Research article

Examination of Optimal Search Method of Unknown Parameters in Tank Model by Monte Carlo Method

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Abstract Recent years, flood disasters have become rampant due to climate change. For the risk mitigation, building up a hydrological run-off model which can be used accurately and quickly helps communities prepare effective disaster prevention measures. Tank Model is a hydrological run-off model proposed in Japan. On one hand, its calculation is relatively simple. On the other hand, many unknown parameters have to be identified. Thus, the more random number it generates at a time, the more it takes time for calibration. This research examines the optimal method of identifying the unknown parameters by Monte Carlo method, considering the improvement of efficiency for practical use. Montel Carlo method can generate the massive number of random samples and help us select the best combinations of unknown parameters. Among the generated random numbers, the optimal parameters are searched which can fit to the actual measured values with the minimal number of samples. This research examines how many random numbers need to be generated at minimum to obtain the optimal parameters. The number (N) of random samples were seven kinds of 100, 1,000, 10,000, 100,000, 1,000,000, 10,000,000 and 100,000,000. Every time random samples generated by Montel Carlo method, the maximum and minimum numbers of each unknown parameter among the five best combinations were applied for the retrieval range of the next simulation. In this way, the simulation was repeated ten times for each kind of sample number. As the result, the watershed with simple land-use could obtain the optimal parameter with fewer samples (N=1,000) than the watershed with complex land-use type (N=1,000,000). With these sample numbers, the prediction accuracy for both watersheds were high. It is considered that the complex land-use watershed had lower accuracy rate because the water runoff was influenced by the underdrainage facilities.

Keywords hydrological runoff model, Tank Model, Monte Carlo simulation, watershed

INTRODUCTION

Hydrological disasters such as storms, flood and drought have been rampant in many parts of the world in the recent years. Especially floods have caused huge economic damages and human casualties. To prevent or mitigate the damages, the improvement of the prediction accuracy and speed on water-runoff by a hydrological model is one of the measures. Generally, the prediction failure of a hydrological runoff model is attributed to errors in input data, model structure and parameter setting.

A hydrological run-off model, Tank Model is a lumped conceptual model to predict rainfall-runoff, developed by Sugawara (1985). It is considered a simple model but requires model parameters to be identified for calibration. To identify optimal parameters, various methods have been studied. Tanakamaru (1995) identified the accuracy of the Stuffled Complex Evolution method and the multistart Powell method for the parameter estimation. Tada (2007) examined the Particle Swarm Optimization algorithm and discussed its effectiveness under certain conditions. Fujihara et al. (2003) investigated the selection of objective functions to be used for identification of the parameters. For other examples, Kalman Filter (Ichihara et al., 2000) and Monte Carlo method (Mukae et al., 2017) have been applied. Monte Carlo is a simple simulation which generates a huge number of numeric random samples. However, the optimal number of samples to be generated has not been examined.

OBJECTIVE

This research aims to clarify the optimal search method by Monte Carlo method to identify the parameters of the Tank Model quickly and accurately. In this study, the simulation of Monte Carlo was implemented by a software, MATLAB developed by MathWorks Inc. The fewer samples, the less time it takes to simulate. Therefore, it is important to find the minimal number of samples to determine the optimal parameters promptly and accurately. Through this examination, it is expected to suggest a minimal number of samples to identify the parameters with expedition and accuracy in the Tank Model.

METHODOLOGY

Study Area and Data Collection

The study sites of this research are watersheds of the Igarashi River and the Soebetsu River. Both of them, in fact, are the size of the stream rather than rivers and tributaries of the Shubuto River, located in southwestern Hokkaido, Japan (Fig. 1). The Igarashi River watershed has the area of 6.9 km^2 and the river length is 7.3 km. This watershed consists of a complex land-use with 2.7 km^2 of pastureland in the downstream basin and 4.2 km^2 of forestland in the upper and middle basin, which covers 31% and 69% of the watershed respectively. This pastureland is mainly used for livestock and there is cropland in a part of the upper basin. Therefore, this watershed contains the land-use of agricultural and forest lands. On the other hand, the watershed area of the Soebetsu is 11.5 km^2, and the river length is 11.1 km. It is a simplex land-use only consisted of forest land. Since these watersheds are close each other, the meteo-hydrological data, such as precipitation amount and evapotranspiration for both areas have the similarities.

This research used data of the daily record of river discharge and precipitation from June 1, 1998 to October 31, 1998 (153 days) observed by Okazawa, et al. (2002). The daily data of temperature, wind speed and hours of sunshine which are required to calculate daily evapotranspiration, are obtained from AMeDAS in Kuromatsunai Town managed by Japan Meteorological Agency.

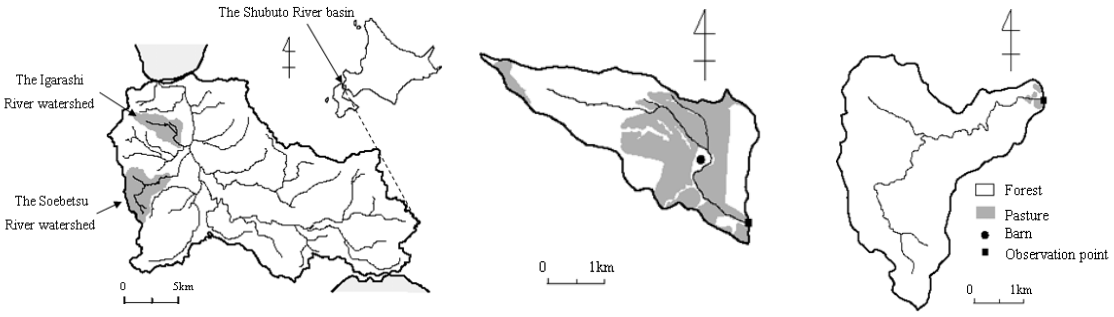

Fig. 1 The Shubuto River Basin, Hokkaido, Japan (Left). Land-use of Igarashi River Watershed (Center) and Soebetsu River Watershed (Right) (Okazawa, et al. 2002)

Hydrological Model: Tank Model

The tank model sets four tanks vertically and sequentially as shown in Fig. 2. In the top tank, precipitation amount is entered and evapotranspiration is subtracted. When there is no water in the top tank, evapotranspiration is subtracted from the lower tanks in order. The water flows from the upper to lower tanks through the bottom outlet as percolation and infiltration or flows out of the side outlets as runoffs which are set at a certain height in each tank. The runoff from the side outlets is considered surface flow in the top tank, intermediate runoff in the second tank, sub-base runoff in the third tank, and base flow in the fourth tank. The total of these runoff becomes the river runoff. Until the water level reaches side outlets, the runoff does not start and the water keeps flowing downward.

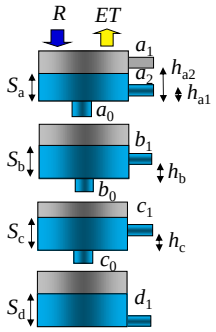

Fig. 2 Concept of Tank Model

The water level of the top tank of simulation is calculated by Eq. (1).

$$S_{a\,i+1} = R - ET + S_{a\,i} - Q_{a1\,i} - Q_{a2\,i} - Q_{a0\,i} \qquad (i = 1 \cdots n) \qquad (1)$$

Where R is daily rainfall (mm), ET is daily evapotranspiration calculated by FAO Penman-Monteith method. Q_{a1} is water volume discharged by the upper side outlet, Q_{a2} is water volume discharged by the lower side outlet and Q_{a0} is water volume discharged to the second tank from the bottom, of the top tank. i is elapsed day(s), the maximum of n is 153 (days). The side and bottom outlets are calculated as Eq. (2) to (6).

$$\text{if } S_{a\,i} \geq h_{a1\,i},\ Q_{a1\,i} = a_1(S_{a\,i} - h_{a1\,i}) \qquad (2)$$

$$\text{if } S_{a\,i} < h_{a1\,i},\ Q_{a1\,i} = 0 \qquad (3)$$

$$\text{if } S_{a\,i} \geq h_{a2\,i},\ Q_{a2\,i} = a_2(S_{a\,i} - h_{a2\,i}) \qquad (4)$$

$$\text{if } S_{a\,i} < h_{a2\,i},\ Q_{a2\,i} = 0 \qquad (5)$$

$$Q_{a0\,i} = a_0\, S_{a\,i} \qquad (6)$$

Where h_{a1} and h_{a2} are the height of side outlet, a_1, a_2 and a_0 are coefficient of discharge in each outlet

in the top tank. The second and third tanks are calculated in the same way as Eq. (7) to (14).

The second tank:

$$S_{b\,i+1} = Q_{a0\,i} + S_{b\,i} - Q_{b1\,i} - Q_{b0\,i} \quad (7)$$

$$\text{if } S_{b\,i} \geq h_{b1\,i},\ Q_{b1\,i} = b_1(S_{b\,i} - h_{b\,i}) \quad (8)$$

$$\text{if } S_{b\,i} \geq h_{b1\,i},\ Q_{b1\,i} = 0 \quad (9)$$

$$Q_{b0\,i} = b_0\, S_{b\,i} \quad (10)$$

The third tank:

$$S_{c\,i+1} = Q_{b0\,i} + S_{c\,i} - Q_{c1\,i} - Q_{c0\,i} \quad (11)$$

$$\text{if } S_{c\,i} \geq h_{c1\,i},\ Q_{c1\,i} = c_1(S_{c\,i} - h_{c\,i}) \quad (12)$$

$$\text{if } S_{c\,i} \geq h_{c1\,i},\ Q_{c1\,i} = 0 \quad (13)$$

$$Q_{c0\,i} = c_0\, S_{c\,i} \quad (14)$$

As the forth tank is considered the bottom, it is calculated as Eq. (11) to (13).

$$S_{d\,i+1} = Q_{c0\,i} + S_{d\,i} - Q_{d1\,i} \quad (11)$$

$$\text{if } S_{d\,i} \geq 0,\ Q_{d1\,i} = d_1\, S_{d\,i} \quad (12)$$

$$\text{if } S_{d\,i} = 0,\ Q_{d1\,i} = 0 \quad (13)$$

Calibration of water runoff in the tank model requires to calculate and identify the sixteen parameters, which are "a_1", "a_2", "a_0", "b_1", "b_0", "c_1", "c_0", "d_1", "$S_{a\,1}$", "$S_{b\,1}$", "$S_{c\,1}$", "$S_{d\,1}$", "h_{a1}", "h_{a2}", "h_b" and "h_c" as seen in Fig. 2. *a*, *b* and *c* are coefficient of discharge from the side and bottom outlets in the top, second and third tanks respectively. The bottom tank has only one side outlet, *d*. *S* is water level of each tank. *h* is the height of the side outlets from the bottom of each tank. Only the top tank has two side outlets.

