm length.

Variation of Intake Air Velocity

Table 1 presents the cases used in the analysis with different ambient air temperatures and variable RH levels.

Table 1 Summary of cases of temperature and RH used in the analysis

Case No.	T_a (°C)	RH 1 (%)	RH 2 (%)	RH 3 (%)	RH 4 (%)
1	23.00	80.00	85.00	90.00	-
2	25.00	75.00	80.00	85.00	90.00
3	29.00	75.00	80.00	85.00	90.00
4	31.00	75.00	80.00	85.00	90.00

By applying these cases in the computation along with different variations of intake air velocity considering a maximum velocity of 4 m/s, the theoretical water generation rate was obtained and the results were shown in Fig. 2. It can be observed from the results that increasing the air velocity generally increases the water generation rate for most of the cases presented.

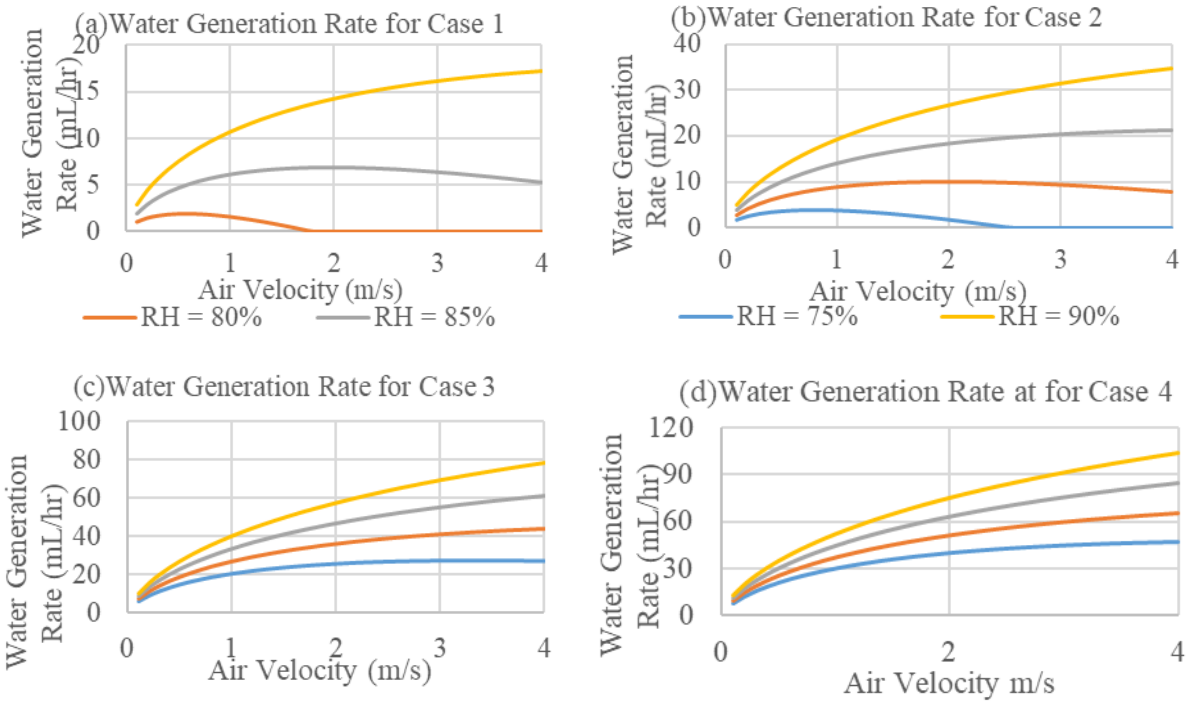

Fig. 2 Theoretical Water Generation Rate at different Air Velocities for (a) Case 1, (b) Case 2, (c) Case 3, (d) Case 4, and (e) Case 5

For Case 1 and Case 2, there was low ambient air temperature paired with low RH levels. It can be observed in Fig. 2 (a) and (b) that between RH of 75% to 80%, the water generation rate increased initially when the air velocity was also increased but then decreased at higher magnitudes of air velocity. Hence, the air velocity of the fans can be adjusted at peak water generation rate when the AWG device is subjected to low relative humidity such as in Case 1 and Case 2.

For Case 3 and Case 4, the increase in air velocity also increases the of water generation rate. For this case, the increase in the value of the mass transfer coefficient resulting from the increase in air velocity outweighed the decrease in the difference between the partial pressure of the surrounding air and partial pressure at the fin surface.

Based from the results shown in Fig. 2, Table 2 summarizes the appropriate intake air velocity at different climatic conditions. The values indicated in Table 2 were then incorporated into the design of the AWG in which the air velocity varied depending on the climatic conditions.

Table 2 Summary of appropriate air velocity at different climatic conditions

Relative humidity	Intake air velocity (m/s)			
	23°C ≤ 24°C	24°C ≤ 26°C	26°C ≤ 28°C	28°C ≤ Ta
75%<80%	0.00	0.20	2.00	4.00
80%<85%	0.60	2.00	4.00	4.00
85%<90%	2.00	4.00	4.00	4.00
90% ≤ 100%	4.00	4.00	4.00	4.00

Construction and Experimental Analysis of the Device

The study utilized the 9 cm copper fin length and the magnitudes of variable intake air velocity in the design of the AWG device. Figure 3 shows the blow-up figure of the AWG prototype.

The AWG device was continuously operated for 30 days in a secure open space located at Manolo Fortich, Bukidnon for the experimental analysis. The testing area for the field test was located in the backyard of a residential lot located in a rural community at Manolo Fortich, Bukidnon. The period of testing was between September to October 2021 and the experimental

setup is shown in Fig. 3b. The average hourly RH, and the ambient air temperature were shown in Fig. 4 and the average hourly water collection was shown in Fig. 5.

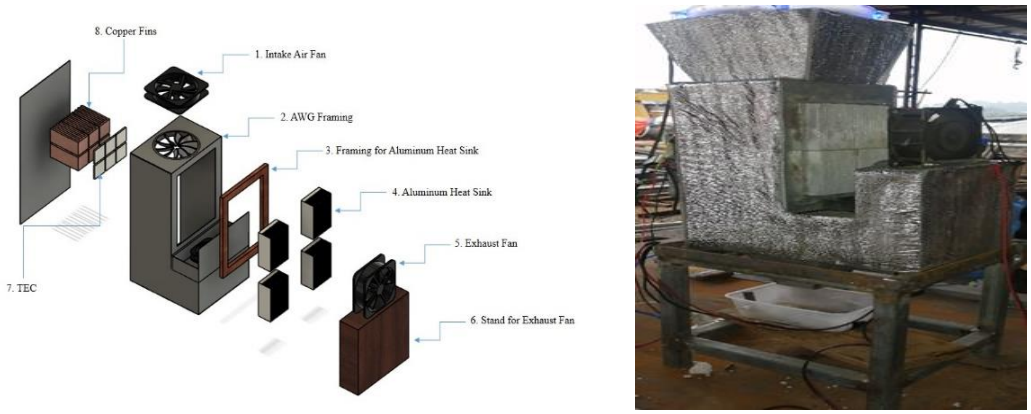

Fig. 3 Blow-up picture of the AWG Device with its corresponding parts (a) and finished product and experimental setup (b)

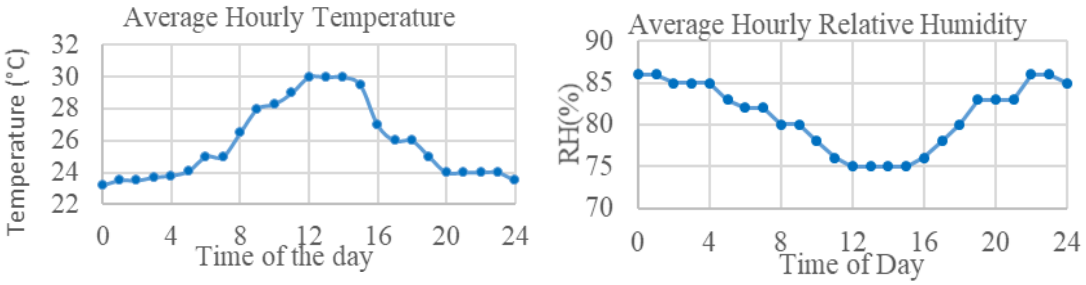

Fig. 4 Average hourly ambient air temperature and relative humidity

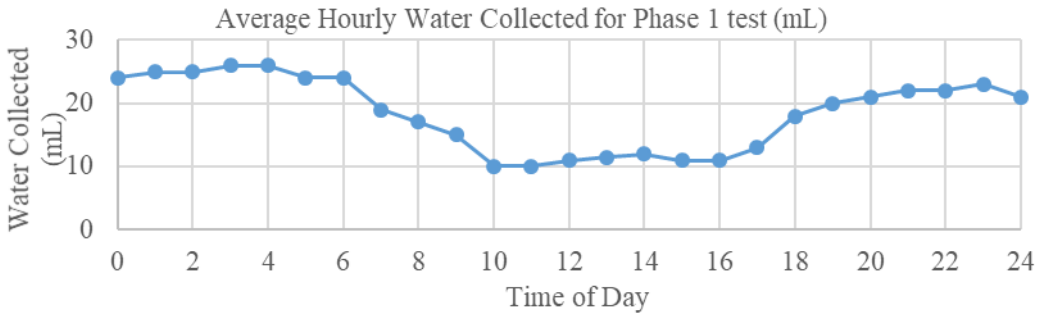

Fig. 5 Average hourly water collection for the AWG device

It can be seen in Fig. 5 that the highest water collection rate of the AWG was during nighttime since there were high RH levels paired with low surrounding temperatures. Overall, the highest recorded amount of water collected in a day was 526 mL. Table 3 shows the comparison between the outputs of this study compared to past literature.

Table 3 Comparison of water collected per day to past literatures

Researcher	Location	Water collected (mL/day)
Joshi et al. (2017)	India	480
Liu et al. (2017)	China	525
Present work	Philippines	526

CONCLUSION

The cold side fin length and air velocity are two important features of an AWG device that are needed to be designed to improve the efficiency and water generation rate. The study observed that while increasing the length of copper fins increases the cooling surface area, making the fin length excessively longer does not positively impact the water generation rate of the AWG. Longer fin lengths will develop dry regions along their length thus becoming inefficient.

Finally, the results of this study showed that there was an ideal air velocity at every climatic condition to harness the maximum water generation rate for the AWG device. Low air velocities were assigned to low surrounding temperature with low relative humidity conditions while high air velocities were designated for high surrounding temperature and high relative humidity conditions. The highest amount of water collected in a day was 526mL.

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Research article

DNA Fingerprinting of Selected Maize (*Zea mays* L.) Genotypes using SSR Markers

SAN KYI*
Yezin Agricultural University, Nay Pyi Taw, Myanmar
Email: sankyi747@gmail.com

KYAW KYAW WIN
Pro-Rector's Office of Administration, Yezin Agricultural University, Nay Pyi Taw, Myanmar

HLA THAN
Pro-Rector's Office of Academic, Yezin Agricultural University, Nay Pyi Taw, Myanmar

SOE WIN
Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University, Nay Pyi Taw, Myanmar

NYO MAR HTWE
Advanced Center for Agricultural Research and Education, Yezin Agricultural University, Nay Pyi Taw, Myanmar

AYE LAE LAE HLAING
Plant Molecular Biology Laboratory, Biotechnology Research Section, Department of Agricultural Research, Nay Pyi Taw, Myanmar

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Abstract Molecular marker has been used for variety identification, genetic diversity of genotypes and additional using intellectual property protection in DUS testing. DNA fingerprinting of fourteen maize genotypes had been studied at Plant Biotechnology Laboratory, DAR, Myanmar during 2020-2021. Nine hybrids and five inbreds were analyzed using 24 polymorphic SSR markers, resulted a total number of 101 alleles with a range from 2 to 9 alleles per locus. Polymorphism has been sufficiently detected with the average of 0.66 per SSR locus. Cluster analysis separated all the maize genotypes as five major groups and indicated the existence of genetic variation among the observed inbreds and hybrids. Six SSR primer pairs (dupssr12, bnlg1940, umc1248, umc1586, bnlg1518 and bnlg1028) were selected as final marker set for variety identification with the selection criteria such as detection rate of the SSR fragment, the presence of rare allele, PIC value, and reproducibility and PCR band pattern of SSR fragments. In this study, all tested genotypes have been fingerprinted with unique profile identity (ID) to support the DNA fingerprint catalogues of Myanmar Maize Molecular DUS test guidelines.

Keywords DNA fingerprinting, maize SSR markers, varietal identification

INTRODUCTION

Maize (*Zea mays* L.) is the most diverse crop species characterized at both morphological and molecular levels (Anderson and Cutler, 1942; Buckler et al., 2006; Zheng et al., 2008). Genetic identification of maize is essential in the process of crop improvement, crop quality estimation and the finding of parent components and their crosses.

SSR markers were able to discriminate maize genotypes depending upon their hybridization level and their genetic relationships among the different inbred lines (Kamal et al., 2010). It is the most powerful biotechnological tool, suitable for detecting of genetic purity status of maize hybrids.