As an evaluation function, the compatibility of the actual value of river discharge and the estimated value is evaluated by Nash-Sutcliffe efficiency (*NSE*) as Eq. (18). The closer the *NSE* value is to 1.0, the higher the accuracy of the simulation is. Moriasi et al. (2007) divided *NSE* into ≤0.50, 0.50 to 0.65, 0.65 to 0.75 and >0.75 and evaluated unsatisfactory, satisfactory, good and very good, respectively. N stands for the total number of calculation time, Q_{obs}(i) is the actual river discharge at any time step of i, Q_{sim}(i) is the estimated river discharge of at any time step of i, and Q_{av} is the mean value of the actual river discharge. *NSE* value is calculated as Eq. (18).

$$NS = 1 - \frac{\sum_{i=1}^{N}[Q_{obs}(i) - Q_{sim}(i)]^2}{\sum_{i=1}^{N}[Q_{obs}(i) - Q_{av}]^2} \quad (18)$$

Calibration approach

The flow of this research method is as shown in Fig. 3. The initial retrieval range for each parameter was decided as shown in Table 1. The random numbers were created between the minimum and maximum value for each parameter by Monte Carlo method. The numbers of random samples were $1.0\text{x}10^2$, $1.0\text{x}10^3$, $1.0\text{x}10^4$, $1.0\text{x}10^5$, $1.0\text{x}10^6$, $1.0\text{x}10^7$ and $1.0\text{x}10^8$. These samples were calculated in the tank model to obtain the *NSE* value for each sample. From the top five of highest *NSE* value, the maximum and minimum values of each parameter were confirmed and used as the next retrieval range of maximum and minimum. This process was repeated nine times. In this way, the retrieval range was narrowed down. The value which has the highest *NSE* value was selected as the parameter obtained from the 10th simulation.

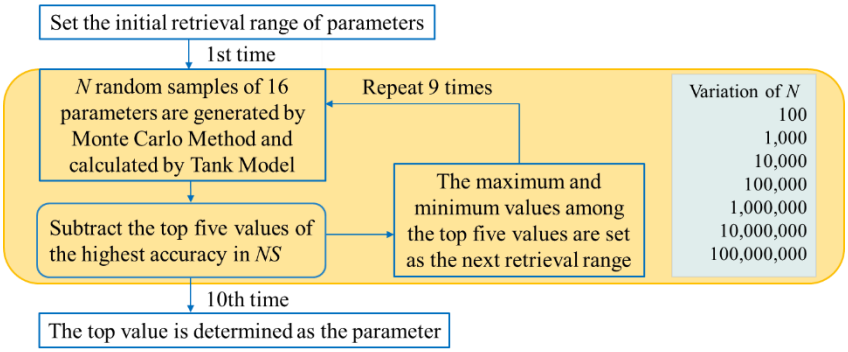

Fig. 3 Flow of calculation method with Monte Carlo method

Table 1 Initial retrieval range of value in each parameter

	a_1	a_2	a_0	b_1	b_0	c_1	c_0	d_1
Min. value	0	0	0	0	0	0	0	0
Max. value	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1

	S_{a1}	S_{b1}	S_{c1}	S_{d1}	h_{a1}	h_{a2}	h_b	h_c
Min. value	0	0	0	0	15	0	20	20
Max. value	30	50	200	300	50	20	50	100

RESULTS AND DISCUSSION

The results of the simulation for Igarashi River and Soebetsu River watersheds are shown in Table 2. In general, the higher the sample number (*N*) is, the higher *NSE* value is obtained. For the Igrarashi River watershed where land-use is the mix of forest and agriculture, the increase of *NSE* value slowed down after N=1.0x10^7 (*NSE* value = 0.801). However, since the increase from N=1.0x10^6 (*NSE* value = 0.799) to N=1.0x10^7 is very slight and the value was rather decreased at N=1.0x10^8 (*NSE* value = 0.798), the minimal and optimal sample number was considered N= 1,000,000. The *NSE* value was insufficient in N=1.0x10^2 as the value was lower than 7.0. On the other hand, for the Soebetsu River watershed where land-use is solely forest, the *NSE* value was high enough even for N=100 (*NSE* value = 0.848). The increase from N=1.0x10^3 onward was limited. Thus, N=1.0x10^3 is considered optimal.

Comparing both watersheds, the forest watershed could obtain the optimal parameter with much fewer samples than the mixed-land use watershed. From these, it is considered that the simple land-use watershed has the simple water movement, thus could obtain the optimal parameter with fewer sample numbers.

Table 2 NSE value in Igarashi and Soebetsu watersheds after the tenth simulation

No. of random sample numbers	1.0 x 10^2	1.0 x 10^3	1.0 x 10^4	1.0 x 10^5	1.0 x 10^6	1.0 x 10^7	1.0 x 10^8
NSE Value in Igarashi watershed	0.690	0.766	0.765	0.776	0.799	0.801	0.798
NSE Value in Soebetsu watershed	0.848	0.872	0.872	0.875	0.878	0.880	0.882

Hyetograph and hydrograph for each watershed are shown in Fig. 4 and 5. For the Igarashi River, the optimal parameters were obtained from N=1.0x10^6 and for Soebetsu N=1.0x10^3. Comparing to the actual river discharge, both simulation had high accuracy. However, in the Igarashi, although the gap was little at the peak of discharge at the rainfall time, it was large when water is calm with little rain (base flow condition of river). In addition, the value of simulation is higher than the actual value in June when rainfall is low. On the other hand, the value of simulation was lower than the actual value in July when there is almost no rainfall. Such occurrence is considered because of drainage facilities such as underdrain in agricultural lands. Therefore, water movement becomes

more complicated in agricultural watershed than forest watershed. For this reason, the prediction accuracy becomes lower in agricultural watersheds than forest watershed by four layers of tank model.

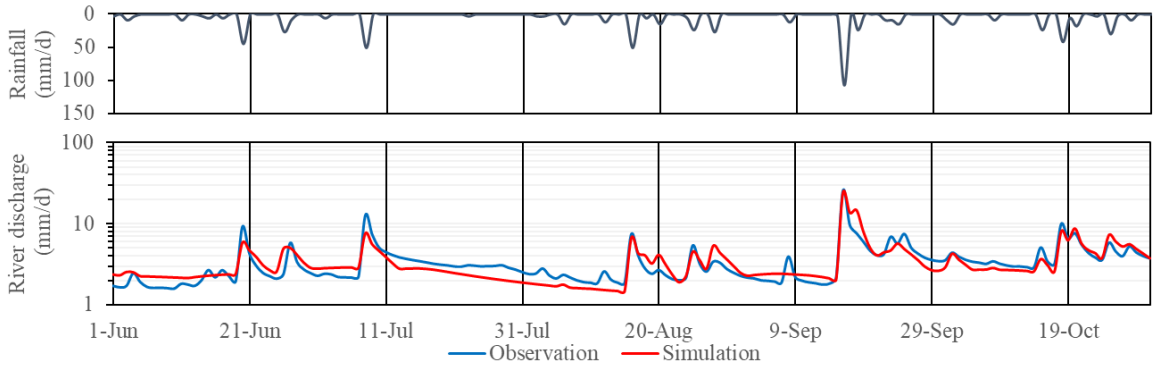

Fig. 4 Hyetograph and hydrograph with Tank model simulation in the Igarashi

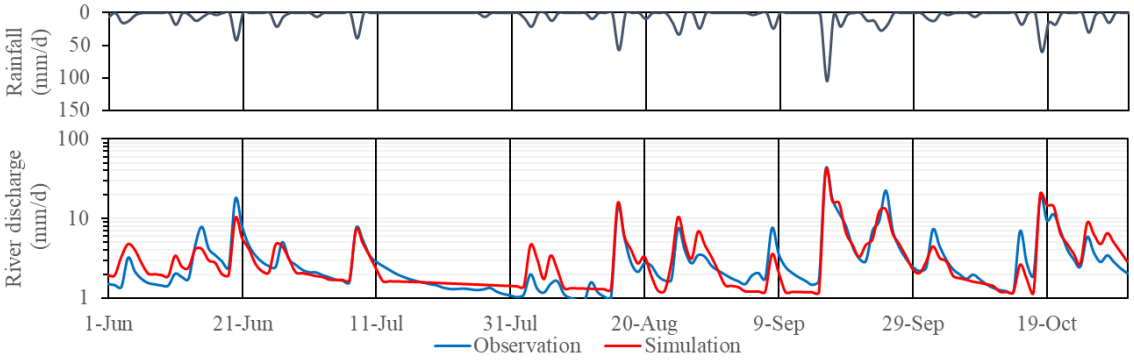

Fig. 5 Hyetograph and hydrograph with Tank Model simulation in the Soebetsu

The above results showed that the larger number of sample is, the higher the *NSE* value tends to be obtained up to a certain point. When the land-use is simple, the high accuracy is obtained with fewer samples than the case of complex land-use. Although there are several different methods to identify parameters, by using Monte Carlo method with an appropriate software, it is able to predict the rainfall-runoff for simple-land use area with a limited time and effort. In case of complex land-use, it is suggested to conduct the prediction considering the time required to conduct the calibration a number of times.

CONCLUSION

This research showed the predictability of rainfall-runoff with the minimal number of samples to obtain the results as swiftly and accurately as possible. The results showed that the larger number of sample numbers is, the higher the *NSE* value is obtained. However, the increasing rate is slowed down at certain sample numbers and the further attempts seemed unnecessary for both watersheds. In the research site for this study, the simple forest watershed required fewer number of random samples, which was N=1.0x10^3, compared with the complex land-use watershed with forest and agricultural lands, which was N=1.0x10^6. It is assumed that agricultural watersheds have lower accuracy in four layers of tank model as they require additional calculation in parameter setting as the runoff is influenced by drainage facilities. In the future study, it is important to continue testing in different cases to generalize the optimal number of random samples to confirm the parameters by Monte Carlo method in the tank model. For the case of agricultural watersheds, it needs to consider the water movement influenced by drainage facilities in the calibration process.

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Research article

The Influence of Percolation Patterns on Copper and Cadmium Uptake, Growth and Yield of Rice Plants in Copper- and Cadmium-polluted Stratified Paddy Fields

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Abstract Combined pollution in farmland soil is a recognized issue in Japan. The measurement of combined pollution has been discussed because the interaction between heavy metals is complex. To date, soil dressing has been the primary method employed to tackle this problem. The objective of this study is to clarify how the percolation patterns of polluted subsoil affect Cu and Cd uptake, and the growth and yield of paddy rice plants. We prepared six stratified paddy-field models to test growth with plowsole and subsoil in open and closed percolation patterns. Each model consisted of a 12.5-cm-thick plowed layer and an upper plowsole made of a non-polluted soil dressing and underlying polluted plowsole and subsoil. Three soils with three levels of Cu contaminations (100, 250, and 500 mg Cu kg^{-1}) were prepared by adding a Cu solution to Cd-contaminated paddy-field soils (1.7 mg Cd kg^{-1}). Three of the six models were open systems, and the other three were closed systems. During the tests, a constant water-ponding system was adopted. As a result, the polluted plowsole and subsoil became oxidized in the open system and reduced in the closed system. The Cu and Cd concentrations in the rice grains were 5% higher in the open models than in the closed models, regardless of the original Cu concentrations in the polluted soils. Interestingly, the Cd concentrations in the grains had an inverse relationship with the Cu concentrations. No significant difference was observed in the growth and yield of the rice plants the models. We concluded that the Cu and Cd concentrations in rice plants were affected by the percolation patterns of polluted plowsole and subsoil, even though they were covered with non-polluted soil-dressing layers.

Keywords copper, cadmium, soil dressing, percolation patterns, rice

INTRODUCTION

Heavy metal contamination became an apparent problem when severe damage was caused by Cu contamination to paddy fields in the lower reaches of Watarase River near Ashio Copper Mine and Cd contamination caused Itai-itai disease among people living near Jintsu River, Toyama prefecture (Asami, 2010). In the 1970s, the *Agricultural Land Soil Pollution Prevention Act* came into effect, identifying Cu, Cd, and As as harmful substances.

Arao et al. (2010) reviewed the history of heavy metal contamination in agricultural soil in Japan and the countermeasures against contamination such as soil dressing, water management, and chemical washing. They pointed out that while soil dressing was very effective in reducing Cd absorption by paddy rice, the biggest problem was its high cost.

When it comes to combined heavy metal contamination in agricultural lands, soil dressing has mainly been applied for remediation (e.g., Ogoya Copper Mine, Ishikawa prefecture, Japan; Asami, 2010). However, recently low-cost countermeasures have gradually been introduced such as multiple heavy metal insolubilization treatments and heavy metal absorption materials (Kanamori et al., 2019). Clarifying the complex interaction among multiple heavy metals and its effect on the growth and yield of crops is a lengthy process.

It has been pointed out that the contaminated lower soil layers of stratified paddy fields with soil dressing are under oxidizing and reducing conditions in open and closed percolation patterns, respectively (Fan et al., 2018a). Paul et al. (2011a, 2011b) and Sasaki et al. (2016a, 2016b) focused on these phenomena and studied the effects of percolation patterns on root uptake of Cd and the growth and yields of crops using models of contaminated stratified paddy fields with a soil dressing. They found that Cd concentration in brown rice was significantly higher when the contaminated layer was in the open system percolation pattern than its closed system percolation pattern counterpart. Paul et al. (2011a), who used Andosol in their experiments, found a significant difference in the growth and yield of paddy rice, between open and closed system percolation patterns. On the contrary, Sasaki et al. (2016a), who used alluvial soil, did not find any such difference. Fan et al. (2018a, 2018b) conducted a growth experiment by using stratified paddy field models with a soil dressing on a Cu contaminated soil layer under open and closed system percolation patterns. They reported that Cu concentrations in brown rice were higher in the open system percolation pattern than those in the closed system percolation pattern. They also found no significant difference in growth and yield between the two percolation patterns.

In Japan, paddy fields with Cu and Cd combined contamination have been recognized downstream of some mines for decades. There has been an introduction of countermeasures against such contamination, soil dressing being the most popular. However, few studies have clarified the characteristics of heavy metal absorption by rice plants, the degree to which contamination varies based on the percolation pattern used, nor the impact of the percolation pattern on the growth and yield of rice crops. The purpose of this study is to investigate the effects of percolation patterns on heavy metal absorption (for Cd and Cu) and the growth and yield of rice plants in paddy fields with combined heavy metal contamination.

The experimental devices and the stratified paddy field models adopted in this study were the same as those in Sasaki et al. (2016a). Three soils with three levels of Cu contamination (100, 250, and 500 mg Cu kg^{-1}) were prepared by adding a Cu solution to Cd contaminated paddy field soils (approximately 1.72 mg Cd kg^{-1}; Sasaki et al., 2016a). We found that Cd and Cu concentrations in brown rice were higher in open system percolation patterns than those in closed system percolation patterns. No significant difference was found in the growth and yield of the rice crop. As a result, we concluded that the type of percolation patterns had a significant impact on Cd and Cu absorption but little on the growth and yield of the paddy rice plants.

METHODOLOGY

Materials and Methods

In this study, we used stratified paddy field models and conducted a growth experiment in open and closed percolation systems following Sasaki et al. (2016a). Table 1 details the physical and chemical

properties of the soils used in this study. Non-contaminated soil (light clay; International Union of Soil Science) was sampled from the plow layer of the paddy field at the Kanagi Farm of Hirosaki University, Aomori prefecture (hereafter referred to as "Kanagi soil"). Cd and Cu combined contaminated soil was prepared by adding $CuCl_2 \cdot 2H_2O$ to Cd contaminated soil (clay loam), collected from the plow layer of Cd contaminated paddy fields in Japan (hereafter referred to as "contaminated soil"). The 0.1 M HCl extracted Cu concentrations in the original contaminated soil were 12.2 mg Cu kg^{-1}, and we made three concentrations of Cu contaminated soil; 100, 250 and 500 mg Cu kg^{-1}. This meant that one was below the Japanese standard of 125 mg Cu kg^{-1}, and the other two were above that. The Kanagi soil and gravel were 3.7 and 0.8 mg Cu kg^{-1}, respectively.

Table 1 Physical and chemical properties of soil samples and gravels

	Density	Soil Texture	MgO	Na_2O	CaO	K_2O	Cd	Cu	T-C	T-N	C/N	OM
	(g/cm^3)				(mg/kg)				(%)			(%)
Kanagi Soil	2.62	LiC	120	64	400	120	0.14	3.70	2.07	0.16	13.3	3.6
Contaminated Soil	2.44	CL	640	128	2280	288	1.81	12.2	2.96	0.21	14.1	5.1
Gravel	2.68	-	147	18	539	600	0.13	0.80	-	0.00	-	0.1

The Cu concentrations in the combined contaminated soils were 20 to 100 times higher than those in average non-contaminated soils of paddy fields in Japan (which are approximately 5 mg Cu kg^{-1}) (Asami, 2010). In this study, we prepared such highly Cu contaminated soils because of a regionally unique situation in the Aomori prefecture. In this prefecture, apple has long been the center of the economy and culture, and apple orchards often use a Bordeaux mixture (i.e., a mixture of copper sulfide and calcium carbonate), as a pesticide. As a result, Cu concentrations in surface soil have at times been found to be higher than 500 mg Cu kg^{-1} (Aoyama, 2012). Nowadays the number of apple producers has been decreasing due to the lack of successors and parts of apple orchards have been converted into other land uses, including paddy fields. This is especially the case in lowlands, where some of them were once used as paddy fields.

Notably, no significant change was found in soil Cu concentrations before and after the experiment.

Experimental Design

We adopted the design of Sasaki et al. (2016a), where we used two types of stratified paddy field models in our experiment; an open system percolation model and a closed system percolation model. Each stratified field model consisted of a 12.5 cm soil dressing (12.5 cm Kanagi paddy soil), a 15 cm soil polluted by Cd and Cu, and a 35 cm gravel layer. We defined O-100 as an open system percolation model in which Cu concentration in the plowsole and subsoil was 100 mg Cu kg^{-1}. C-100 was the closed system percolation model in which the Cu concentration in the subsoil was 100 mg Cu kg^{-1}. Similarly, O-250 and C-250 were defined as models with 250 mg Cu kg^{-1} in subsoils whilst O-500 and C-500 were defined as models with 500 mg Cu kg^{-1} in the subsoil. Note that 'O' and 'C' stand for the open system percolation pattern and the closed system percolation pattern, respectively. The two percolation patterns have been used by Sasaki et al. (1992). Each stratified paddy field model was constructed in an iron box (30 × 50 × 70 cm), filled with three layers of soil. The box has several holes on its side walls. The plow layer was 0 to 10 cm deep, with dry density in puddling condition of 1.04 g cm^{-3}. The plowsole was 10 to 20 cm deep with dry bulk densities of 1.23 and 0.89 g cm^{-3} at depths of 10 to 12.5 cm and 12.5 to 20 cm, respectively. The subsoil was 20 to 62.5 cm deep. It had dry bulk densities of 0.89 and 1.40 g cm^{-3} at depths of 20 to 27.5 cm and 27.5 to 62.5 cm, respectively. These layers were formed by compaction. The ground water levels of the open and closed system percolation models were controlled at 57.5 cm and 12.5–20 cm depth, respectively. In the closed system percolation models, the holes on the side walls of iron boxes were blocked to prevent the penetration of air. In the open system percolation models, these holes remained

open at the lower part of the plowsole and the upper part of the subsoil to enable aeration of these layers. After those two types of models were prepared, fifteen paddy seedlings (plant length and leaf stage were about 18 cm and about 5 leaves, respectively), named '*Oryza sativa* L., Tsugaru Roman' were transplanted as per Sasaki et al., (2016a) and Fan et al., (2018b). The paddy seedlings were transplanted in 10 cm intervals. The fertilizer used consisted of 2 g of N, 2 g of P_2O_5 and 2 g of K_2O for each model. This fertilizer was mixed with the entire plow layer before transplanting. During the cultivation period, a water ponding condition was adopted and there was no mid-summer drainage. Paddy seedling transplants and harvesting was conducted at the end of May and the end of September, respectively. Our experiment was conducted in a greenhouse on the university campus.

Measuring Method

Examination of rice plants such as plant length, leaf stage, the number of stems and panicles, the weight of straw, the number of brown rice and its weight was done using the Iwate Agricultural Experimental Station standard methods (1981). The quantitative analysis of Cu concentrations in rice grains, stems and leaves, roots and soils extracted by HCl solution was measured using atomic absorption spectroscopy (AAS) (MAFF, 1979). Other measurements were conducted with the standard methods used in Japan. The Oxidation-Reduction Potential (ORP) meter (Central Kagaku Co., Ltd., model UC-203), was used for measuring oxidation-reduction potential (Eh). An ORP sensor was set in each soil layer.

RESULTS AND DISCUSSION

Oxidation-reduction Potential (Eh)

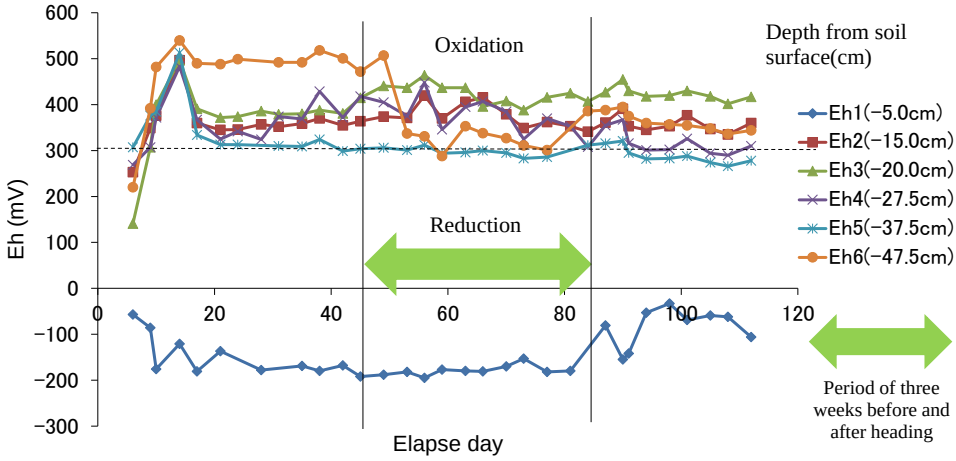

Fig. 1 The Eh of the open system percolation model (O-250)

The trend of Eh in each soil layer showed similar changes from transplanting to harvest among O-100, O-250 and O-500, and among C-100, C-250 and C-500. Figure 1 presents the Eh of the open system percolation model (O-250) and Figure 2 presents the Eh of the closed system percolation model (C-250). The oxidized layer in a paddy field is defined as the layer in which the Eh value is greater than +300 mV (Yamane, 1982). In the open system percolation model (O-250), the Eh of the plow layer became a reduced layer (less than 0 mV) during cultivation of paddy rice. The Eh of the plowsole and the subsoil became oxidized layers (> +300 mV). On the other hand, in the closed system percolation model (C-250), the Eh of all layers gradually declined and became reduced layers after transplanting. In all open system percolation models (O-100, O-250 and O-500), the plowsoles became oxidized layers during the cultivation period. In contrast, all layers of the closed system

percolation models (C-100, C-250 and C-500) became reduced layers during the cultivation period. The absorption of Cu and Cd by rice plants was influenced by the redox potential of the soil (Matsunaka, 2014). Based on these results, we anticipated adverse effects of soluble Cu and Cd on rice in the open system percolation models. The variation of Eh values in each layer was attributed to non-uniform contact between the Eh sensor and soil particles.