SSR also used in DNA fingerprinting analysis for identification of individuals, populations, inbred lines, and hybrids, making the description of the species at the molecular level, to protect the breeders' Rights and its protection.

Plant varietal protection and patents are the most important end products of plant breeding institutes to get back their research investment by mean of intellectual property protection. DNA fingerprinting technology is useful for preventing counterfeit and fake varieties in the market and this fingerprinting information is additional information for DUS characterization (Wang et al., 2013). UPOV (2010) recommends SSRs for current construction of DNA fingerprint databases that have been well-defined and tested. In the present study, the SSR primers set were used to differentiate hybrids and inbreds, and to create the DNA fingerprint catalogues for supporting of Myanmar Maize DUS test guidelines for identifying maize genotypes in infringement case, and for utilizing as a source of parental line for future breeding programs.

METHODOLOGY

Plant Materials and Genomic DNA Extraction

Fourteen maize genotypes (Table 1) were used to study molecular characterization at Plant Biotechnology Laboratory, Department of Agricultural Research (DAR), Myanmar during 2020-2021. Nine hybrids (imported by private companies) and five inbred lines (developed by DAR) were used. Genomic DNA extraction, DNA quantification and qualification were carried out according to the procedure of Hlaing et al. (2017).

Table 1 List of selected maize genotypes for molecular characterization

No.	Genotypes	Type	Source	No.	Genotypes	Type	Source
V1	Asia Seed (A.55)	Hybrid	China	V8	NK-621	Hybrid	Syngenta
V2	Asia Seed (A.99)	Hybrid	China	V9	TSF-1633	Hybrid	Thailand
V3	AA-737	Hybrid	Thailand	V10	YZI-10-054	Inbred	DAR
V4	GT-722	Hybrid	Thailand	V11	YZI-10-095	Inbred	DAR
V5	NK-625	Hybrid	Syngenta	V12	PAC-999	Inbred	Thailand
V6	KMHE-3550	Hybrid	India	V13	C7	Inbred	DAR
V7	CP-111	Hybrid	Thailand	V14	YZCI-16-019	Inbred	DAR

PCR Amplification and Gel Electrophoresis

Twenty-four SSR primer pairs were used to identify the studied maize genotypes. These highly polymorphic primer sets, PCR amplification and agarose gel electrophoresis were conducted following the methods reported by previous research findings (Hlaing et al., 2017).

Statistical Analysis on Marker Data

The SSR allele segregation data were used to construct Nei distance dendrogram (Nei, 1972) using NTSYSpc 2.1 software (Rohlf 2000). Polymorphism Information Content (PIC) for each SSR was calculated by the formula $PIC=1-\Sigma X^2k/n$ developed by Ni et al. (2002) where, X^2k represents the frequency of the k^{th} allele, and n represents the number of genotypes.

Development of Core SSR Marker Set for DNA Fingerprinting (DUS testing)

Based on their specific discrimination capacity of SSR markers, the core marker set was developed with the following criteria: (1) PCR banding pattern of SSR fragments (2) the presence of rare allele (3) PIC values and (4) marker's reproducibility. Furthermore, the genetic fingerprint map of tested maize genotypes was constructed using the coding-based system with the original allele size coded by the assigned numeric values which set in two numeric codes from "01", "02", "03", etc. The transformation was generated to all cores SSR ID set based on allele size (bp) range. The final SSR fingerprinting map of maize genotypes was produced to support variety identification and DUS testing on PVP system.

RESULTS AND DISCUSSION

Amplification Profile, SSR Polymorphism and Cluster Analysis on Diversity Assessment

SSR markers have been proven to be powerful tools in the assessment of genetic variation within and among the species. A total of 24 SSR primers were used for identification of maize genotypes through evaluation of DNA fragment polymorphisms. A total number of 101 alleles were detected with a range from 2 to 9 alleles per locus. These varied number of alleles indicated that there is a high level of genetic diversity among tested genotypes. The primer pairs bnlg1028 showed the highest number of 9 alleles per locus, umc1248 showed 8 alleles in all tested genotypes and umc1586, bnlg1940 and dupssr12 showed 6 alleles in all samples (Table 2).

Table 2 Data on number of alleles, total number of alleles, and PIC value obtained among 14 maize genotypes for 24 SSR markers

No.	SSR marker	No. of alleles	Total no. of alleles	PIC value	No.	SSR marker	No. of alleles	Total no. of alleles	PIC value
1.	umc1397	4	20	0.63	13.	bnlg1617	4	14	0.72
2.	umc2234	3	20	0.62	14.	umc1520	5	22	0.71
3.	dupssr12	6	30	0.77	15.	umc1248	8	38	0.85
4.	umc1542	3	20	0.62	16.	umc1393	3	15	0.66
5.	umc2372	4	19	0.70	17.	umc1671	5	24	0.59
6.	bnlg1940	6	28	0.74	18.	umc2395	3	16	0.53
7.	bnlg1160	3	23	0.63	19.	bnlg1065	3	20	0.65
8.	umc1501	4	16	0.73	20.	umc1586	6	48	0.80
9.	umc2061	4	16	0.72	21.	umc2359	2	14	0.41
10.	umc1101	3	19	0.61	22.	umc1962	5	34	0.77
11.	umc1752	2	14	0.50	23.	bnlg1518	4	18	0.67
12.	umc1792	2	15	0.48	24.	bnlg1028	9	36	0.78

The Polymorphism Information Content (PIC) value reflects the evidence of allele diversity and allele frequency among the tested genotypes (Pervaiz et al., 2009). In present study, PIC value ranged from 0.41 to 0.85 with an average value of 0.66 (Table 2). The highest PIC value was obtained for umc1248 followed by umc1586, bnlg1028, dupssr12, umc1962, bnlg1940, respectively. The PIC values of umc1248, umc1586, bnlg1028, dupssr12, and umc1962 were higher than 0.75 that were considered as the best markers for studied genotypes.

The SSR markers with PIC value of 0.5 or higher indicate that these are highly informative and extremely useful in distinguish the polymorphism rate of a marker at a specific locus (DeWoody et al., 1995). In this study, the genetic diversity of each SSR locus appeared to be associated with number of alleles detected per locus, i.e. the higher the PIC value of a locus, the higher the number of allele detected.

Moreover, the amplification profile of the 14 maize genotypes using 24 SSR markers sets showed alleles of different molecular weight, and displayed the higher polymorphism among the tested genotypes (Fig. 1). Our study highlighted the detection of genetic variability among the tested maize genotypes and also agreed the finding of polymorphic SSR markers by Liu and Muse (2005).

Cluster Analysis is a classification to determine whether the genotypes could be regarded as consisting of a number of partially dissociated groups. Genetic dissimilarities obtained from SSR marker data of 9 hybrids and 5 inbred maize genotypes were used to create a cluster diagram using Nei's genetic distance and the unweighted pair group method (UPGMA). Clustering analysis for 14 maize genotypes could be fully distinguished from one another and grouped into five major clusters (Fig. 2).

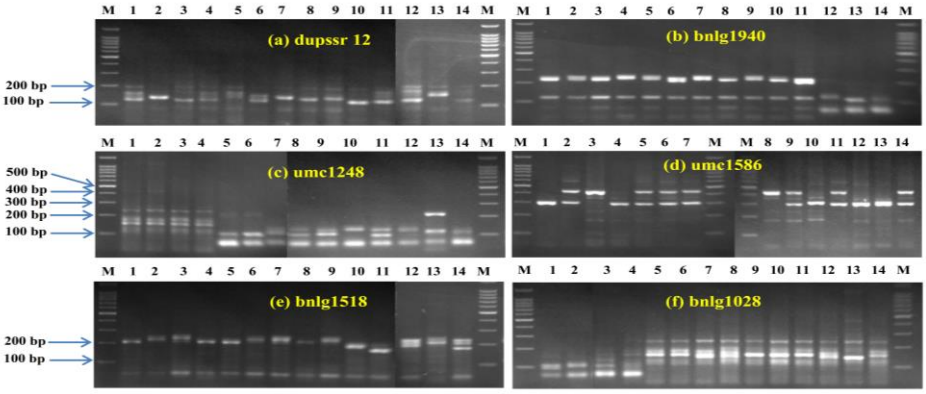

Fig. 1 Amplification of DNA profiles of the 14 maize inbreds and hybrids generated by SSR primers

(a) dupssr 12 (b) bnlg1940 (c) umc 1248 (d) umc 1586 (e) bnlg 1518 and bnlg 1028. Lane M = 100bp DNA Ladder.

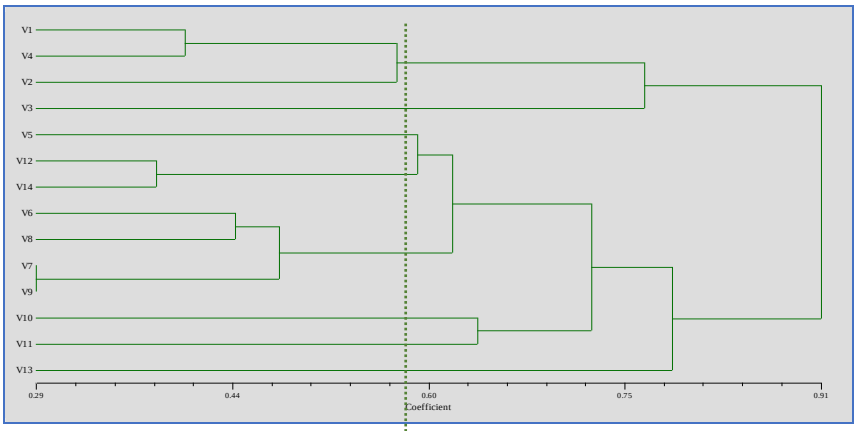

Fig. 2 UPGMA clustering tree of 14 maize genotypes based on Nei's genetic distance

Development of Core SSR Marker Set for DNA Fingerprinting (DUS testing)

The goal of development of core SSR marker set for genotype identification is to maximize distinguishing ability of each marker with a minimum number of markers set in DNA fingerprinting. In this study, the core marker candidate was decided with the selection criteria such as detection rate of the SSR fragment, the presence of rare allele, PIC value, and reproducibility and PCR band pattern of SSR fragments. As a result, six SSR primer pairs were selected as a final marker set for variety identification, i.e., dupssr12, bnlg1940, umc1248, umc1586, bnlg1518 and bnlg1028 due to their characterization and discrimination capacity. These polymorphic marker

pairs revealed that there were four to nine differentiated loci among all genotypes with a fragment length of 50-57 bp to 600 bp across loci (Table 3).

Table 3 Coding system of selected six SSR marker set based on allele size (bp) range

Code	dupssr12	bnlg1940	umc1248	umc1586	bnlg1518	bnlg1028
01	110-115	60-64	50-57	166-182	162	75
02	120-128	106-118	100	237	180	100
03	135-140	121-125	112-120	282-310	190-213	110
04	150-160	212-220	125	341-358	225-238	138
05	170-175	225-234	150	400-415		162
06	197-200	237-240	175-180	600		150
07			200-210			175-187
08			230-232			200
09						246-250

Table 4 SSR fingerprinting map of 14 maize genotypes based on their allele size codes

Genotype name	dupssr12	bnlg1940	umc1248	umc1586	bnlg1518	bnlg1028
Asia Seed (A.55)	020406	0205	050608	03	03	0103
Asia Seed (A.99)	03	0205	050608	030506	04	0104
AA-737	0206	0205	050608	01020405	04	020409
GT-722	0206	0206	050608	010304	03	020609
NK-625	040506	0206	010207	0102030405	03	060709
KMHE-3550	0203	0204	010207	01030405	04	060709
CP-111	03	0205	0103	030405	04	060709
NK-621	0206	0204	010204	010405	03	060809
TSF-1633	0206	0205	010203	0102030405	04	0609
YZI-10-054	0106	0204	0104	01020304	02	0609
YZI-10-095	010304	0204	010204	030506	0102	060709
PAC-999	020506	0103	0104	01030406	0304	0609
C7	0406	0102	010307	0304	03	0509
YZCI-16-019	0206	0103	0103	01030405	020304	060709

This allele size can be assigned as a specific DNA fingerprinting band of the genotypes and can be used as the maize variety identification. The primer bnlg1028 was found the best marker for the identification of studied genotypes as revealed by higher PIC values and showed the highest polymorphism. In other study, DNA fingerprinting with SSR set of tested maize genotypes were fully distinguished from one another compared to the specific SSR markers which differentiated maize hybrids from their parental inbreds (Jhansi et al., 2015). In this study, the genetic fingerprint map of 14 maize genotypes was constructed using the coding-based method with the original allele size coded by the assigned numeric values and the specific marker's allelic fragments were transformed into combine codes as final identity of the genotype, shown in Table 3 and Table 4. By using the core marker set, the results of assigning numeric code or ID described a specific identity of the variety (genotype) that can quantitatively differentiate it from the others. In this study, 14 maize varieties had unique profile ID to support plant variety protection and breeder right, complementing tools for DUS testing purpose. It is noted that these findings not only met the requirements for the minimum number of primers but were also sufficient to fully distinguish the 14 varieties from one another.