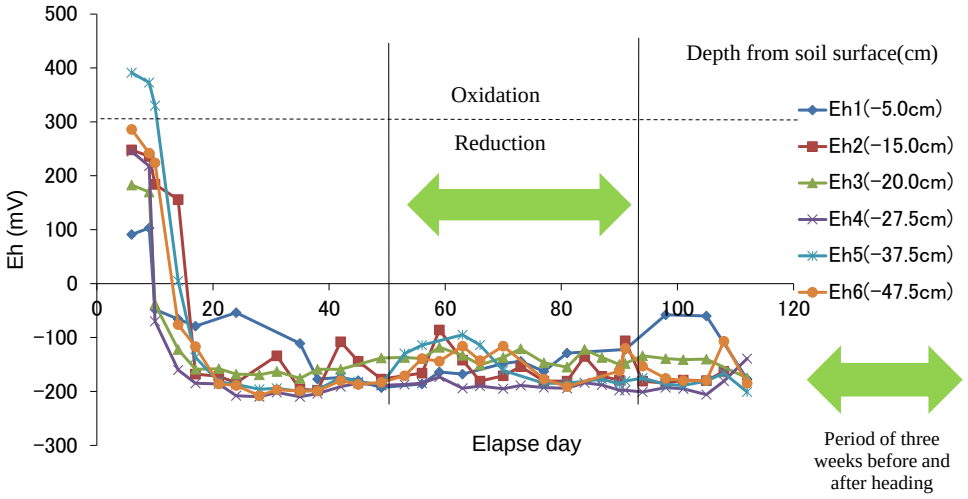

Fig. 2 The Eh of the closed system percolation model (C-250)

Copper Concentrations in Rice Plants

The results of Cu concentrations in rice plants are listed in Table 2.

Rice grains: Cu concentrations in rice grains (n = 7) ranged from 2.5 to 5.4 mg kg^{-1}. The Cu concentrations based on different percolation patterns were O-100 > C-100, O-250 > C-250 and O-500 > C-500. Any increase in Cu concentrations in the rice grains was not recognized despite increased Cu concentrations in soil. The range of Cu concentrations in our brown rice approximated to values indicated by Fan et al. (2018a, b) and Asami (2010). However, our figures were slightly higher than the 2.7 mg kg^{-1} in the Japanese rice ingredient table (MEXT, 2019). Unfortunately, there is an absence of studies applying the 'percolation pattern' concept other than Fan (2018a, b) and Paul et al. (2011b). In our study, Cu concentrations in brown rice were significantly higher (at the 5% level) in the open system percolation models, than those in the closed system percolation models. A significant difference was also observed in brown rice Cu concentrations in Paul et al. (2011b) and Fan et al. (2018a, b). Moreover, Paul et al. (2011b) found that Cu concentrations in brown rice ranged from 2.5 to 4.2 mg kg^{-1} despite low Cu concentrations in the soils (12 mg Cu kg^{-1}). This result suggests that the range of Cu concentrations in brown rice with the difference in Cu concentrations in the lower layer, which ranged from 12 to 500 mg kg^{-1}, was 2.5 to 5 mg kg^{-1}, evidence of the impact of the percolation pattern. One reason for this may be that the immobilization effect is lower than that of Cd as pointed out by Kanamori et al. (2019). Based on these results, it was inferred that the variation of Cu concentrations in brown rice was due to the difference between percolation systems of the stratified paddy fields under combined pollution conditions.

Stems and leaves: The Cu concentrations in the stems and leaves ranged from 1.9 to 4.4 mg kg^{-1}, and there was a significant difference (at the 5% level) between the concentrations in the open system percolation models and the closed system percolation models, where the values of the former were higher than the latter. Fan et al. (2018a, b) and Paul et al. (2011b) also observed a similar concentration difference due to percolation systems. However, Fan et al. (2018a, b), did not observe significant differences in Cu concentrations of 70 and 100 mg kg^{-1} based on the type of percolation system. This was presumably because of the difference in soil type. This indicates that there may be no significant difference in Cu concentrations in the stems and leaves when soil Cu concentrations

in the lower layer are less than 250 mg kg^{-1}. However, when soil Cu concentrations are greater than 250 mg kg^{-1}, the difference in the percolation system may affect the Cu concentrations in the stems and leaves.

Roots: The Cu concentrations in roots (n=5) ranged from 12.7 to 18.6 mg kg^{-1}. The difference in the soil Cu concentrations in this study was 400 mg kg^{-1}. However, the difference in root Cu concentrations was approximately 6 mg kg^{-1}. The Cu concentrations in the roots observed by Fan et al. (2018a, b) also ranged from 13.7 to 20.3 mg kg^{-1}, and they could not identify whether this difference was due to the type of percolation system. However, there was no significant difference in Cu concentrations in the roots, providing clarity on the extent to which the type of percolation pattern influences brown rice, and the stems and leaves. Based on these results, it is presumed that there is a difference in Cu concentrations due to the type of percolation patterns in the transport mechanism of Cu in the above-ground biomass of rice plants.

The Cu concentrations in rice plants among the six models were in the order of roots > rice grains > stems and leaves on average, and the ratio was 5.7: 1.3: 1. This ranking was similar to that of the paddy rice indicated by Shibuya (1979) and Paul et al. (2011b), and that of the soybeans indicated by Li et al. (2017). This result is considered to be a result of the Cu transport mechanism in the rice plant. It is surmised that Cu concentrations in rice plants tend to be maintained within a certain range, similar to Zn concentrations (Shibuya et al., 1979), despite an increase in soil Cu concentrations.

The results indicated that there was a significant difference in Cu concentrations in rice grains, stems and leaves due to the type of percolation patterns. In contrast, such difference was not discernible for Cu concentrations in the roots even if the percolation pattern was different.

Table 2 Cu concentrations in rice grains, stems, leaves and roots in the plow layer

Model	Rice grains n = 7	Roots of plow layer n = 5	Stems and leaves n = 5
O-100	4.77 ± 0.50^{a}	16.19 ± 1.19^{ab}	3.38 ± 0.31^{b}
C-100	2.99 ± 0.34^{c}	17.82 ± 3.12^{a}	1.90 ± 0.10^{cd}
O-250	5.40 ± 0.64^{a}	18.56 ± 1.28^{a}	4.35 ± 0.66^{a}
C-250	2.94 ± 0.20^{c}	15.06 ± 2.89^{ab}	1.89 ± 0.18^{cd}
O-500	3.72 ± 0.30^{b}	15.58 ± 1.42^{ab}	2.42 ± 0.52^{c}
C-500	2.53 ± 0.20^{c}	12.72 ± 0.85^{b}	1.53 ± 0.41^{d}

Note: Tukey-Kramer test was performed at the 5% level; letter indicates significant difference. The numerical value of ± shows standard deviation.
Unit: mg kg^{-1}

Cadmium Concentrations in Rice Plants

The results of Cd concentrations in rice plants are listed in Table 3.

Rice grains: Cd concentrations in rice grains (n=7) ranged from 0.01 to 0.16 mg kg^{-1}. The Cd concentrations associated with the different percolation systems were O-100 > C-100, O-250 > C-250 and O-500 > C-500. This concentration range approximated the range from 0.03 to 0.17 mg kg^{-1} found by Sasaki et al. (2016a, b). In addition, the figures were higher in the open system percolation model (O-100 and O-250) than the 0.06 mg kg^{-1} in rice grains from Japan (MAFF, 2019). The increase in Cd concentrations in rice grains due to the increase in Cu concentrations was not observed in C-100, C-250 and C-500. However, these Cd concentrations in the open system percolation models were higher in the order of O-100> O-250> O-500. Until now there research on heavy metal concentrations caused by different percolation systems is lacking, with the exception of Sasaki et al. (2016a, b) and Paul et al. (2011b). In this study, Cd concentrations in brown rice were significantly higher (P value < 5%) in the open system percolation pattern than in closed system percolation pattern, except for 500 mg Cu kg^{-1}. Similarly, the Cd concentrations in rice grains indicated by Paul et al. (2011b) and Sasaki et al. (2016a, b) showed a significant difference due to the type of

percolation patterns. In addition, models with an open system percolation pattern in the lower layer, were found to have Cd concentrations in rice grains that decreased in inverse proportion to the increase of Cu concentrations in the lower layer ranging from 100 to 500 mg kg^{-1}. One reason for this may be that an increase in the Cu concentrations suppresses the uptake of Cd.

Based on these results, the type of percolation pattern of stratified paddy field models under a combined pollution condition would create differences in Cd concentrations in brown rice. Additionally, when contaminated soil was in the closed system percolation pattern, the uptake of Cd was suppressed.

Stems and leaves: The Cd concentrations in the stems and leaves were range from 0.06 to 1.04 mg kg^{-1}, and a significant difference (at the 5% level) was confirmed in Cd concentrations between the open system percolation models and the closed system percolation models, with concentrations in the former being higher than the latter. The exception to this was for 500 mg kg^{-1}. Sasaki et al. (2016b) and Paul et al. (2011b) also observed similar results, where concentration differences were due to the type of percolation pattern. In these studies the soils of the models were only contaminated by Cd. This was presumably because the contaminated soils were in the open system percolation models, which were oxidized, so the solubility of Cd increased compared to those in the closed system percolation models (Arao et al., 2010).

These results indicate that the type of percolation patterns affects the Cd concentrations in the stems and leaves under combined contamination conditions when the Cu concentrations in the contaminated soils are lower than 500 mg kg^{-1}.

Roots: The Cd concentrations in the roots (n=5) ranged from 1.00 to 1.97 mg kg^{-1}. The Cd concentrations in the contaminated soils in this study were approximately 1.72 mg kg^{-1}. However, the biggest difference in the Cd concentrations among the roots was 0.97 mg kg^{-1}. Regardless of the type of percolation model, which was under the same condition (1.81 mg kg^{-1}) as in Sasaki et al. (2016), no significant difference was observed.

Cd concentrations in rice plants were in the order of roots > stems and leaves > rice grains on average, and the ratio was 28:7:1. This ratio was slightly lower than 100:10:1, as found in Ito and Iimura (1976).

Table 3 Cd concentrations in rice grains, stems, leaves and roots in the plow layer

Model	Rice grains n = 7	Roots of plow layer n = 5	Stems and leaves n = 5
O-100	0.16 ± 0.05^{a}	1.60 ± 0.15^{ab}	1.04 ± 0.35^{a}
C-100	0.01 ± 0.00^{c}	1.06 ± 0.13^{c}	0.09 ± 0.02^{b}
O-250	0.08 ± 0.03^{b}	1.34 ± 0.23^{bc}	0.71 ± 0.24^{a}
C-250	0.01 ± 0.00^{c}	1.00 ± 0.24^{c}	0.10 ± 0.02^{b}
O-500	0.04 ± 0.01^{c}	1.97 ± 0.31^{a}	0.18 ± 0.05^{b}
C-500	0.01 ± 0.01^{c}	1.65 ± 0.18^{ab}	0.06 ± 0.02^{b}

Note: Tukey-Kramer test was performed at the 5% level; letter indicates significant difference. The numerical value of ± shows standard deviation. Unit: mg kg^{-1}

Growth and Yield of Rice Plants

The results of this experiment for the growth and yield of rice plants are shown in Tables 4 and 5, respectively.