CONCLUSION

The goal of this research is to develop DNA fingerprinting catalogue of maize genotypes (both inbreds and hybrids) using SSR polymorphic information and their genetic variance supporting Myanmar maize DUS guidelines. In this study, the six pairs SSR sets generate the genetic fingerprint map (coding system) of typical maize genotypes which can be used in DUS testing for identification of hybrids and inbreds at any stage of crop growing cycle. Furthermore, molecular based SSR testing provide a higher degree of detection efficiency in DUS testing than traditional morphological based DUS method with regard to the verification of new varieties or genotypes.

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Research article

Toxicity of Plant Essential Oil from Khok Phutaka Resources Protection Area, Khon Kaen Province Against Storage Pest, *Sitophilus oryzae*

DUANGRAT THONGPHAK*
Entomology Section, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
E-mail: duathg@kku.ac.th

PRAPAPORN PIANGSUWAN
Entomology Section, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

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Abstract Botanical insecticides may offer an alternative solution for pest control. The objective was to test on the repellant, contact, and fumigant effect of the essential oils of 10 indigenous plants from Khok Phutaka Resources Protection Area, Khon Kaen Province including *Limnophila aromatica*, *Piper sarmentosum*, *Clausena harmandiana*, *Streptocaulon juventas*, *Litsea glutinosa*, *Thunbergia laurifolia*, *Eupatorium odoratum*, *Rothmannia wittii*, *Ficus altissima*, *Clausena harmandiana* and *Gymnopetalum integrifolim* to control the rice weevil, *S. oryzae*. The essential oils of plants were extracted by using hydro-distillation method and then they were tested against rice grain weevil, *S. oryzae* for contact, fumigant and repellent activities in laboratory condition. Adults of weevil were different tested oil at the concentrations of 0, 25, 50, 75 and 100 percentage (w/v). The maximum repellency action, 80% when *L. glutinosa* oil, at the concentrations of 100% (w/v) were applied for after 72 hours follow *by L. aromatica* (73.33%) at the concentrations of 25% (w/v) were applied for after 2 hours. The fumigant and contact test of all 10 essential oils resulted in all lower rate mortality (less than 50%), at all the concentrations.

Keywords essential oil, *Sitophilus oryzae*, repellency, fumigant, contact, Khok Phutaka Resources Protection Area

INTRODUCTION

The rice weevil, *Sitophilus oryzae* Linnaeus 1763 (Coleoptera: Curculionidae) is a serious and severe insect pest of stored products (Park, 2003) and one of the most widespread and destructive stored product pests of rice throughout the world. Treatment of rice with synthetic insecticides is not recommended because of direct and indirect health hazards to humans. Plants are sources of natural insecticides that are produced to defend themselves against those insect pests. Many plants are rich in secondary compounds with insecticidal activities. The several efforts have been focused on the use of plant derived materials including essential oils as bio insecticides.

OBJECTIVE

The objective of this study was to screen plant oils of 10 indigenous plants from Khok Phutaka Resources Protection Area, Khon Kaen Province as repellent contact and fumigant against adults of rice weevil, *S. oryzae.*

METHODOLOGY

Insect Rearing

Adults of *S. oryzae* were reared in the laboratory conditions at 25 ± 2ºC, 46.8 ± 5.0% R.H. Approximately, 50 of *S. oryzae* adults were placed in 11×10×5 cm plastic containing 500 g of rice grains. Colonies were reared on whole rice grains in plastic container. The insects were reared for several generations on rice. For the bioassays, the F1 generation of the adults from the rearing was used.

Extraction of Essential Oil

Ten of indigenous plants were collected from Khok Phutaka Resources Protection Area, Khon Kaen Province (Table 1). The essential oils of plants were extracted by using hydro-distillation method.

Table 1 Plant essential oils used in the study

Scientific Name	Family	Plant used
Litsea glutinosa	Lauraceae	Leaves
Thunbergia laurifolia	Acanthaceae	Leaves
Streptocaulon juventas Merr	Asclepiadaceae	Leaves
Ficus altissima	Moraceae	Leaves
Eupatorium odoratum L.	Asteraceae	Leaves
Rothmannia wittii	Rubiaceae	Leaves
Clausena harmandiana	Rutaceae	Leaves
Gymnopetalum integrifolim Kurz.	Cucurbitaceae	Leaves
Limnophila aromatica (Lam.) Merr.	Plantaginaceae	Whole plant
Piper sarmentosum Roxb.	Piperaceae	Leaves

Repellent Activity Bioassay

The repellency test was used the area preference method based on Lü and Ma (2015). The essential oils of plants were diluted in acetone to prepare different concentrations (25, 50, 75 and 100% (w/v)). Pure acetone was used as the control. Each treatment was replicated five times. The number of insects present on the control and treated regions were recorded to 1, 2, 3, 4, 5, 6, 12 and 24 hours after treatment. Mean number of insects present on the control (NC) and treated (NT) regions during the experiment were used to estimate the Percent Repellency (PR) which was equal to [NC/(NC+NT)] × 100 (Nerio et al., 2009).

Contact Toxicity Bioassay

The contact toxicity test was done by the used of impregnated filter paper test method modified from Fournet et al. (1996). The essential oils of the plants were diluted in acetone to prepare four different concentrations (25, 50, 75 and 100% (w/v)). Controls were treated with acetone alone. Ten adults of *S. Oryzae* were released separately into each petri dish and covered with a lid. Five replicates of each treatment and control were set up. Mortality was recorded after 24, 48, and 72 hours. Mortality rate was estimated and corrected according to Abott's formula (Abbott, 1925)

Fumigant Toxicity Bioassay

The fumigant toxicity test was conducted by using space trial test method based on Keita et al. (2001). Series of dilutions of essential oils were prepared different concentrations (25, 50, 75 and 100% (w/v)) using acetone as a solvent. Five replications of each treatment were set up. Controls were maintained in the similar way with the solvent only. Mortality was recorded after 24, 48, and 72 hours. Mortality rate was estimated and corrected according to Abott's formula (Abbott, 1925).

RESULT AND DISCUSSION

Ten different plant oils were tested against the adults of *Sitophilus oryzae* at concentrations of 25, 50, 75 and 100% (w/v) for repellent activity, contact toxicity and fumigant toxicity tests.

Repellent Activity Bioassay

In general, repellency increases with increase in concentration in the treatment. The result indicated variation among the essential oils tested. The Percent Repellency (PR) ranged from 23.33 to 80.00%. The maximum repellency action, 80% when *L. glutinosa* oil, at the concentrations of 100% (w/v) were applied for after 72 hours follow by L. *aromatica* (73.33%) at the concentrations of 25% (w/v) were applied for after 2 hours (Fig. 1). Arshad et al. (2013) that tested the repellents of guava leaf extracts found 20% (w/v) concentration of *P. guajava* was the one with the highest repellent effects on *S. oryzae* with mean % repellent of 70.3% (class 4) might be attributed to presence of some aromatic monoterpenoids that are major constituents of family Mytaceae (Isman, 2000) and this substance is a group of substances found in *L. aromatica* as well (Vairappan and Nagappan, 2014).

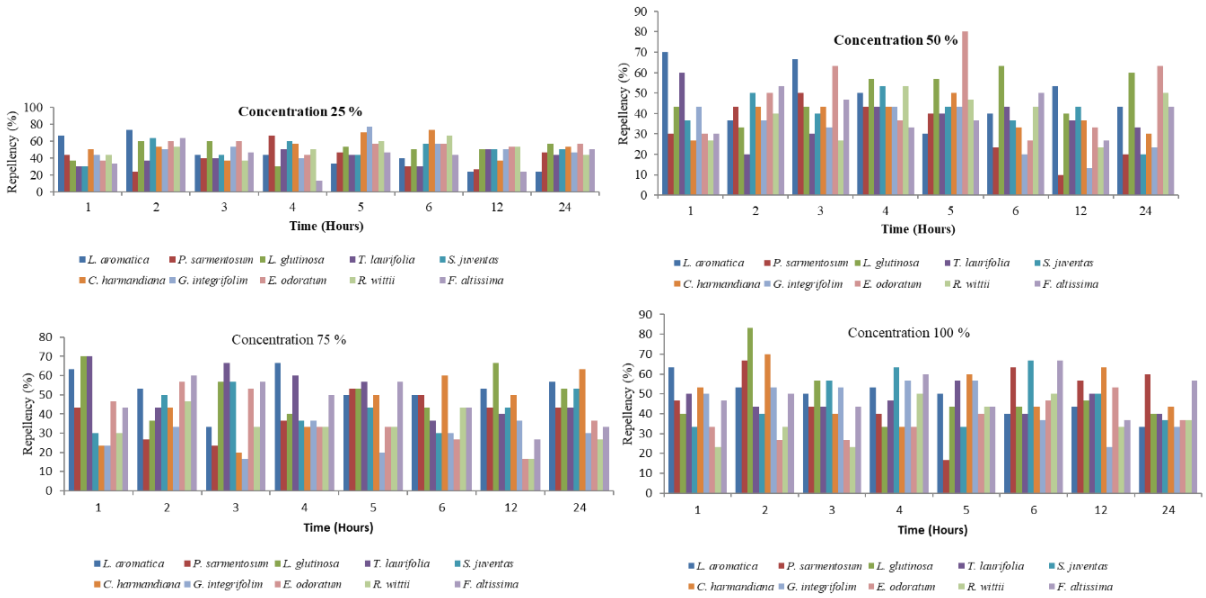

Fig. 1 Comparison percent repellency (PR) of the 10 essential oils with different concentration to *Sitophilus oryzae* adults after exposure time using the area preference method

Contact Toxicity Bioassay

Mortality of *S. oryzae* varied from 0 to 30% after 24, 48, 72 hrs. of treated of 10 essential oils of plants at 25, 50, 75 and 100 concentrations (w/v). These results demonstrate (Fig. 2) that the efficiency of the oils was directly related to concentration and exposure time. Oil from *R. wittii* was the most efficient, causing 30% mortality at concentrations of 100% (w/v) in 72 h. The result indicated that all concentrations are lower rate mortality. Some other studies have found different result from this study such as Mattana et al. (2018) showed that the essential oil of *P. sarmentosum* leaves showed strong contact and fumigant toxicity at 72 h against adults of *S. oryzae*. Differences may be due to the collect from different seasons of the year, soil type and climate, among others

Fumigant Toxicity Bioassay

The result of fumigant toxicity (Fig. 3) showed that adult rice weevil exposure to the 10 essential oil of plant different concentration had lower effect on mortality (less than 50%) except the oil from *T. laurifolia* was the most efficient, causing 56% mortality at 100% (w/v) concentration in 72 hr. Fumigant toxicity of the essential oils gradually increased with increasing exposure time and concentration. Fang et al. (2010) reported that the essential oil of *Carum carvi* L. fruit was insecticidal activity against the maize weevil and red flour beetle adults. Mishra et al. (2012) reported that the essential oils of *Syzygium aromaticum* and *Aegle marmelos* have fumigation toxicity against *S. oryzae* at 48 hours exposure were the LC_{50} values 15.3 and 16.1 µl respectively.

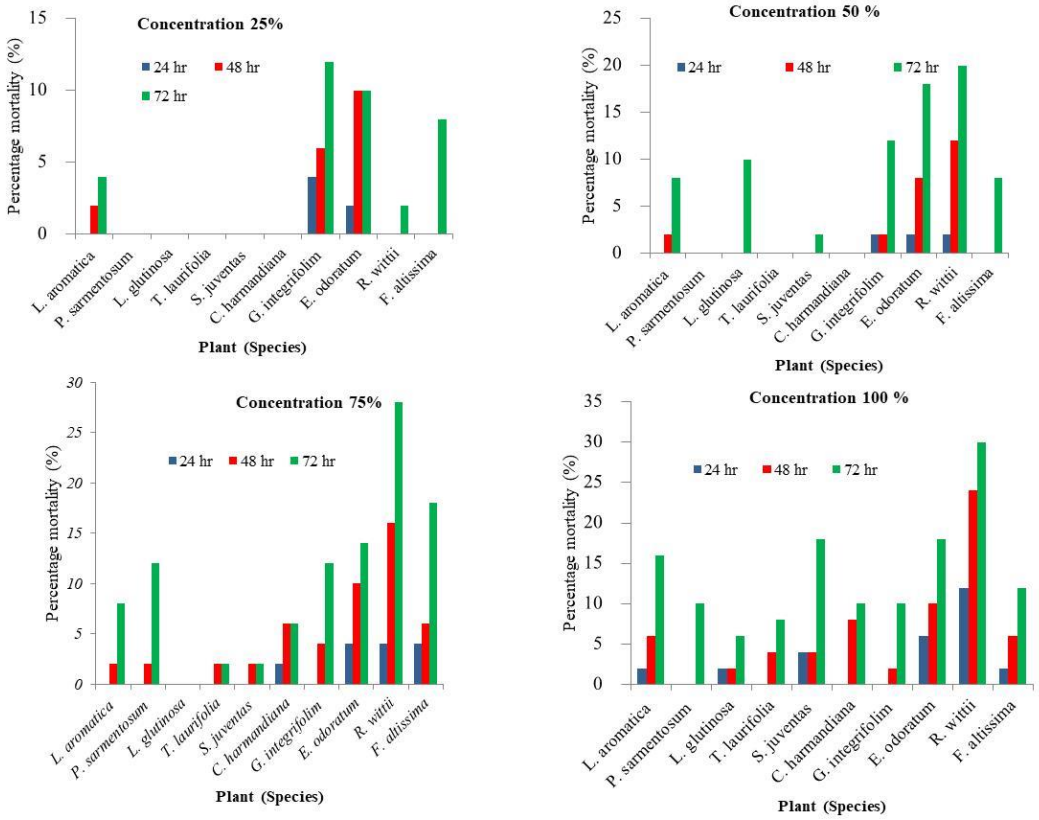

Fig. 2 Comparison contact effect of plant extracts with different concentration to *S. oryzae* adults after exposure time using impregnated filter paper test

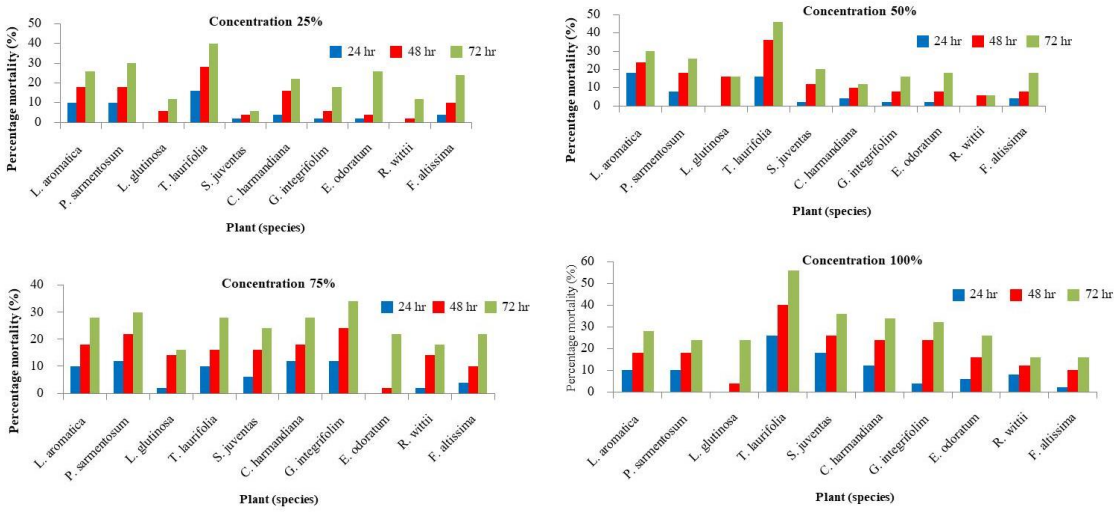

Fig. 3 Fumigant effect of plant extracts with different concentration to *S. oryzae* adults after exposure time using space trial test

CONCLUSION

The results obtained in this study demonstrate that the essential oils tested can be used to control stored grain pests and to support further studies. The toxic effects of essential oils involve many factors, among which are the entry point of toxins, and which may have contact, fumigation, and repellent effects. However, in the present study some of the plant oils did not show any mortality or showed least mortality which might be due to the presence of weak volatile compounds. However, the results of this study indicate that the essential oils might be useful for managing the insect pests in storage especially *S. oryzae*.

ACKNOWLEDGEMENTS

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Research article

Microbial Behavior in Cambodian Homemade-style Pickles

SHUKI MURAMATSU*
Faculty of Health and Food Sciences, Showa Women's University, Tokyo, Japan
Email: s-muramatsu@swu.ac.jp

SOKLY SORM
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan

MASATAKA UCHINO
Faculty of Life Sciences, Tokyo University of Agriculture, Tokyo, Japan

MOTOE SEKIDO
Department of Food and Nutrition, Yamanashi Gakuin Junior College, Tokyo, Japan

YOSHIKI MURAMATSU
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

DAIKI OKA
Faculty of Applied Biosciences, Tokyo University of Agriculture, Tokyo, Japan

YURI TANIOKA
Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Tokyo, Japan

TAKAHIKO NAKAMURA
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

TORU NAKAJIMA
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

MARI ARIMITSU
Extension Center, Institute of Environmental Rehabilitation and Conservation, Tokyo, Japan

MACHITO MIHARA
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

Received 26 January 2022 Accepted 2 May 2022 (*Corresponding Author)

Abstract Pickled products made using vegetables are popular in Cambodia. Many types of homemade pickles are sold at wet markets. Our previous study showed that pickles are seriously contaminated by microbes, including food poisoning bacteria. Such contamination may depend on several factors. The objectives of this study were to investigate the levels of contaminating microbes and their growth patterns in pickles prepared according to traditional Cambodian recipes and to suggest an improved method to ensure the microbial safety of homemade pickles. Three kinds of pickles, namely cucumber pickles with or without fish sauce and bok choy pickles, were prepared following the methods used by local people. Five sample bottles for each kind of pickle were prepared to observe changes in their characteristics over time. The Brix values, salt concentrations, and pH of the samples were measured. Next, we conducted microbiological examination of the samples by testing the presence of total viable bacteria, coliforms, and fungi. More than 5.00 $\log_{10}$ CFU/g of total bacteria were detected in all pickle samples at day 0; moreover, the number of bacteria increased until day 4. A similar concentration of coliforms was observed. Some samples tested positive for fungi. In conclusion, all samples were contaminated by harmful

microorganisms that may cause food spoilage. The results of this study revealed that microbial growth occurred in all tested pickles, resulting in a high risk of food spoilage and food poisoning. We suggest that an additional step of pasteurization would help provide microbiologically safe products. Moreover, use of food additives that do not alter the taste of pickles may allow maintenance of low levels of microorganisms.

Keywords pickles, microorganisms, contamination, microbial quality

INTRODUCTION

Pickled products made using vegetables are popular in Cambodia. Many types of homemade pickles are sold at wet markets. In our previous study, we showed that pickles are seriously contaminated by microbes, including food poisoning bacteria (Muramatsu, 2020a, b). Despite the seriousness of this issue for local people in Cambodia, there are few reports on the food safety of homemade products. In particular, lack of surveys on food poisoning cases in the local population makes it hard to grasp the current state of food safety in Cambodia.

Food safety is a pivotal issue for all countries. Indeed, food safety and/or food sanitation is indispensable for human quality of life and promotes not only good health but also economic growth (Fung, 2018). Nevertheless, the World Health Organization (WHO) reported approximately 600 million cases of foodborne illness and more than 400,000 cases of death from foodborne illness in 2010 (WHO, 2015). Foodborne illness is a serious threat in both developing and developed countries. Most outbreaks of illnesses associated with food consumed at home have been under-diagnosed and/or under-reported (Redmond and Griffith, 2003; Keegan, 2009; Vrbova, 2012). In particular, it is estimated that less than 1% of such cases are reported in developing countries (Satcher, 2000). Especially in developing country, food poisoning incidents are underestimated (Bhaskaran et al., 2020; Rusnan et al., 2020; Le et al., 2021). Thus, investigating only food poisoning incidents that have been reported is not sufficient to ensure public health.

Contamination of homemade-style pickles may have several causes. For instance, microbial behavior during the preparation of pickled products is plausibly associated with food contamination. Therefore, in this study, we focused on microbial quality of homemade pickles and highlight existing issues in cooking methods and types of ingredients and seasoning used for their preparation.

In this study, three kinds of pickles, namely cucumber pickles with and without fish sauce, and bok choy pickles were prepared following the methods used by local people. The samples prepared in this study showed a highly risk to food poisoning. We aimed to investigate the microbiological quality of homemade pickles and suggest an improved method to obtain safe homemade products.

OBJECTIVE

The objectives of this study were 1) to determine the microbial quality and nutritional properties of homemade-style pickles, and 2) to suggest an improved method to obtain safe homemade products.

METHODOLOGY

Materials and Pickle Production Process

Three kinds of pickles were prepared according to recipes used by local Cambodians. The ingredients and seasonings of the pickles are shown in Table 1. Sugar, salt, soy sauce, and fish sauce were purchased in Cambodia and used for seasoning. The other materials used were purchased in Japan. Bok choy was used instead of mustard because of unavailability of the latter. Bok choy belongs to the *Brassica* genus similar to mustard. Cucumbers were washed with tap water and pat dried with a paper towel. The cucumbers used for sample A were rubbed with salt, compressed using a weight, and left to stand for 60 minutes. Then, the salt on the surface of the

cucumbers was wiped off with a paper towel. The cucumbers were cut to fit into a glass bottle and used until the stem end and the tip. For bok choy, the end of each bunch was first cut off, and leaves were separated from the stalks. The leaves were then washed with tap water and pat dried with a paper towel. Garlic and a small onion were peeled and sliced. A piece of chili was sliced into rings. After placing the mixed ingredients and liquid seasoning into glass bottles, these were kept at 30°C for 4 days until the products were ready (Fig. 1). Since the original homemade-style process includes keeping the mixture under the sun for 4 days, in this study, the pickles were kept at 30°C under conditions close to those of the traditional method. Five samples for each kind of pickle were prepared in order to observe changes in their characteristics over time. A mixed sample was kept at 30°C for 30 minutes and used as the sample at day 0. Another sample was kept at 30°C for 20-24 hours and considered the sample at day 1, and samples at days 2-4 were prepared in a similar manner. The samples were stored at 4°C for subsequent analysis.

Table 1 Ingredients and seasonings used in the three kinds of pickles

Ingredients and seasonings	Sample A	Sample B	Sample C
	Cucumber with fish sauce	Cucumber without fish sauce	Bok choy
Cucumber (g)	500	500	-
Bok choy (g)	-	-	500
Steamed rice (g)	-	-	18.0
Sugar (g)	80.0	-	6.0
Salt (g)	70.0	17.5	16.0
Soy sauce (mL)	48.0	-	-
Fish sauce (mL)	48.0	-	-
Hot water (mL)	300	-	-
Water (mL)	-	400	400
Garlic (g)	15	18.75	-
Small onion (g)	5	-	-
Chili (piece)	1	1	-

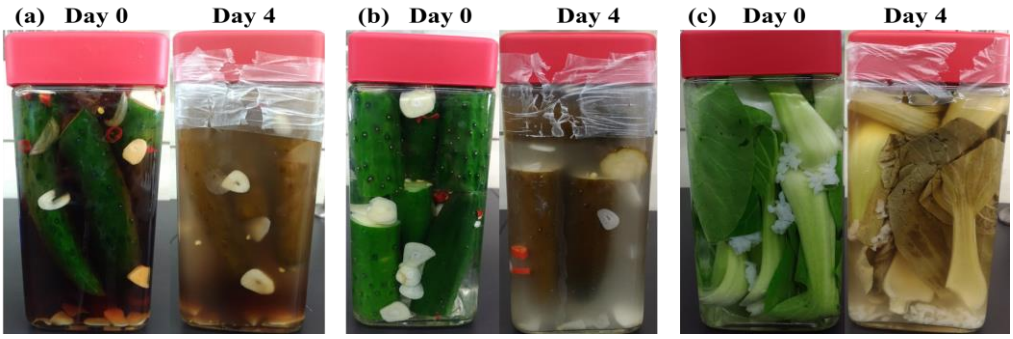

Fig. 1 Appearance of pickles at day 0 and day 4
(a) sample; cucumber with fish sauce, (b) sample B; cucumber without fish sauce, and (c) sample C; bok choy

Measurement of Food Properties

Since the sugar and salt contents and pH of foods affect microbial growth, their values can be good indicators of the preservability of food. Therefore, we measured the Brix sugar content (soluble solids content), salt content, and pH of the pickled liquid of the samples using a Brix refractometer (Atago, Tokyo, Japan), a salt meter (Horiba, Kyoto, Japan), and a pH meter (Horiba), respectively, for all prepared samples.

Detection of Microbes in the Samples

After collecting all samples, several microbial detection assays were performed. Ten grams of each sample containing pickled ingredients and seasoning liquid was mixed with 90 mL of Maximum Recovery Diluent (Merck KGaA, Darmstadt, Germany) solution in a sterilized storage bag. To obtain homogeneous suspensions, samples were homogenized using a Stomacher blender. After stomaching, 1 mL of sample suspension was mixed with 9 mL of Maximum Recovery Diluent solution in a sterile tube. A series of diluted samples was used for the detection of total viable bacteria, coliforms, and fungi. Standard agar medium (AS ONE, Osaka, Japan) was used for the detection of total viable bacteria. Desoxycholate agar medium (AS ONE) was used for the detection of coliforms. Solid plates were incubated at 35 ℃ for 48 hours. For the detection of fungi, plates with Potato Dextrose Agar medium (AS ONE) were incubated at 30 ℃ for 5 days.