Growth of rice plants: The average plant height (n=8) of each model was almost equal, and was between 99.6 to 101.7 cm (Table 4). The leafage of each model ranged from 14.3 to 15.0 leaves, showing very little difference among them. The total straw weight was 12.1 to 15.6 g $hill^{-1}$. No significant difference was observed in plant height, leafage and total straw weight regardless of the percolation system. Paul et al. (2011a) conducted stratified paddy field model experiments using Andosol and reported that the growth items above showed significantly higher figures in the closed system percolation models than the open system percolation models. Sasaki et al. (2016a, 2016b)

and Fan et al. (2018a, 2018b), used percolation systems that were clearly conditioned as per our experiments, but did not observe any significant difference (at the 5% level) in the growth of rice plants between the closed and open system percolation models. Shibuya et al. (1979) reported that Cu concentrations in the Cu polluted soil layer had an influence on the growth of rice plants. However, in our study, any influence of the Cu and Cd concentrations on the growth of rice plants was not noticeable, and may be a result of the soil dressing application.

Yield of rice plants: The weight of one panicle and the number of grains of brown rice per unit hill were between 2.3 and 2.8 g panicle^{-1} and between 597 and 724 grains hill^{-1}, respectively (Table 5). In addition, the percentage of ripening and the 1000 grain weight of brown rice were between 85.5 and 97.6% and between 20.2 and 22.2 g, respectively. No significant differences (at the 5% level) were found in any of the items of the models for the different percolation systems. Paul et al. (2011a) reported that yield components of the closed system percolation model were significantly higher than those of the open system percolation model although their experiment was conducted using a different soil type for Cd polluted soil layers. Sasaki et al. (2016a, 2016b) and Fan et al. (2018a, 2018b), used percolation systems that were clearly conditioned as per our experiments, and did not observe any significant difference (at the 5% level) in the yield components between closed and open system percolation models. Shibuya et al. (1979) reported that Cu concentrations had an influence on the number of panicles and the percentage of ripening. However, in our study, the mixed effect of the Cu and Cd concentrations on the growth of rice plants was unremarkable, which may be attributed to the application of soil dressing.

Transfer prevention of nutrients from the stems and leaves to grains (100 × weight of brown rice / weight of total straws) ranged from 82 to 120%. In the models of O-500 and C-500, rather low values of 83 and 82% were obtained, respectively, suggesting influence from the higher Cu concentration of 500 mg kg^{-1}. Sasaki et al. (2016b) did not recognize any transfer prevention in their experiments using Cd contaminated soils and controlling percolation patterns in the plow sole and subsoil. This suggests that Cu has much more influence on paddy rice growth and yield than Cd (Yamane et al., 1997).

Table 4 Parameters of rice plant growth

Model	Plant length (cm)	Leaf age (leaf)	Weight of dry straw (g hill^{-1})
O-100	101.66 ± 5.52^{ab}	14.88 ± 0.35^{ab}	12.61 ± 2.58^{a}
C-100	99.60 ± 1.97^{b}	14.25 ± 0.46^{c}	12.13 ± 3.59^{a}
O-250	100.48 ± 4.22^{ab}	14.63 ± 0.52^{abc}	13.15 ± 3.45^{a}
C-250	99.90 ± 6.03^{b}	14.38 ± 0.52^{bc}	13.51 ± 3.29^{a}
O-500	101.40 ± 1.54^{ab}	15.00 ± 0.00^{a}	14.45 ± 3.38^{a}
C-500	106.15 ± 3.50^{b}	15.00 ± 0.00^{a}	15.61 ± 4.41^{a}

Note: Tukey-Kramer test was performed at the 5% level; letter indicates significant difference. The numerical value of ± shows standard deviation.

Table 5 Parameters of rice plant yield

Model	Weight of one panicle (g)	Percentage of ripening (%)	Number of brown rice grains per unit hill (grains hill^{-1})	Weight of 1000 rice grains (g)
O-100	2.27 ± 0.50^{b}	93.17 ± 1.30^{ab}	700.13 ± 143.73^{a}	20.23 ± 0.59^{b}
C-100	2.59 ± 0.18^{ab}	89.69 ± 4.93^{bc}	597.38 ± 134.56^{a}	20.24 ± 0.68^{b}
O-250	2.51 ± 0.36^{ab}	91.60 ± 2.74^{abc}	761.38 ± 217.21^{a}	21.01 ± 0.31^{ab}
C-250	2.71 ± 0.38^{ab}	85.50 ± 7.50^{c}	628.13 ± 127.81^{a}	20.44 ± 1.50^{b}
O-500	2.63 ± 0.27^{ab}	95.97 ± 4.73^{ab}	685.63 ± 133.67^{a}	22.21 ± 0.77^{a}
C-500	2.79 ± 0.27^{b}	97.57 ± 0.82^{a}	723.88 ± 136.85^{a}	22.18 ± 0.79^{a}

Note: Tukey-Kramer test was performed at the 5% level; letter indicates significant difference. The numerical value of ± shows standard deviation.

CONCLUSION

Using six types of Cu and Cd combined in polluted stratified paddy field models, we conducted an experiment to clarify the effects of percolation patterns in the sub-layer (both plowsole and subsoil) on Cu and Cd concentrations in rice plants and growth and yield. The models had a 15 cm thick Cu and Cd polluted soil layer and a 12.5 cm thick non-polluted soil dressing with a Cu and Cd concentration of 3.7 mg kg^{-1} and 0.14 mg kg^{-1}, respectively. The six polluted soils were prepared by mixing each with a different concentration of Cu (100, 250 and 500 mg kg^{-1}) and a Cd concentration of 1.72 mg kg^{-1}.

The results of our experiment show that in open system percolation models the sub-layers became oxidized and in the closed system percolation models the sub-layers became reduced. Cu and Cd concentrations in the rice grains of the open system percolation models were significantly higher (at the 5% level) than those observed in the closed system percolation models. Cu and Cd concentrations in the stems and leaves also showed a significant difference between the models for different percolation systems. It was found that in the open system percolation models a higher Cu concentration reduced the Cd concentration in the brown rice, suggesting a coexistent effect of Cu and Cd. However, there was no significant difference in the growth and yield of rice plants between the two percolation systems.

Under the above conditions, the difference in percolation systems of the stratified paddy field models did little to affect the growth and yield of rice plants. However, it had an influence on Cu and Cd concentrations in the rice plants.

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Research article

Development of a Simplified Water Storage Operation Curve at Irrigation Ponds for Flood Mitigation -A Case from Tamatsu District in Tottori, Japan-

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Abstract In recent years, Japan has been receiving heavy rainfall, and the flooding of irrigation ponds is a major concern. The irrigation ponds in the Tamatsu district in Tottori, Japan, are small and overflow easily during heavy rainfall. Pre-releasing water from these ponds was suggested as a simple, safe, and low-cost solution. However, local governments have prepared no clear guidelines or instructions on the amount of water that should be pre-released or regarding the desired water level after pre-release. Currently, the water volume that is pre-released from the ponds depends entirely on the pond manager's experience. To mitigate this situation, we first observed the water level and discharge of the irrigation ponds and collected rainfall data from the nearest meteorological station. We then assessed the water storage operations of pond managers at three irrigation ponds in the Tamatsu district in 2018. Subsequently, we prepared the height–volume curve (H–V curve) of each pond by level survey and 3D image analysis, and a cumulative water demand curve based on the volume of water released from each pond during no rainfall periods. Considering the cumulative water demand curve and the height of the intake tap of each pond, we prepared water storage operation curves for the irrigation ponds. This will assist pond managers to determine the appropriate water level reduction during heavy rainfall events without causing an irrigation water shortage. We confirmed the extent to which the pond management curve could cope with rainfall. Using the developed water storage operation curve, managers can easily understand the drop of the water level in the pond. Moreover, the curves are easily constructed from the information on the beneficial area, precipitation, water level fluctuations of the irrigation pond during dry days, and the H-V curves of ponds. Finally, the effectiveness of the water storage operation curve is evaluated for different rainfall events.

Keywords flood mitigation, disaster prevention, irrigation pond, pre-release of water

INTRODUCTION

In recent years, disasters caused by heavy rain have increased throughout Japan. The heavy rains in July 2018 caused heavy damage in western Japan, and in Hiroshima Prefecture, the pond broke down. The pond is small and is in the study area, Tamatsu district, and the possibility of flooding during heavy rain increases. Disaster prevention and mitigation measures for ponds, therefore, are urgently needed. The government, after conducting an emergency inspection of ponds nationwide, took measures such as selecting ponds for disaster prevention, preparing pond maps, developing an emergency communication system, creating inundation potential area maps, and creating hazard maps (MAFF, 2018). The government also suggested pre-release in preparation for heavy rainfall by lowering the water level of the pond in advance and providing sufficient storage capacity. The spillways of most irrigation ponds in Japan require repairs to safely pass the probability of flood occurrence, once every 200 years, which is the design criteria set by the Japanese government (MAFF, 2015). Because of the large number of ponds and the high repair costs, extensive time,

however, will be required to repair the spillways of every irrigation pond. We, therefore, developed a low-cost pre-release of water. The advantage is that there is no need to build a special facility and no funding is required, but there is no specific guideline for the pre-release amount, which depends on the experience of the manager.

OBJECTIVE

In this study, we evaluated water storage management during heavy rains in July and September 2018 and created a water storage operation curve to guide the pre-discharge at three ponds in Tamatsu district of Tottori City in 2018. Furthermore, we investigated how much rainfall the ponds could withstand without flooding when the water level was controlled by the water storage operation curve.

METHODOLOGY

Study Area

Figure 1 shows an overview of the study area. There are six irrigation ponds in the study area, Tamatsu District, Tottori City, Tottori prefecture, Japan. There are three ponds currently functioning for water intake management, namely the Yutani, Shinjoji, and Daigo irrigation ponds. These ponds are stored only by runoff from their basins. A canal connects the Yutani and Shinjoji ponds to the Daigo pond and can be switched between flowing into the Daigo pond and flowing into the river by operating the weir. Table 1 shows the specification of each pond. The main crop is paddy, and the total paddy area is about 6 ha. In this area, there is a rule that water is drawn during the daytime, and each farmer freely takes water from the ponds. The pond manager performs water pond maintenance and the pre-release of water except for water intake.