RESULTS AND DISCUSSION

Nutritional Properties of Pickles Prepared According Traditional Recipes

The nutritional properties of the final pickled products are shown in Table 2. Sample A showed the highest Brix value and salt concentration. The measured pH values varied slightly among replicates. The pH value could be affected by the microbes present in the samples; therefore, differences in the identity of contaminating microorganisms would result in variations in pH.

Table 2 Nutritional properties of final pickled products

Measured item	Sample A	Sample B	Sample C
	Cucumber with fish sauce	Cucumber without fish sauce	Bok choy
Brix	11.2	4.4	4.7
pH	4.55	4.5	4.88
Salt (%)	5.1	2.3	2.4

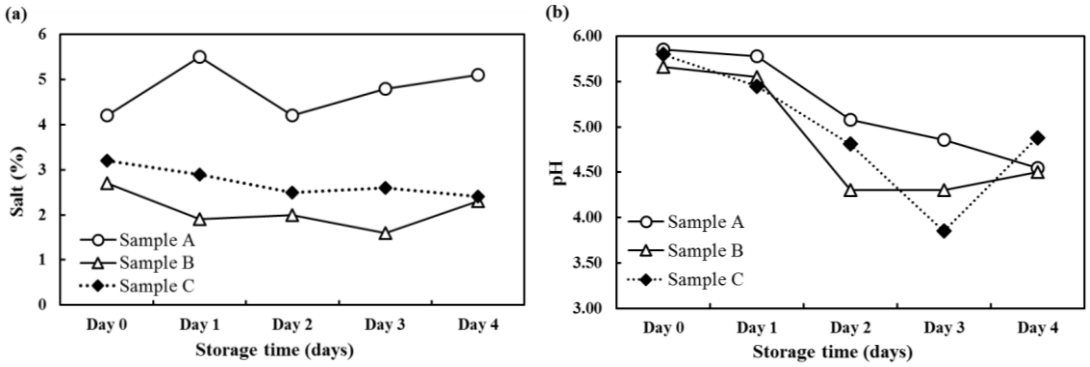

Fig. 2 Changes in chemical properties of the three kinds of pickles (a) salt concentration and (b) pH

The Brix values of all pickles did not change much from day 0, just after pickling, to day 4, and were approximately constant (data not shown). The lack of decreasing Brix values indicates that the microorganisms in samples A and C were unlikely to utilize sugar. During the 4-day storage period, the salt concentrations in samples B (cucumber without fish sauce) and C (bok choy) decreased slightly, whereas that in sample A (cucumber with fish sauce) remained almost constant (Fig. 2(a)). All samples first displayed pH values of approximately 6, but these gradually decreased over time (Fig. 2(b)). Decreasing pH values indicated that the microbes in the samples produced acids. *Clostridium botulinum*, which can trigger deadly diseases, can grow at a minimum pH of 4.6. Improper home canning of vegetables and improperly fermented and processed foods have caused outbreaks in many countries (Matthews, 2017). In particular, pickles in sealed containers with pH higher than 4.6 seem to have considerable potential to cause severe food poisoning. Moreover, the Brix value and salt concentration of pickles are presumably not sufficient

to inhibit the growth of most bacteria and yeasts; therefore, molds grow regularly in pickles (Matthews, 2017).

Microbial Behavior in Homemade Pickles

A total of five samples (from day 0 to day 4) for each of the three kinds of pickles were used to observe changes in microbial composition over time. We tested the presence of total viable bacteria, coliforms, and fungi (Fig. 3). More than 5.00 $\log_{10}$ CFU/g of total bacteria were detected in all pickle samples at day 0; also, the number of bacteria increased until day 4 (Fig. 3(a)). Coliforms were detected at a level similar to that of total viable bacteria. The initial number of coliforms in samples B and C was almost 5.00 $\log_{10}$, and sample A also tested positive for these bacteria. The concentration of coliforms increased until day 4 (Fig. 3(b)). Coliforms are considered indicators of fecal contamination; however, they have been recently acknowledged to be able to grow in non-fecal sites such as food, water, and waste (Matthews, 2017). Therefore, contamination by coliforms, as shown in Fig. 3(b), does not directly imply insanitary conditions. Izumi (2010) reported that vegetables dipped in tap water showed a total bacterial count of approximately 5 $\log_{10}$. This suggests that only washing vegetables with tap water does not eliminate harmful microorganisms.

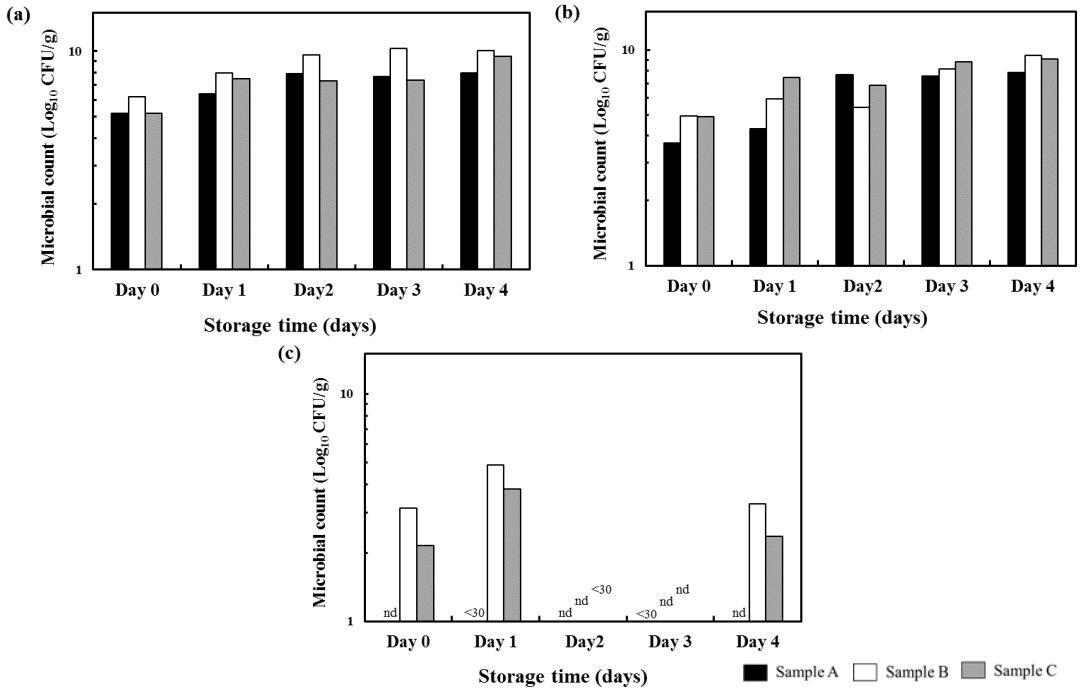

Fig. 3 Changes in the number of microbes in the three kinds of pickles (a) total viable bacteria, (b) coliforms, and (c) fungi

Colony observation on agar plates revealed that many samples were contaminated by dangerous microorganisms that could cause food spoilage. Thus, none of the prepared pickles were safe to eat. Fungi were not detected on day 0 in sample A, and some samples tested negative or positive for fungi on days 1-4. Conversely, samples B and C showed fungal contamination on days 0, 1, and 4. We believe that continuous growth was not observed because each sample for microbial counting was placed in an independent bottle in order to prevent contamination of the sample once opened for analysis. The microflora of vegetables is generally composed by 80% bacteria and 20% fungi (Izumi, 2008). This observation suggests that bacteria remained in all samples prepared by washing with tap water, but fungi were eliminated from some samples. The results of this study suggest that microbial growth occurred in all three kinds of pickles, resulting in a high risk of food spoilage and food poisoning. Therefore, the current production process needs to be modified to improve microbial quality. The addition of a pasteurization step and/or the use of

food additives is an effective and practicable solution. Similar cucumber pickles containing a similar amount of salt, after storage at 30°C for 2 days, were reported to carry 8 $\log_{10}$ CFU/g of total viable bacteria and maintain this initial concentration for 8 days at 4°C (Miyao, 2004). Moreover, some trials of pickle production showed that the products were of uneven quality. This implies that the traditional methods and ingredients used in this study do not allow spontaneous desirable fermentation into safe products.

In this study, pickles were prepared following homemade-style recipes and analyzed for their microbial quality. We suggest that pasteurization is required to obtain microbiologically safe products. Moreover, the use of food additives such as glycine, which does not alter the taste of pickles, sorbic acid, or alcohol during preparation seems to be effective in controlling the concentration of microorganisms.

CONCLUSION

In this study, three kinds of pickles were prepared following local traditional methods. To observe changes over time, five pickle samples were prepared for days 0 to 4. The Brix value, salt concentration, and pH of the pickling liquids were measured, and microbial detection assays were performed. More than 5.00 $\log_{10}$ CFU/g of total bacteria was detected in all the samples at day 0; also, the number of bacteria increased until day 4. Coliforms showed concentrations similar to those of total viable bacteria. Some samples were positive for fungi. In conclusion, all samples were contaminated by harmful microorganisms that could cause food spoilage.

The results of this study revealed that microbial growth occurs in all pickles, posing high risk to food spoilage and food poisoning. We suggest that pasteurization would help obtain microbiologically safe products. Moreover, use of food additives that do not alter the taste of pickles may allow maintenance of low levels of microorganisms.

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Research article

Impact Analysis of Population Growth and Fertilizer Use on Nitrogen Runoff in Nam Ngum Basin, Laos

KOSHI YOSHIDA*
Graduate School of Frontier Sciences, The University of Tokyo, Chiba, Japan
Email: kyoshida@edu.k.u-tokyo.ac.jp

ISSAKU AZECHI
Graduate School of Bioresources, Mie University, Mie, Japan

TOSHIAKI IIDA
Faculty of Agriculture, Iwate University, Iwate, Japan

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Abstract Human population growth has led to increased energy and food production, fertilizer usage and wastewater flows. Increased nitrogen availability is a worldwide cause of eutrophication of rivers, lakes and estuaries, however, quantitative evaluation the impacts of nitrogen loads has been insufficient in developing countries because of poor data availability. The Nam Ngum River basin, Laos, which supplies quality water for domestic use in the Vientiane Metropolis, was selected as the target area for this study. The Nam Ngum River basin is 415 km long with a 17,000 km^2 catchment area, and the main land uses in 2000 were paddy (15.6%), forest (32.3%), shrub (40.3%) and urban (0.2%). By UN estimation, population in Laos is expected to increase 2.1 times from 2000 to 2050, and fertilizer use also will increase to produce sufficient food. Therefore, future water quality is a main concern in this river basin. Meteorological and hydrological data from 1995 to 2004, and spatial data such as topography, land use, and soil properties were collected for model simulation. A conceptual nitrogen balance model with three nitrogen pools was developed and combined with a rainfall runoff model. Simulated river discharge and nitrogen loads agreed with the observed data. Then, we investigated future nitrogen load variations in the basin under different population growth and agricultural modernization scenarios. As a result, even when population in the basin increased 2.1 times, nitrogen load did not change significantly (11,676 tons/year in 2000 and 11,822 tons/year in 2050). However, the fertilizer increase scenario, from 25 kg/ha/season to 50 kg/ha/season, showed significant increase in nitrogen loading, from 11,676 ton/year to 17,010 ton/year. Our results provide initial insight into the magnitude and spatial distribution of nitrogen loading in Nam Ngum River Basin, showing that this type of model may be useful for future impact assessments.

Keywords nitrogen load, point sources, diffuse pollution, agricultural modernization

INTRODUCTION

As the population increases, especially in developing countries, there is a need to increase food production. This can be achieved in two ways: by expanding farmland and by increasing the yield per unit area. The area of agricultural land in the world has already begun to decrease due to soil degradation and other reasons, thus it is difficult to expect a significant increase in the area of agricultural land. Therefore, the most realistic approach is to increase the yield per unit area (i.e. increase the number of crops planted per year by switching to high-yielding varieties and introducing irrigation systems). The introduction of high-yielding varieties, known as the Green Revolution, has increased agricultural productivity, but chemical fertilizer inputs and advanced management of agricultural water (irrigation and drainage) have become prerequisites for cultivation of such crops. As a result, pollution in closed water bodies in Asia has become a problem due to excessive nutrient runoff caused by rapid population increase and the massive

application of chemical fertilizers. The water quality problem is particularly serious in the rapidly developing tropical Asian monsoon region, where more than 30% of the world's chemical fertilizers are applied. Because the population is still increasing, and it is necessary to develop infrastructure to achieve stable food production and water environmental conservation (Tanaka et al., 2013). Normally, water quality is observed at the mainstream only, limiting understanding of the spatial distribution of nutrient runoff from monitoring surveys alone. Additionally, it is difficult to understand the spatial and temporal distribution of water resources and nutrient loading in developing countries due to low observation density and lack of observation data at the tributary level. A variety of methods have been used to model nitrogen transfer in river basins. Conceptual and physically based models (Lee et al., 2006; Conan et al., 2003; Whitehead et al., 2006) describe the processes responsible for nitrogen wash-off into surface water and leaching to groundwater in large heterogeneous basins. Such models allow forecasting and a better understanding of processes. However, even if these facts are well known, few scientific works on water quality in developing countries have been published until recently, because available data are quite limited in such regions. In this study, a water cycle and nitrogen dynamics model, which considered the local cultivation and water treatment system, was developed and applied to a tropical Asian monsoon basin with a paddy rice culture similar to that of Japan.

METHODOLOGY

Study Area

The Nam Ngum River basin in Laos is a tributary of the Mekong River. The river is about 415 km long with a catchment area of about 17,000 km^2. The Nam Ngum 1 dam has an effective storage capacity of 4.7 billion m^3, located in the middle stream of the basin (Fig. 1).

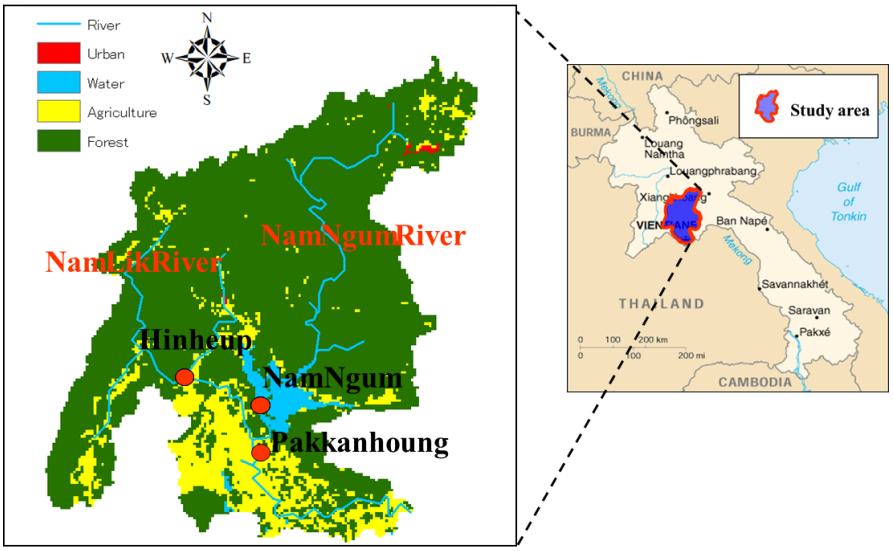


Fig. 1 Nam Ngum River basin

The Nam Ngum 1 dam is dedicated to power generation, and supplies electricity to the Laos capital, Vientiane, as well as exporting it to Thailand. The estimated basin population is 420 thousand persons and the average population density of the basin is about 25 people/km^2. The basin area accounts for 7% of the total land area and the basin population accounted for 9% of the total population of Laos in 2000. The sewerage penetration rate in Laos is estimated to be 19.2%, but this is mainly in urban areas.

Modernization in the agricultural sector is also lagging, with an irrigation rate of only 11%. According to interviews in farming villages near Vientiane, the amount of fertilizer applied is still

low, averaging 25 kgN/ha/season, and some farmers do not apply any fertilizer in rainfed paddy fields. The land use in the basin is paddy fields (16%), forests and bushes (72%), and residential land (only 0.2%). The Nam Ngum 2 dam (effective storage capacity: 2.6 billion tons, completed in 2011) and the Nam Ngum 5 dam (effective storage capacity: 250 million tons, completed in 2012) are already in operation in the basin (Kudo et al., 2013), but this study considered only the Nam Ngum 1 dam, because the meteorological, hydrological data required for the model simulation, and collected from the hydro yearbook published by the Mekong River Commission, were only available from 1995-2004. Water samples were collected monthly at Pakkanhoung station and the total nitrogen concentration was measured at the National University of Laos in 2003-2004. Additionally, a field survey on water use, water treatment, irrigation, and cultivation methods were conducted in the KM6 irrigation area in Nam Ngum basin. The factors affecting the water environment can be broadly classified into point source loadings from people and livestock and non-point source loadings from forest, farmland and urban areas. For the point source load, statistical data, such as those on population and number of livestock, were collected from the Bureau of Statistics, and the units of nitrogen loading in the Mekong River basin were used (Tanaka et al., 2013). In Laos, households use septic tanks, is the simplest facility in sewage treatment. The tanks receive domestic wastewater, which is treated by sedimentation and anaerobic decomposition before the supernatant liquid is discharged into the drainage river. In Laos, the temperature is high all year round, and the active decomposition of microorganisms is expected to rapidly decompose excreta, but the treatment efficiency is extremely low due to lack of proper maintenance. Livestock excrement is directly disposed in farmland and grassland, then discharged into the ground water system after decomposition and absorption processes in the surface soil.

Rainfall-Runoff Model

To evaluate nitrogen transportation according to the river water flow, a distributed water cycling model was developed and applied to analyze the water balance in the basin. TOPMODEL was employed for the rainfall-runoff analysis. Such a distributed model can include the spatial distributions of topography, land use, and soil characteristics. Therefore, TOPMODEL is widely used for hydrological characteristic analysis, water management, water quality analysis, and future forecasting. TOPMODEL was proposed by Beven and Kirkby (1979) based on the contributing area concept in hill slope hydrology. This model is based on the exponential transmissivity assumption, which leads to a topographic index $\ln(a/To/\tan b)$, where a is the upstream catchment area draining across a unit length, To is the lateral transmissivity under saturated conditions, and $\tan b$ is the local gradient of the ground surface. Fig. 2 illustrates the conceptual structure of the water cycle as estimated by TOPMODEL. Additionally, a dam operation model was combined with TOPMODEL to calculate water storage in the reservoirs (Hanasaki et al., 2007). For details, please see Yoshida et al., 2017.

Nitrogen Balance Model

A conceptual nitrogen balance model considering three pools in soil such as organic N, Ammonium N and Nitrate N was developed for this study, as shown in Fig. 3. Soil N, mainly present in organic form, is almost unavailable to plants.

The vegetation mainly uses inorganic forms of N, which are made available by organic matter decomposition. Soil microorganisms convert the N contained in organic matter in a process called mineralization. Although plants can use both forms of inorganic N, Nitrate is preferred because of its greater solubility in water. In other words, nitrates quickly dissolve in the pore solution, which is taken up by plants. On the other hand, this also means that nitrate is easily leached to groundwater. Ammonium N is less mobile because it strongly adsorbs on clay minerals due to its positive charge. Denitrification is the anaerobic microbial reduction of N, and is used as an electron acceptor, resulting in the transfer of soil nitrogen to the atmosphere.

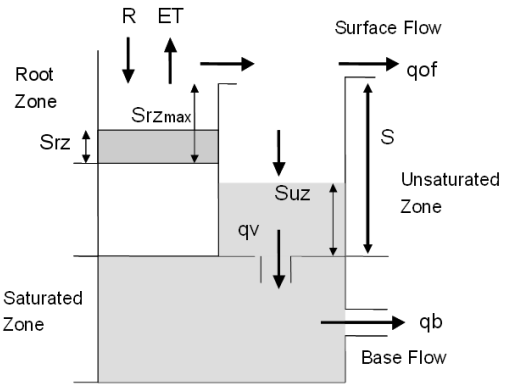
The budget of each pool is expressed in the following equations.

$$\frac{dN_{org}}{dt} = PSNL - MinerN - RunoffN_{org} \quad (1)$$

$$\frac{dN_{ammo}}{dt} = DepoN_{ammo} + FertiN + MinerN - PupN_{ammo} - NitriN - RunoffN_{ammo} \quad (2)$$

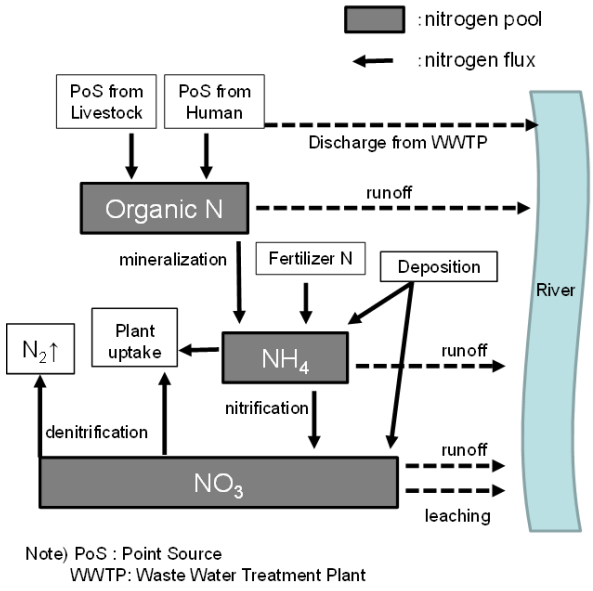
$$\frac{dN_{nitra}}{dt} = DepoN_{nitra} + NitriN - PupN_{nitra} - DenitN - LeachN_{nitra} - RunoffN_{nitra} \quad (3)$$

where N_{org} is organic nitrogen (kg/ha), *PSNL* is input N from point-sources (kg/ha/day), *MinerN* is the mineralization rate (kg/ha/day), *RunoffN* is the nitrogen loss by surface runoff (kg/ha/day), *Nammo* is ammonium nitrogen (kg/ha), *DepoN* is nitrogen deposition (kg/ha/day), *FertiN* is fertilized nitrogen (kg/ha/day), *NitriN* is the nitrification rate (kg/ha/day), *Nnitra* is nitrate nitrogen (kg/ha), *PupN* is the plant uptake rate (kg/ha/day), *DenitN* is nitrate nitrogen loss by denitrification (kg/ha/day), and *LeachN* is nitrate nitrogen loss by leaching (kg/ha/day). For details on the calculation methods for each nitrogen flux and denitrification process, please see Yoshida et al., 2017.



Notes: R:precipitation, ET: evapotranspiration, Srz: storage in root zone, Srzmax: maximum storage in root zone, Suz: storage in unsaturated zone qv: discharge from unsaturated to saturate zone, S: soil water deficit until saturated condition, qof:surface flow discharge, qb: base flow discharge

Fig. 2 TOPMODEL structure



Note) PoS : Point Source
WWTP: Waste Water Treatment Plant

Fig. 3 Structure of the nitrogen balance model in soil

Future Population Growth and Fertilizer Increase Scenarios

According to the United Nations prediction of 2000, the Laos population will increase 2.1 times by 2050. At the same time, chemical fertilizer use will also increase to produce sufficient food by agricultural modernization. This study evaluated the impacts of such population and fertilizer increases on nitrogen loading in the Nam Ngum River basin. In 2000, the total population of Nam Ngum basin was 420 thousand. Therefore, a population increase of 460 thousand people by 2050 was assumed and used for impact analysis. Additionally, we assumed that fertilizer use would increase from 25 kgN/ha/season to 50 kg/ha/season to check the sensitivity of the model.

RESULTS AND DISCUSSION

Using the proposed model, water and nitrogen balances from 1995 to 2004 in the Nam Ngum Basin were calculated at a 1 km × 1 km resolution. The first 5 years of data were used for parameter calibration and the latter 5 years of data were used for validation. Parameters were calibrated by trial-and-error method to maximize the Nash-Sutcliffe efficiency (NSE) of discharge and total nitrogen (TN) concentration at Pakkanhoung (catchment area: 14,300 km^2) station. Fig. 4 shows the observed and calculated river discharge at Pakkanhoung station. The estimated NSE in the calibration and validation periods were 0.54 and 0.50, respectively.

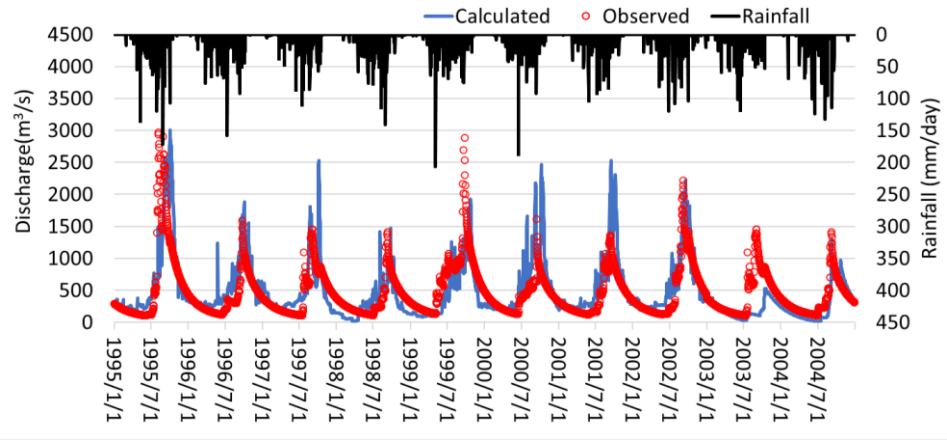


Fig. 4 Calculated and observed river discharge at Pakkanhoung station

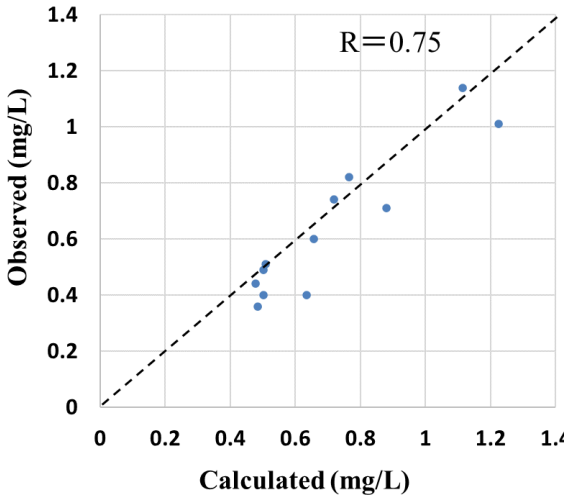


Fig. 5 Calculated and observed TN concentration at Pakkanhoung station

Model performance can be evaluated as "satisfactory", if NSE > 0.50 (Moriasi et al., 2007). The reason for the relatively low accuracy is that the input rainfall was only one point at Pakkanhoung station. Fig. 5 shows a comparison of the calculated and measured TN concentrations at Pakkanhoung station. The data used in this study were TN concentrations that were measured by the authors from 2003-2004; the observed and calculated TN concentrations are compared here. The correlation coefficient between the calculated and observed values was R = 0.75, indicating that the calculated values were slightly overestimated compared to the observed values. The estimated average annual nitrogen load at Pakkanhoung station was 11,676 t/year and 8.1 kg/ha/year per unit area. Fig. 6 shows the spatial distribution of the annual mean TN concentration (1995-2004) and population density (persons/km^2) map in 2000. In the Nam Ngum River basin, the total nitrogen concentration was almost less than 1 mg/L because of low population density and low fertilizer use in the farmland. This analysis found that the total nitrogen concentration was not affected by the spatial distribution of population density but was calculated to be relatively high in the farmland during simulation periods.