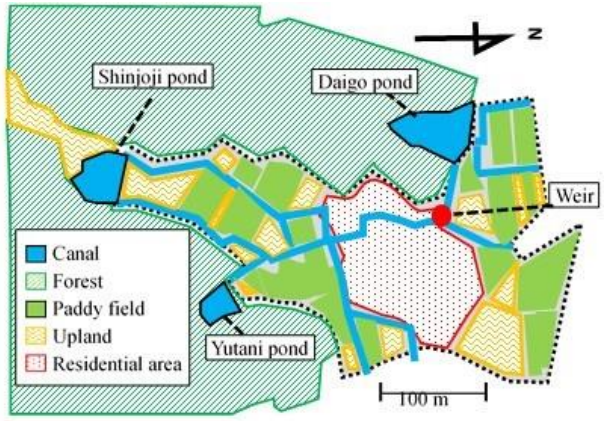

Fig. 1 Study area

Table 1 Information of irrigation ponds

	Yutani	Shinjoji	Daigo
Height of dike（m）	4	6	4
Length of dike（m）	50	88	123
Storage（10^3 m^3）	3.8	19.0	18.0
Catchment area（km^2）	0.08	0.44	0.05
Width of spillway（m）	0.8	5.8	0.5
Height of spillway（m）	0.5	1.2	0.5

Hydrological Observation

To clarify the water level fluctuation of the pond, a pressure-type self-recording water level gauge was installed at the bottom and water surface of the pond, and observations were made hourly. Using a small UAV, the aerial view of the pond was created and a three-dimensional image was created based on the image. The water area for each pond's water level was calculated to create a water level-volume curve. From the water level of the pond and the water level-volume curve, the capacity of the pond was calculated. To clarify the intake status and the operation status of the weir, a capacitance-type self-recording water level gauge was installed in the canal, and the water level was observed at 5-minute intervals. The observation period was from late May to late September 2018, and the mid-drainage period for paddy rice fields is from late June to mid-July. Precipitation data were obtained from the Japan Meteorological Agency (Tottori Observatory).

Estimation of Pre-release of Water

As a method of quantitatively indicating the pre-release rate, we estimated the average daily water requirement during the irrigation period. This was based on the amount of storage change of each pond during the continuous drought period (14 days from August 1 to 14) with precipitation of less than 5 mm/d. Using the average daily requirement, the cumulative required water volume was calculated retrospectively to create a pond management curve. The two types of management curves for each pond are shown based on the land-use status of the target area in 2018 and the assumption that all the farmland in the area is paddy rice, that is, with maximum water demand.

Estimation of Water Storage Operation Curve

Flood arrival times in 60-minute rainfall events were calculated for different probability year using the formula of Talbot, Kadoya–Fukushima, as shown in Eqs. (1) ~ (3), and the water level rise from full and from each intake tap position was calculated. From the result, if the water level is maintained according to the water storage operation curve, it is determined at which probability year the rainfall will not exceed the top of the embankment until 60 minutes of rainfall.

To simulate the water balance and water level of the pond under heavy rainfall, 60-minute rainfall events at return periods of 10, 20, 30, 40, 50, 60, 70, 100, and 200 years were estimated using the Iwai method.

$$I = \frac{a}{t+b} \tag{1}$$

$$t_p = C \cdot A^{0.22} \cdot r_e^{-0.35} \tag{2}$$

$$r_e = f_p \cdot I \tag{3}$$

where I is the rainfall intensity (mm/h), t is the duration of rainfall (min), a and b are the constant parameters related to the meteorological conditions, t_p is the peak flow arrival time (min), C is the parameter related to the land-use conditions, A is the catchment area (km^2), r_e is the average effective rainfall intensity (mm/h), and f_p is the peak runoff coefficient.

The rational equation to determine the peak discharge from the catchment area and average effective rainfall intensity are expressed in Eq. (4).

$$Q = \frac{1}{3.6} \cdot r_e \cdot A \tag{4}$$

The discharge from the spillway was calculated using rectangular weir formulas according to the water level. The formulas used in the calculation are expressed in Eq. (5).

$$Q_s = C_s \cdot b \cdot H^{\frac{3}{2}} \tag{5}$$

where Q_s is the discharge from the spillway, C_s is the discharge coefficient for the rectangular weir,

b is the width of the spillway (m), *H* is the water level of the spillway (m). Calculations continued until the water level reached the top of the spillway.

The water balance and increase rate of the water level of the pond were calculated using the peak runoff as the inflow element and the discharges from the spillway. Due to the assumption of short and heavy rainfall, evaporation and infiltration from the pond were ignored (Shimizu et al., 2016).

The created water storage operation curve of each pond is evaluated for the different rainfall events. In our analysis, the extra height of each pond was defined as the height of the spillway in case of seepage collapse of the dike. There are three main reasons for damage to irrigation ponds by heavy rainfall, namely overflow erosion, sliding, and seepage failure. In the case of seepage failure, internal erosion occurs from the upstream slope near the full water level. In the case of sliding, a failure starts at the toe of an embankment. Overflow failure occurs at the crest above the gut of the foundation (Hori et al., 2002). We, therefore, set the upper limit to the height of the spillway.

RESULTS AND DISCUSSION

Evaluation of Water Storage Management during Heavy Rain

Figure 2 shows the water level fluctuation and precipitation of each pond. It is probable that pre-discharge was not performed at Shinjoji and Daigo ponds because the water level did not drop before the heavy rain. Pre-discharge was not performed at the Shinjoji pond because the manager judged there was no necessity to perform pre-discharge because the spillway of the Shinjoji pond was large enough, as shown in Table 1. Pre-discharge was not performed in the Daigo pond because the water storage rate of the pond was low, about 60%, and the weir was operated so that water from the Yutani and Shinjoji Ponds did not enter the pond. Furthermore, the Daigo pond has a larger water storage capacity for the catchment area than the Yutani and Shinjoji ponds. For a detailed description, Fig. 3 shows the water level fluctuation of the Yutani pond during heavy rains in July (308 mm) and September (180 mm). Since the water level dropped before the heavy rainfall, it was confirmed that the pre-discharge was performed. The water level of the Yutani pond did not rise more than 30 cm from the full water level, the peak of the water level was reduced, and the effectiveness of the pre-discharge was reduced.

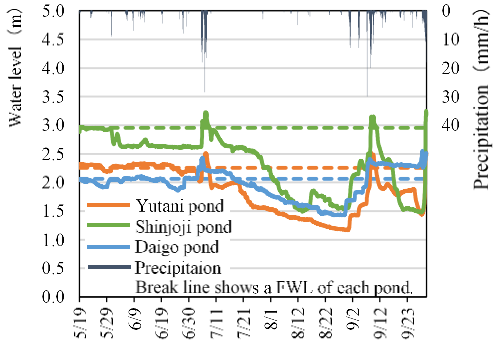

Fig. 2 Water level fluctuation at 3 ponds

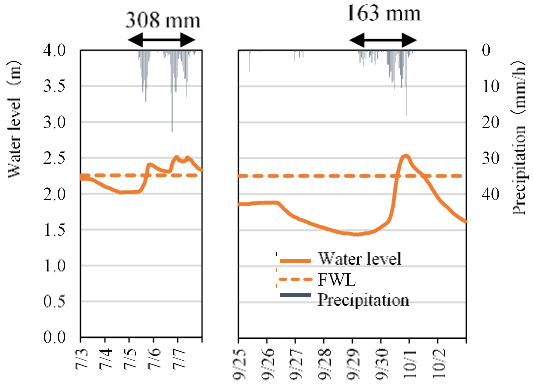

Fig. 3 Water level fluctuation at Yutani pond

Creating Water Storage Operation Curve

Table 2 shows the daily irrigation requirement based on the paddy rice area in 2018 and the daily irrigation requirement assuming that paddy rice is grown in all the fields. Figure 4 (a) ~ (c) shows the water storage operation curves of each pond. The break-line indicates the amount of water stored with a full water level in each pond. When the water storage operation curve falls below the dotted line, pre-release is possible. The dotted line indicates the amount of water storage corresponding to the position of the intake tap in each pond, and the water level can be lowered to the position of the intake tap by opening the intake tap immediately above the water storage operation curve at the time

of pre-release. Water storage operation curves created from the land-use situation in 2018 show that the water storage capacity of the Yutani and Daigo ponds is always lower than the water storage capacity of the irrigation pond during the irrigation period. It was shown that pre-release was possible. Regarding the water storage operation curve, assuming the maximum water demand in the area, the management curve of the Daigo pond (Fig. 4 (c)) has fallen below the full storage volume of the pond since June 13th. It was shown that there was room for pre-release from the stage. However, in the management curves of the Yutani (Fig. 4 (a)) and Shinjoji ponds (Fig. 4 (b)), there is no room for water storage until the end of the irrigation season because of the higher ratio of upland fields and fallow land in the beneficiary areas at the Yutani and Shinjoji ponds. Because paddy rice fields are usually irrigated, but upland crop fields are rain-fed, if the ratio of the paddy rice fields increased, the irrigation water requirement also increased accordingly. The reservoir manager can open the intake tap based on this curve to keep the water level in the vicinity of the opened intake tap position and prepare for heavy rainfall.

Table 2 Beneficial area

Name of pond		Yutani	Shinjoji	Daigo
Paddy rice area (ha)	2018	0.15	2.64	2.50
	Maximum paddy rice area	1.84	3.95	2.90
Average water demand per day (m^3/d)	2018	15.56	391.95	206.74
	Maximum water demand	187.15	586.30	324.04

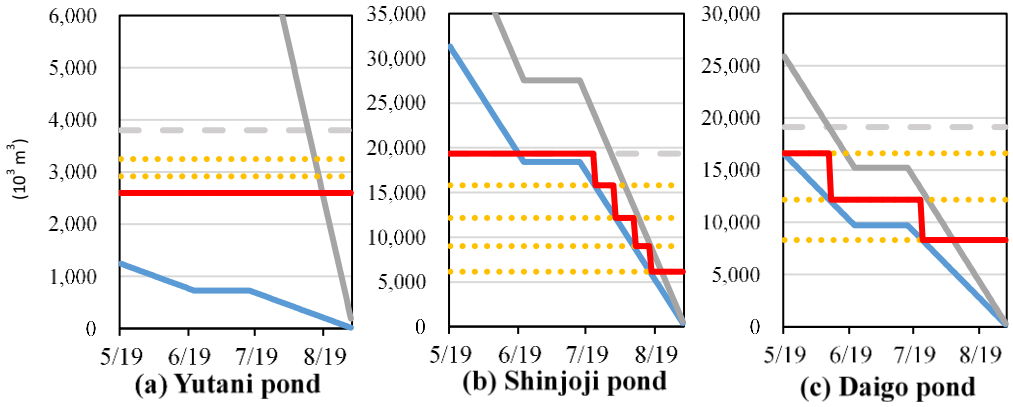

Fig. 4 Water-storage operation curve (red line)

Evaluation of the Effectiveness of the Water Storage Operation Curve

We investigated how much rainfall each pond could withstand without flooding when the water level was controlled by the water storage operation curve. Table 3 summarizes the simulation results. In the Shinjoji pond, the water level did not exceed the upper limit in any rainfall events because the spillway is large enough to pass the flood. In the Yutani pond, the rainfall over the 10-year probability 60-minute rainfall at the full water level exceeds the upper limit. When the water level, however, is lowered to the height of the intake tap No.1, the pond withstands flooding with a 50-year probability 60-minute rainfall. The Daigo pond cannot withstand any rainfall at the full water level or when the water level is at the height of water intake tap No.1. The pond can withstand a 40-year probability 60-minute rainfall if the water level is lowered to the height of water intake tap No.2. Since the water level in the ponds cannot be lowered in a short period of time by opening the intake tap with a small diameter, it is necessary to constantly lower the water level of the ponds or install an emergency discharge device to increase the ability to lower the water level.

CONCLUSION

The pre-discharge of ponds is a simple, safe, and cost-effective method against heavy rainfall in case the spillway is not constructed, but the pond manager uncertain to what extent the water level of the pond can be lowered. Given this, a water storage operation curve was developed by considering paddy rice irrigation, and its effectiveness was evaluated based on the probability of rainfall for different years. The developed method is applicable to any ponds and the created curve makes it easy for pond managers to visually understand how much to lower the water level at what time of irrigation period. Further refinement of the curve is required by more accurate hydrological observation. Also, not only short rainfall events but longer rainfall events such as one to two days long should be considered.

Table 3 Effectiveness of water storage operation curve

Yutani pond				
Return period (y)	Full water level	Intake tap No.1	Intake tap No.2	Intake tap No.3
10	○	○	○	○
20	×	○	○	○
30	×	○	○	○
40	×	○	○	○
50	×	○	○	○
60	×	×	○	○
70	×	×	○	○
100	×	×	○	○
200	×	×	×	×
Daigo pond				
Return period (y)	Full water level	Intake tap No.1	Intake tap No.2	Intake tap No.3
10	×	×	○	○
20	×	×	○	○
30	×	×	○	○
40	×	×	○	○
50	×	×	×	○
60	×	×	×	○
70	×	×	×	○
100	×	×	×	○
200	×	×	×	×

○: water level does not exceed the upper limit
×: water level exceeds the upper limit

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Research article

Evaluation of Drought Tolerance for Improved Rice Lines in terms of Yield, Chlorophyll content and Water Use Efficiency

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Abstract Rice (*Oryza sativa* L.) is an important target crop for water use reduction because of its greater input water requirement than other crops. The pot experiment was conducted to evaluate the effect of two different levels [full irrigation and deficit irrigation (50% Plant Available Moisture)] on the growth, yield, chlorophyll content and water use efficiency of Yezin Agricultural University improved rice lines. Preliminary test for drought tolerance for the one hundred improved rice lines was conducted and screened under pot experiments in the dry season of 2018. After screening this test, the selected rice lines were grown at two different water levels in the screen house during the rainy season of 2019. Each experiment was assigned as a randomized complete block design with three replications at Yezin Agricultural University. The result of the preliminary test in 2018 found that among the one hundred YAU improved rice lines, seven lines were tolerant to deficit irrigation. In 2019, all selected rice lines were also tolerant to deficit irrigation. These lines also produced the best performance of the plant growth, the grain yield and yield component characters when compared with the checked variety. However, deficit irrigation for all selected lines reduced these characters when compared with full irrigation. The five rice lines under deficit irrigation produced the high chlorophyll content and water use efficiency when compared with full irrigation. Thus, it can be concluded that the highest drought- tolerant rice lines would be useful for plant breeding program.

Keywords deficit irrigation; screening rice lines; water use efficiency

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop for more than half of the population of the world. It is cultivated over 167 million hectares with the production of 780 million tonnes (FAO STAT, 2017). It is grown under various environmental conditions in both upland and lowland rainfed ecosystem. Crop productions are affected by many climatic and environmental factors, which can be abiotic and biotic factors. Among them, drought is the most significant environmental factor to impact on the growth and yield of crop in accordance with the global climate change in the world's agricultural lands. In Myanmar, especially in the central dry zone areas, rice yield is quite low due to the salinization, drought, and low soil fertility (Oo et al., 2017). Among them, drought is an increasingly severe problem in rainfed rice production. To increase crop yield in these areas, it is needed to study the plant responses to conditions with the ultimate goal of improving crop performance in areas where water scarcity has a problem. According to further improvement of rice

breeding program in national level, it offers doing research and providing rice varieties for farmer needs are recently lined out. The water requirement for rice genotypes vary with different stages of its establishment processes, and to determine the best tolerance on rice varieties in our country is one of the advantages and encouraging rice production to climate adaptability.

OBJECTIVES

This study was to evaluate the most drought tolerance rice lines based on the effects of water stress on the growth, yield, chlorophyll content and water use efficiency of improved rice lines.

MATERIALS AND METHODS

Evaluation of Improved Rice Lines at Vegetative Stage

A population of 100 improved rice genotypes (provided from the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University) with Yar-8 (tolerant check) were tested at the Department of Soil and Water Science, Yezin Agricultural University, Myanmar.

Preliminary test for drought tolerance screening trial was conducted in a net house with 41/23°C day/night temperatures and a minimum relative humidity of 75% during the day in the dry season of 2018. This trial was laid out in a randomized complete block design with three replications. Two water levels were used as full irrigation and deficit irrigation (50% Plant Available Moisture). Five kilograms of 2-mm-sieved air-dried soil was filled in each black plastic pot of 15-cm height and 20-cm diameter. Pre-germinated seeds of 100 rice lines were sown at two-three seeds on soil surface of each pot. Each plot was well-watered (soil moisture close to the field capacity) before starting the deficit irrigation which was started at 35 days after sowing. Daily soil water status was monitored by using soil moisture meter. Fertilizer was applied as the recommended rate of urea, triple superphosphate and muriate of potash (Buresh and Witt, 2006). Hand weeding and insecticide spraying were done whenever necessary. Drought tolerance was rated using a modified standard evaluation system (SES) in rating the visual symptoms of water stress (IRRI, 2013). This scoring discriminates the susceptible from the tolerant and the moderately tolerant genotypes. Leaf rolling and dry scores were started at 10 days after starting the deficit irrigation.

Evaluation of Selected Improved Rice Lines at Various Stages

This experiment was conducted in a randomized complete block design with three replications in the rainy season of 2019. The selected seven rice lines, after screening at vegetative stage, with Yar-8 (tolerant check) were grown at two different water levels (full irrigation and deficit irrigation (50% PAM)) in the net house. The black plastic pots (30-cm height and 30-cm diameter) were filled with twelve kilograms of 2-mm-sieved air-dried fertilized soil. Three to four pre-germinated seeds of test entries were placed on soil surface of each pot. Two weeks after seeding, seedlings were thinned to one per pot. Maintain soil water status daily and protect the plants from any pests and diseases were performed. Fertilizer was applied as the recommended rate. Plant height (cm), the number of tillers per hill, the number of panicles per hill, the number of spikelets per panicle, filled grain percent, 1000-grain weight, dry matter and grain yield were recorded at harvesting. Chlorophyll content was measured by using chlorophyll meter (SPAD-502, Minolta, Japan) at vegetative and panicle initiation stages. Water use efficiency was calculated as grain yield (usually the economic yield) divided by water used to produce yield consumed by the crop during the growing season (Boutraa, 2010). In order to identify the drought tolerant rice lines, drought susceptibility index (DSI) (Fischer and Maurer, 1978), stress tolerance (TOL) (Rosielle and Hamblin, 1981), mean productivity (MP) (Hosssain et al., 1990), stress tolerance index (STI) (Fernandez, 1992), yield index (YI) (Lin et al., 1986) were also taken into consideration.

Data Analysis

The collected data were examined statistically using Analysis of Variance (ANOVA) Techniques, and means were compared by least significant difference (LSD) method at 5% level of probability. All statistical analyses were done using Statistix 8.0 software and Excel program (2010).

RESULTS AND DISCUSSION

Evaluation of Improved Rice Lines to Drought Stress at Vegetative Stage

All one hundred improved rice lines were grown strongly and showed uniform green colour under both soil water levels. According to the leaf rolling and dry scores, the rice lines differed significantly for drought tolerance at vegetative stage among the rice lines ranging from score 0 (highly tolerant) and score 9 (highly susceptible) under deficit irrigation (data not shown).

The one hundred improved rice lines were classified into five groups from highly tolerant (score 0) to highly sensitive (score 9) as 0 (highly tolerant), 10 (tolerant), 20 (moderately tolerant), 16 (sensitive) and 54 (highly sensitive) at vegetative stage. The effects of water stress on rice plants were complex and it was difficult to interpret the results. Hence, the selected seven rice lines from ten tolerant lines were evaluated for all stages in the net house.

Evaluation of Selected Improved Rice Lines to Drought Stress

Mean comparisons of selected improved rice lines in terms of plant height and number of tillers per hill under two different irrigation levels at harvesting are shown in (Table 1). The plant height was significantly different among the rice lines under deficit irrigation, whereas it was not different in full irrigation. The number of tillers per hill was not significantly different among the rice lines under full irrigation, while it was significantly different under deficit irrigation at 5 % level. Similarly, the number of panicles per hill was not significantly different among the rice lines under full irrigation, whereas it was significantly different under deficit irrigation (Table 2). YAU-1211-82-1-1 and YAU-1211-118-1-1 had the highest (16.7 and 15.7) values, respectively. The number of spikelets per panicle was significantly different among the rice lines under full irrigation at 1 % level. In contrast, it was not significantly different under deficit irrigation (Table 2).

Table 1 Mean comparison of plant height and number of tillers per hill in different improved rice lines at harvesting

Improved rice lines	Plant height (cm)		D (%)	Number of tillers per hill		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	118.5	105.0 b	8.8	20.0	11.3 d	30.0
YAU-1201-90-2-4	128.5	97.1 bc	24.5	20.3	13.3 bcd	34.4
YAU-1211-118-1-1	125.3	90.5 c	27.7	17.7	16.3 ab	7.5
YAU-1211-195-1-1	121.5	100.5 bc	17.3	17.0	15.0 abc	11.8
YAU-1201-26-1-1	126.7	101.6 bc	21.9	13.7	13.3 cd	2.4
YAU-1201-26-1-3	124.2	104.7 b	15.7	17.0	13.0 bcd	23.5
YAU-1211-82-1-1	117.5	106.7 b	11.7	19.0	17.0 a	10.5
Yar-8 (Tolerance check)	127.6	119.3 a	8.2	17.7	15.3 abc	13.2
F-test	ns	**		ns	*	
C.V %	5.2	6.2		21.6	13.7	

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (**) significantly different at P≤0.01, (*) significantly different at P≤0.05, ns − not significant,
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

The data regarding filled grain percent and 1000-grain weight of selected improved rice lines under two different irrigation levels at harvesting are presented in Table (3). There was significant

difference in filled grain percent under full and deficit irrigation at 5 % and 1 % level, respectively. YAU-1211-195-1-1 had the highest filled grain percent (79.1) among the rice lines. The filled grain percent of this rice line under full irrigation was lower than that under deficit irrigation. 1000-grain weight was significantly different among the rice lines under full irrigation at 1 % level, while it was not different under deficit irrigation.