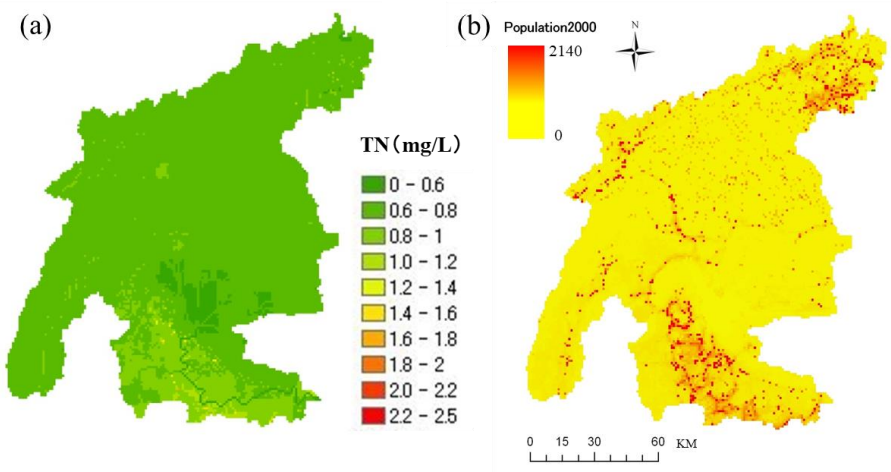


Fig. 6 Spatial distribution of (a)annual mean total nitrogen concentration and (b) population density (persons/km^2)

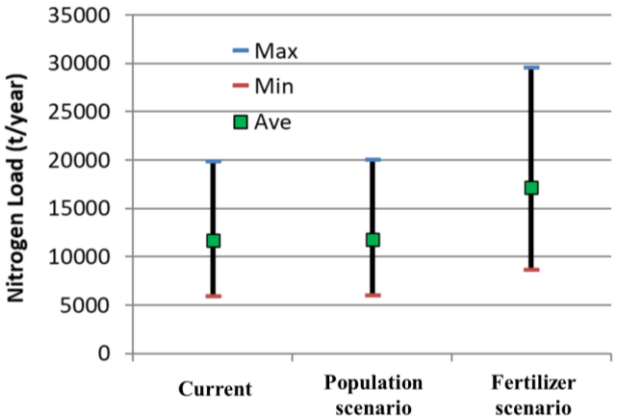


Fig. 7 Change in annual mean nitrogen load under the future scenarios

Fig. 7 shows the change in annual mean nitrogen load under the population growth and fertilizer increase scenarios. The population of the Nam Ngum River basin was 420 thousand in 2000 and will increase 2.1 times to 860 thousand in 2050. The nitrogen load did not change significantly (11,676 t/year in 2000 and 11,822 t/year in 2050) as a result of population increase in the basin. The maximum population density in the Nam Ngum River basin in 2000 was about 2,140 persons/km^2, with most people living in rural areas. Even if the population were to increase by 2.1 times, the population density would remain low; thus, there would be no significant impact on the

water quality environment of the basin. The fertilizer increase scenario, however, from 25 kg/ha/season to 50 kg/ha/season, showed a significant increase in nitrogen loading, from 11,676 t/year to 17,010 t/year. The current fertilizer application rate is 25 kgN/ha, which is extremely low. To increase food production in response to future population growth, it is necessary to increase production per unit area. Therefore, we assumed a scenario of increasing the amount of applied fertilizer and evaluated the impact on the water quality environment of the watershed. Doubling the fertilizer application rate to 50 kg/ha resulted in a 46% increase in the annual nitrogen load at Pakkanhoung station. The nitrogen discharge load per unit area increased from 8.1 kg/ha/year (equivalent of 0.66 mg/L) to 11.8 kg/ha/year (equivalent of 0.95mg/L) under this scenario, however, the water quality environment was still favorable.

CONCLUSION

The Nam Ngum River basin, Laos, which supplies high quality domestic water to Vientiane Metropolis, was selected as the target area for this study. The UN has estimated that the population in Laos will increase by 2.1 times between 2000 and 2050, and producing sufficient food for the higher population will require increased fertilizer use. Therefore, changes in future water quality is the main concern for this river basin. Meteorological and hydrological data from 1995 to 2004, and spatial data such as topography, land use, and soil properties were collected for model simulation. A conceptual nitrogen balance model with three nitrogen pools was developed and combined with the rainfall runoff model. Simulated river discharge and nitrogen loading agreed with the observed data. Next, we investigated future variations of nitrogen loading in the basin under the population growth and agricultural modernization scenarios. As a result, even when population in the basin increased by 2.1 times, the nitrogen load did not change significantly (11,676 t/year in 2000 and 11,822 t/year in 2050). However, the fertilizer increase scenario, from 25 kg/ha/season to 50 kg/ha/season, showed a significant increase in nitrogen load from 11,676 t/year to 17,010 t/year. Our results provide a first insight into the magnitude and spatial distribution of nitrogen loading in Nam Ngum River Basin. This type of model may be useful for future impact assessments.

ACKNOWLEDGEMENTS

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Research article

Nursery Propagation of Apple Mangrove *Sonneratia alba*

ARNIE C. TRANGIA*
Cebu Technological University, Cebu City, Philippines
Email: arnie.trangia@ctu.edu.ph

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Abstract Mangrove rehabilitation conducted on the seafront was a failure because of small survival due to wrong species planted and zonation. Apple mangrove (*Sonneratia alba*), "pagatpat," is the most widely distributed mangrove globally, particularly in coastal regions. The study showed that the *Sonneratia species* bears plenty of fruits, but seedlings rarely grow in the wild. The researcher introduced a ninety-day analysis using various soil media and different watering regimes in a designed concrete tank to determine the survival and growth rates of the nursery propagated apple mangrove seedlings. He observed that the highest average survival rate of S alba seedling was in watering regime Treatment 3 and the type of soil medium was sandy clay. The researcher measured the average survival rate at 23.70% in clay, 52.10% for sandy clay, 44.32% for sandy soil under a watering regime, 37.41% in clay, and 43.21% in sandy clay, and 39.41% in sandy soil. Research showed that the seedlings watered under Treatment 3 observed the highest growth gain (5.41 ± 0.68 cm), while seedlings under Treatment 1 recorded the lowest growth gain (1.87 ± 0.23 cm) under the watering regime. Seedlings planted in sandy-clay soil exhibited the highest growth gain (4.15 ± 0.52 cm), while seedlings planted in clay recorded the lowest growth gain (4.0 ± 0.50 cm) for soil media. Moreover, the researcher observed that growth showed a significant difference in the different watering regimes but had no significant difference in the type of soil media.

Keywords apple mangrove, water regimes, soil media, survival rate, growth rate

INTRODUCTION

The Philippines is ranked fourth out of the 180 countries in the 20 years (2000-2019), following Puerto Rico, Myanmar, and Haiti among the countries most affected by extreme weather according to the Germanwatch report (Global Climate Index, 2021).

Mangroves are a natural coastal defense against violent storms that bring storm surges and flooding. It is one of the most effective mitigating measures against climate change. In addition, mangroves can hold back the sea waves and reduce wave forces with their extensive and dense above-ground roots by an estimated 70-90% on average (Macintosh, 2010). Furthermore, a study conducted by Harada et al. (2012) demonstrated that mangroves are as effective as concrete seawall structures in reducing tsunami-hit house damage behind the forest.

Mangrove systems have contributed significantly to the well-being of coastal communities through a wide array of ecosystem services classified into regulating, provisioning, cultural, and supporting (Manual on Community-Based Mangrove Rehabilitation: Box 1, 2012). Fringing mangroves in the Philippines and the rest of Southeast Asia are naturally lined by a band of *Avicennia marina* and *Sonneratia alba* front-liners with *Rhizophora stylosa* and *R. apiculate* immediately behind (Manual on Community-Based Mangrove Rehabilitation, p. 6, 2012).

Primavera et al. (2014) averred that *Sonneratia alba* (pagatpat) dominates the eastern Panay coastline. The species has been proven superior even to *the Avicennia marina* for the rehabilitation of sandy fringes. Most of the plantations used *Rhizophora species* whose propagules are easy to collect and plant but which cannot withstand wave action. Hence only 10% of these plants survived in open seaward sites in Calauag Bay, Quezon. These activities can best describe as planting by convenience rather than ecology (Primavera, 2005; Primavera and Esteban, 2008).

Avicennia marina and *Sonneratia alba* are the two significant fringing colonizers of the coastlines. However, wildlings are much rarer than the latter, and nursery techniques are relatively undeveloped compared to the first, according to protocols for growing *Sonneratia alba* (Mangrove Manual Series No. 2: Box 7, 2012).

Mangrove rehabilitation/reforestation programs in seafront areas and building coastal greenbelts as a mitigating measure in protecting coastal communities can still be a total failure. Develop the nursery propagation of apple mangrove first since this species is the primary colonizer of the sandy fringing coastlines. It is a suitable mangrove species to be planted in the seafront zone. Moreover, it is bigger, sturdier, and can withstand nature's forces as compared to the usual *Rhizophora species.*

The study used a tide simulation to address the gap using different watering regimes of pure seawater and various soil media. Using a concrete tank regulates the additional watering controls. Inundation of seawater to the seedlings should not be more than 30 percent of the time per day. The production of nursery propagated seedlings will fill the gap of the rareness of apple mangrove seedlings. The establishment of mangrove nurseries can provide mangrove seedlings of the required species in the required numbers and sizes at a given time; otherwise, planting will be highly dependent on the availability of propagules, seeds, or wildlings (Mangrove Manual Series No. 1: Box 3, 2012).

OBJECTIVE

The purpose of this research study is to produce nursery reared apple mangrove seedlings to supply the much-needed right planting materials and to correct the existing practice of coastal mangrove rehabilitation/reforestation using *Rhizophora species*. Specifically, the study aimed to: (1) determine the survival rate of *Sonneratia alba* seedlings reared in three types of soil media using different watering regimes; (2) assess the growth rate of apple mangrove seedlings reared in three types of soil media using different watering regimes; and (3) conduct pilot testing to assess what type of soil media and corresponding watering regime propagated apple mangrove seedlings grow best.

METHODOLOGY

The environment: The researcher conducted apple mangrove (*Sonneratia alba*) nursery propagation research in Daanbantayan, Cebu, Central Philippines.

LEGEND:
T1= watered with seawater once a day (the natural way)
T2= watered once a day (totally submerged for two hours)
T3= watered with seawater twice a day (totally submerged for two hours for each treatment

Fig. 1 The design of the research tank

The concrete tank: The study used a concrete tank measuring 8 meters in length by 2 meters in width by 0.24 meters in depth (8 m x 2 m x 0.24 m.). The tank is further subdivided into 16 compartments; measuring approximately one square meter in area respectively (Fig. 1).

The plant pot and soil media: The research used 18 centimeters in diameter synthetic pots in its top portion by 15 centimeters in height, and it utilized three types of soil media treatments, sandy, sandy clay, and clay. Each treatment used nine pots, each filled with the corresponding soil. Since there will be three treatments with five replications, the total number of banks used was 45 in each treatment or 135 pots for all the three treatments.

Seedling preparation phase: Mature bigger fruits that had no holes bored by insects do not suffer from extreme weather conditions, and were ripe in a good parent tree, were collected early in the morning or late in the afternoon through handpicking. Fruits of *S. alba* will freely fall when ripe and mature and naturally separate from their calyx before dropping to the ground (Fig. 2).

Fig. 2 Ripe fruit and seeds of *Sonneratia alba* ideal for collection

By using the bare hands, macerate the fruits by pressing. Usually, the number of seeds found inside ranged from 80 to 160. The seeds were soaked and washed in a basin with freshwater/rainwater and let stand for a few minutes allowing the viable seeds to float. The seeds were dried for 2 to 3 hours to break seed dormancy. Avoid prolonged drying of sources, for it will affect seed germination.

The study utilized seedboxes measuring 40 x 90 cm. Sandy clay soils were used as soil medium (5-7 cm thickness) and taken from the parent tree area. The seeds were soaked overnight with rainwater to hasten germination. After twenty-four (24) hours, the seeds that showed signs of sprouting were collected and sown in the seedboxes, covered with 2.54 cm-thick soil, and allowed to germinate for one month before transplanting individually. Water the seeds with rainwater diluted with seawater to acclimatize the seeds. After 30 days of propagation from the seedbed, the researcher transplanted the seedlings.

Experimental phase: The tank's 15 compartments should be re-checked carefully for its watertight worthiness by filling the tank with seawater and cross-checking the draining system to see if it functions well. The study closely followed the watering regime scheduled time during the flooding of the tanks. The researcher should do general cleaning of the tank every fifteen days.

Watering regimes: In treatment 1, the plants were watered once, just like ordinary plants. Treatment 2 was submerged once for two hours daily, and Treatment 3 was submerged twice for two hours in each submersion. Two cm above the apex of the seedling's leaves, seawater was inundated. Drain the tank's compartments by pulling out the cover of the drainage pipe after two hours. The researcher simulated treatments like the tide of the sea, which coincides with the study (Kjerfe 1990) that mangroves grow at or above mean sea level or MSL, which is not more than the sea 30% of the time tidally inundated.

Seedling management: The study used three treatments of different soil media and three watering regimes with five replications each. The study needed an adequate and accessible supply of clean seawater to efficiently facilitate the filling-up and drain of the seawater in the tank. The project should strictly follow a watering schedule. After ninety (90) days of managing period, the seedlings are now ready for extension purposes by planting the produced seedlings in the selected rehabilitation areas.

Collection of data: During the initial stage of transplanting, the seedlings had an initial height of 2 centimeters. The researcher measured the seedlings from the top of the soil to the last middle leaf of the plant. Every 15 days, the plant's data, survival, and growth rate were taken and monitored for three months.

Statistical treatment: The study used a Randomized Complete Block Design (RCBD) research design. A two-way ANOVA of SPSS Statistics to get the mean difference to determine if there is a significant difference in survival rate and growth rate in the three watering regimes and three different soil media. The variables studied survival rate and growth rate. The study used following Equation (1) to get the survival rate.

$$\textit{Surviving rate} = \frac{\textit{Number of survivors}}{\textit{Initial number}} \textit{ x 100} \quad (1)$$

The growth rate was taken using following Equation (2).

$$\textit{Growth rate = Height 1 - Height 2/ Height 1 x 100} \quad (2)$$

RESULTS AND DISCUSSION

Survival rate: Figure 3 showed a significant relationship between the watering regime and Sonneratia alba's survival. The survival rate of *S. alba* was highest in Treatment 3, was increased in Treatment 2, but very low in Treatment 1. The experiment implies that the inundation of seawater twice daily favors the survival of *Sonneratia alba* seedlings as long as the submersion time was not more than 30% of the time. The inundation of fresh seawater brought nutrients to seedlings. The *S. alba* average survival rate in the three watering regimes is highest in sandy-clay soil with 43.21%, sandy soil with 39.41%, and clay with 37.41%.

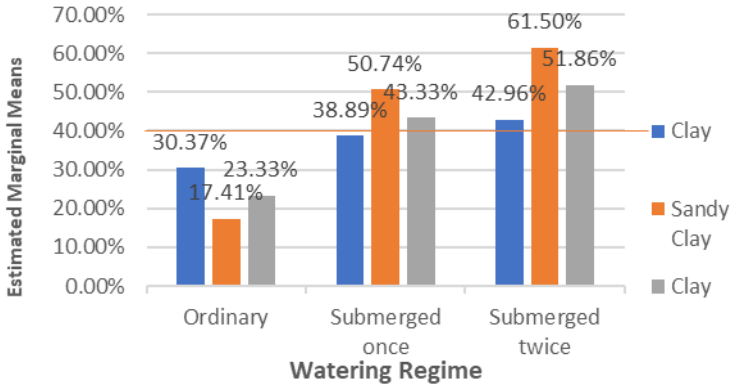

Fig. 3 Survival rate of the apple mangrove seedlings in various treatment

The study implies that in the soil type where most of its parent trees lived, *S. alba* seedlings survive best. However, this is in contrast to Deloffre et al. (2006) and Viles et al. (2008) study, which showed that for both *Aviccenia* and *Sonneratia*, short inundation (5 h day -1) without sediment treatment resulted in 100% survival throughout the experiments.

Results of analysis of variance (ANOVA) computation revealed a significant relationship on the survival of *S. alba* in different watering regimes ($p=.000<0.05$) at a 5% level of probability; but has no meaningful relationship with the survival of *S. alba* in other soil media ($p=0.493 > 0.05$) at 5% level of probability also. Furthermore, it has no significant effect on the survival of *S. alba* seedlings in the different watering regimes and soil type interaction ($p=0.125>0.05$) at a 5% probability level.

ANOVA implies that within the duration of the study the survival of *S. alba* seedlings has a significant difference when watered naturally, submerged once a day, or submerged twice a day but has no significant difference when grown in clay sandy clay or sandy soil. Moreover, the survival

of *S. alba* seedlings has no significant difference whether watered naturally, submerged once a day, or submerged twice a day interacted with different soil mediums.

Table 1 Analysis of variance (ANOVA) table on survival rate

Source	Type III Sum of squares	df	Mean square	F	P-value
Corrected model	9720.335[a]	8	1215.042	5.610	.000
Intercept	86577.691	1	86577.691	399.732	.000
Watering regime	7753.435	2	3876.717	17.899	.000
Soil type	311.275	2	155.637	.719	.493
Watering regime * Soil type	1655.626	4	413.906	1.911	.125
Error	9746.515	45	216.589		
Total	106044.541	54			
Corrected total	19466.850	53			

Growth rate: The study used an estimated margin of 4.0 cm to interact with the watering regime and soil type if it affects the growth of the *S. alba* seedlings. All the seedlings planted in different soil media interacted with the watering administration. The study found that Treatment 3 and Treatment 2 were above the estimated marginal means.

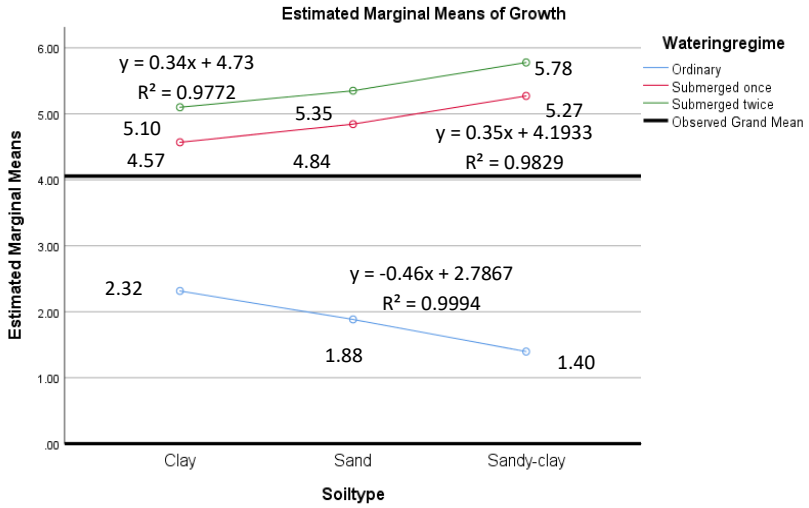

Fig. 4 Growth rate of the apple mangrove seedlings in various treatment

It means that the result of the study coincides with the report of Kjerfe (1990) that mangroves grow at or above mean sea level or MSL, which is not more than 30% of the time tidally inundated.

Results of Analysis of Variance (ANOVA) showed a significant relationship on the growth of *S. alba* in different watering regimes ($p=.000<0.05$) at a 5% level of probability; but has no vital relationship with the survival of *S. alba* in other soil media ($p=0.9777>0.05$) at 5% level of probability also. Furthermore, it has no significant effect on the survival of *S. alba* seedlings in the different watering regimes and soil type interaction ($p=0.909>0.05$) at a 5% probability level.

Table 2 Analysis of variance (ANOVA) table on the growth rate

Source	Type III Sum of squares	df	Mean square	F	P-value
Corrected model	137.488[a]	8	17.186	3.278	.005
Intercept	888.491	1	888.491	169.460	.000
Watering regime	132.035	2	66.018	12.591	.000
Soil type	.240	2	.120	.023	.977
Watering regime * Soil type	5.213	4	1.303	.249	.909
Error	235.939	45	5.243		
Total	1261.918	54			
Corrected total	73.427	53			

It implies that within the span of the study from days 0-90, the growth of *S. alba* seedlings has a significant difference when watered naturally, submerged once a day, or submerged twice a day but has no significant difference when grown in clay, sandy-clay, or sandy soil. Moreover, the growth of *S. alba* seedlings has no significant difference whether watered naturally, submerged once a day, or submerged twice a day interacted with different soil mediums whether grown in clay, sandy clay, or sandy soil.

CONCLUSION

The study can conclude that the soil medium having the highest average survival of *Sonneratia alba* seedlings grown in the concrete tank is the sandy-clay soil. The ideal watering regime for their growth is Treatment 3, in which the seedlings are submerged twice for two hours per submersion. With this study, the production of the correct species of mangrove seedlings is available, and the output can correct the present trend of mangrove rehabilitation/reforestation. Because of this research saves much time, effort, and money. The paper can realize the long-term dream of building coastal greenbelts to make the coastal community well-protected and resilient against the threats of climate change and global warming.

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International Society of Environmental and Rural Development

Philosophy of ISERD:

Recently, in developing countries, subsistence agriculture is being converted to export-oriented mono-culture, and the amounts of agricultural chemicals applied to the farmland are increasing every year. The applied chemicals in farmland cause serious environmental problems downstream such as eutrophication, unusual growth of aquatic plants, decrease in dissolved oxygen and accumulation of bottom mud in water resources. Also, there seem to be many cases in which people apply agricultural chemicals without understanding its impact to health and food safety. Therefore, it is necessary to promote and enhance understanding of sustainable rural development among local stakeholders including farmers.

Sustainable rural development aims to meet human needs while preserving the natural environment. As it should cover not only social and economic development but also natural environment conservation, no single organization can achieve sufficiently the aspirations of sustainable rural development. Collaboration among international, governmental and non-governmental organizations, together with the academe and scientific sector, is indispensable.

The knowledge and intelligence accumulated in universities and research institutions are also expected to make the programs facilitated by the international, governmental and non-governmental organizations more adequately implemented and meaningful to societal development. However, these cases especially those implemented locally have been scattered without having been summarized well or recorded in annals academic or scientific societies.

So, the International Society of Environmental and Rural Development founded in 2010, aims to discuss and develop suitable and effective processes or strategies on sustainable rural development focusing on agricultural and environmental aspects in developing countries. The ultimate goals of the society are to contribute to sustainable rural development through social and economic development in harmony with the natural environment, and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

Purposes of ISERD:

The primary purposes of ISERD are to contribute to sustainable rural development through social and economic development in harmony with the natural environment and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

In order to enhance the realization of the primary purposes of ISERD, the secondary purposes are;

- to facilitate interaction among international, governmental, non-governmental organizations and local communities,
- to hold conferences or symposia on environmental and rural development,
- to edit the International Journal of Environmental and Rural Development,
- to confer some awards based on scientific achievement, research paper or poster presentation, and
- to encourage and develop local awareness concerning sustainable rural development.

Membership:

There shall be two categories of membership.
(a) Individual
(b) Organizational
An application for membership of ISERD shall be submitted to the secretariat of ISERD, where is located in the Research Center at Institute of Environmental Rehabilitation and Conservation (Japan) by writing or by other appropriate means.

Also, every presenter who attends the International Conference on Environmental and Rural Development (ICERD) is registered as an Individual Member of ISERD.

ISERD Secretariat:

Research Center, Institute of Environmental Rehabilitation and Conservation (ERECON)

2987-1 Onoji Machida-shi, Tokyo 195-0064, Japan
Tel/Fax: +81-42736-8972
E-mail: iserd.secretariat@gmail.com
Webpage: www.iserd.net

Collaborated with

Association of Environmental and Rural Development (AERD)

93/64 Moo.3, Sinsab Village 2, Bungyeetho Sub-Ddistrict, Thanyaburi District,
Pathum Thani 12130, Thailand
Tel/Fax: +66-2957-8064
E-mail: iserd.secretariat@gmail.com
Webpage: www.iserd.net

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