Table 2 Mean comparisons of number of panicles per hill and number of spikelets per panicle in different improved rice lines at harvesting

Improved rice lines	Number of panicles per hill		D (%)	Number of spikelets per panicle		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	17.0	10.7 cd	29.4	169 ab	124	23.9
YAU-1201-90-2-4	19.3	9.7 d	50.0	123 d	121	1.1
YAU-1211-118-1-1	17.3	15.7 a	9.6	161 bc	111	31.3
YAU-1211-195-1-1	16.0	14.0 abc	12.5	149 bc	131	12.7
YAU-1201-26-1-1	12.3	12.0 bcd	2.7	142 cd	106	25.7
YAU-1201-26-1-3	15.7	10.7 cd	31.9	189 a	125	33.8
YAU-1211-82-1-1	17.0	16.7 a	2.0	154 bc	118	24.1
Yar-8 (Tolerance check)	16.3	15.0 ab	24.0	186 abc	122	21.2
F-test	ns	*		**	ns	
C.V %	19.8	15.0		8.9	10.8	

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (**) significantly different at P≤0.01, (*) significantly different at P≤0.05, ns − not significant
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

Table 3 Mean comparisons of filled grain percentage and 1000-grain weight in different improved rice lines at harvesting

Improved rice lines	Filled grain (%)		D (%)	1000-grain weight (g)		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	80.9 ab	68.5 bc	15.4	25.5 d	24.4	4.1
YAU-1201-90-2-4	85.7 a	72.5 abc	15.4	31.7 a	28.9	9.0
YAU-1211-118-1-1	79.5 ab	76.4 ab	4.0	28.2 bc	25.7	8.7
YAU-1211-195-1-1	77.2 b	79.1 a	-2.4	24.7 d	24.7	0.2
YAU-1201-26-1-1	85.6 a	75.3 abc	12.0	28.8 b	28.6	0.6
YAU-1201-26-1-3	69.7 c	58.0 d	16.8	26.5 cd	25.8	2.5
YAU-1211-82-1-1	85.1 a	64.9 cd	23.6	29.2 b	25.2	13.9
Yar-8 (Tolerance check)	73.7 ab	76.6 ab	5.4	29.5 b	25.5	13.7
F-test	*	**		**	ns	
C.V %	5.2	8.4		4.4	7.4	

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (**) significantly different at P≤0.01, (*) significantly different at P≤0.05, ns − not significant
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

In comparing the seven improved rice lines, the effect of drought stress on grain yield was significantly different under deficit irrigation, whereas it was not different under full irrigation (Table 4). Yar-8 (Tolerance check) had the highest grain yield (38.8 g) than the rice lines and followed by YAU-1211-195-1-1 which had the highest grain yield (35.4 g) among the rice lines. In contrast, YAU-1201-26-1-3 had the lowest yield (19.9 g).

The evaluation of drought tolerant promising rice lines based on a single criterion index was incongruous (Table 4). Lower DSI and TOL values indicated the more resistant to drought (Winter et al., 1988; Rosielle and Hamblin, 1981). In this study, regarding to DSI and TOL values, YAU-1211-195-1-1 and YAU-1201-26-1-1 were the most drought tolerant rice lines, while YAU-1201-90-2-4 and YAU-1211-82-1-1 were the least relative tolerant lines. According to MP, YAU-1211-

118-1-1 was the most tolerant rice lines, while YAU-1201-26-1-1 was the least rice lines. Concerning to STI, YAU-1211-118-1-1 was the best tolerant rice lines, whereas YAU-1201-26-1-3 was the worst relatively tolerant lines. Regarding to YI, YAU-1211-195-1-1 was the greatest tolerant rice lines, while YAU-1201-26-1-3 was the poorest relatively drought tolerant lines.

Table 4 Evaluation of improved rice lines based on drought tolerance indices

Improved rice lines	Grain Yield (g per hill)		D (%)	DSI	TOL	MP	STI	YI
	FI	DI						
YAU-1211-14-1-1	58.9	25.3 de	57.1	1.17	33.60	42.09	0.46	0.44
YAU-1201-90-2-4	63.9	24.5 de	59.7	1.27	36.21	42.59	0.45	0.43
YAU-1211-118-1-1	63.4	33.2 abc	47.7	0.98	30.26	48.28	0.64	0.58
YAU-1211-195-1-1	45.3	35.4 ab	22.0	0.45	9.99	40.35	0.49	0.62
YAU-1201-26-1-1	41.7	29.3 bcd	29.7	0.61	12.40	35.49	0.37	0.51
YAU-1201-26-1-3	54.4	19.9 e	63.5	1.29	34.57	37.13	0.33	0.35
YAU-1211-82-1-1	66.2	27.2 cd	58.9	1.20	38.99	46.74	0.55	0.48
Yar-8 (Tolerance check)	66.6	38.8 a	41.7	0.85	27.72	52.69	0.79	0.68
F-test	ns	**						
C.V %	22.8	10.4						

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (**) significantly different at P≤0.01, ns − not significant,
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

Table 5 Mean comparisons of chlorophyll content (SPAD reading) in different improved rice lines at vegetative and panicle initiation stage

Improved rice lines	Chlorophyll content at vegetative stage		D (%)	Chlorophyll content at panicle initiation		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	39.8	47.2	-18.6	38.9	39.6	-1.6
YAU-1201-90-2-4	41.1	44.1	-7.2	33.3	40.6	-21.9
YAU-1211-118-1-1	46.1	46.7	-1.3	42.5	39.7	6.6
YAU-1211-195-1-1	40.0	47.0	-17.4	34.8	41.8	-15.0
YAU-1201-26-1-1	35.5	44.0	-24.0	30.7	37.2	-21.3
YAU-1201-26-1-3	39.9	43.2	-8.1	31.4	39.6	-26.1
YAU-1211-82-1-1	42.8	45.3	-5.8	37.9	39.3	-3.6
Yar-8 (Tolerance check)	42.2	44.4	-5.1	36.1	39.7	-10.0
F-test	**	ns		**	ns	
C.V %	5.1	5.5		6.2	19.4	

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (**) significantly different at P≤0.01, ns − not significant
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

The effect of drought stress on chlorophyll content was significantly different under full irrigation among the improved rice lines, while it was not different under deficit irrigation for both vegetative and panicle initiation stages. In comparing between two irrigations, chlorophyll content of the most rice lines resulted from deficit irrigation was higher than that from full irrigation, indicating that drought tolerant lines had a high chlorophyll concentration. Kalaji et al. (2016) stated that chlorophyll content was increased in abiotic stress tolerant crops, although it was reduced in stress susceptible crops. YAU-1211-195-1-1 had the highest chlorophyll content among the rice lines under deficit irrigation and followed by YAU-1201-90-2-4 rice line.

Mean comparisons of selected improved rice lines in terms of dry matter production and water use efficiency under two different irrigation levels at harvesting are presented in (Table 6). The result

showed that there were significant differences in dry matter production among the rice lines under both irrigations. In comparing the seven improved rice lines, there was significant difference in WUE under deficit irrigation, whereas it was not different under full irrigation. WUE ranged from 0.42 kg m^{-3} to 0.75 kg m^{-3}. The maximum WUE value (0.75 kg m^{-3}) was found from Yar-8 (Tolerance check) and it was followed by YAU-1201-26-1-1 and YAU-1211-195-1-1, (0.69 kg m^{-3} and 0.68 kg m^{-3}, respectively) under deficit irrigation.

Table 6 Mean comparisons of dry matter production and water use efficiency (WUE) in different improved rice lines at harvesting

Improved rice lines	Dry matter (g)		D (%)	WUE (kg m^{-3})		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	125.7 abc	70.2 d	26.3	0.62	0.42 d	32.5
YAU-1201-90-2-4	160.6 a	72.9 cd	25.7	0.67	0.59 abcd	12.6
YAU-1211-118-1-1	139.4 ab	78.9 bcd	23.7	0.67	0.63 abc	6.2
YAU-1211-195-1-1	110.3 bc	80.0 abcd	24.0	0.48	0.68 ab	-42.6
YAU-1201-26-1-1	91.0 c	85.3 abc	26.7	0.44	0.69 ab	-57.3
YAU-1201-26-1-3	128.7 abc	84.8 abc	22.7	0.57	0.45 cd	21.8
YAU-1211-82-1-1	171.7 a	87.1 ab	27.3	0.69	0.53 bcd	23.9
Yar-8 (Tolerance check)	146.1 ab	92.4 a	24.0	0.70	0.75 a	-6.1
F-test	*	*		ns	*	
C.V %	20.3	9.2		22.2	19.2	

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (*) significantly different at P≤0.05, ns − not significant, FI: Full Irrigation, DI: Deficit Irrigation, D (%): decrease down

CONCLUSIONS

In conclusion, differences of the selected improved rice lines were observed for relative drought tolerance in terms of growth, grain yield, chlorophyll content and water use efficiency. From this study, five tolerant rice lines had good performance in the areas where drought has a problem.

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Research article

Evaluation of Water Shortages in Agricultural Water Use in the Sangker River Basin, Cambodia

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Abstract The shortage of agricultural water in the Sangker River basin of Cambodia is becoming a severe problem, and the river flow seems to have decreased. The present study assesses the excess and deficiency of irrigation water resources in this river basin for agricultural production. The Soil and Water Assessment Tool (SWAT) is used to analyze the water balance at the main headwork in this river from 2014 to 2018. SWAT was used to estimate the available volume of stream water at the ungauged point of the Kang Hot headwork, and the model performance was evaluated at a gauged point downstream by the Nash–Sutcliffe efficiency (NSE). The model was calibrated manually and automatically by using data from 2007 to 2013. Furthermore, the flow rates in the two main irrigation canals were measured from June 2018 to October 2019 to obtain the actual irrigation water supply, and the evaluation was made by checking the difference between supplied water volume and irrigation water demand. The model output showed good agreement between observed and simulated monthly streamflow during the validation period (NSE = 0.69, RSR = 0.55). From the results of water balance analysis, water shortage rates exceeding 20% of the monthly water requirement occurred mostly between April and June from 2014 to 2017. Furthermore, there was excess water supply in 2018 because of abundant river flow that year. The actual irrigation water supply during the study period showed rates of water shortage of 52% and 41% in the left and right main canals, respectively, at the headwork. This study provides new insights for field technicians to consider irrigation planning for present and future water resources management and development for sustainable irrigation agriculture.

Keywords SWAT, water balance, irrigation, rice paddy, water supply and demand

INTRODUCTION

Many river basins worldwide are facing perceived water shortages because of increasing demands for water from all sectors. In Cambodia, increasing water demands and competitiveness among sectors and between upstream and downstream of the river system are also becoming crucial, and the concern is that the country will face highly restricted water resources (Technical Service Center & JICA, 2014). Accordingly, the shortage of agricultural water is becoming a serious problem in the river basins, and the streamflows appear to be decreasing. Contributing 22% of gross domestic product collectively, agriculture, forestry, and fishing are essential to the growth of Cambodia's economy, and of the 80% of Cambodian people who live in rural areas, 65% rely on those three sectors (USAID, 2019). The Royal Government of Cambodia continues to enhance the management of water resources, develop irrigation systems, and undertake repair and maintenance of the irrigation infrastructure where required. Furthermore, headwork and multipurpose dams have been constructed

in the river basins to meet the increased demand for water and flood control. The Sangker River basin in northwest Cambodia is one of the largest agricultural production areas in the nation and faces similar water-resource issues. An irrigation project has been implemented in this area, but improved management is required to solve the water-deficit problems.

The state-of-the-art method for estimating water deficiency is to analyze the balance between the water supply and the demand for irrigation water (IW). Masona et al. (2018) revealed a shortfall in IW use by applying the relative water supply (RWS), the ratio of water supply to water demand; an RWS of 1.6 showed that the targeted scheme received much more water than its IW demands. To assess water deficits in the Heibe River basin of China, Ji et al. (2006) established a model of the balance between water supply and demand based on meteorological, hydrological, land use, and socio-economic data. They found that the water supply was insufficient to meet the water demands of the various irrigation districts, and indeed the Pingchuan irrigation district has already experienced a water supply crisis. By comparing the actual water supply with crop water requirements, Shakir et al. (2010) revealed an annual water shortage of more than 40% in the Upper Chenab Canal of Pakistan. However, with regard to the spatial distribution of operational parameters, calculating the supply-and-demand balance of water resources does not resolve the regional problem of water-resource utilization on a relatively large scale in an inland basin (Bormann et al., 1999). Therefore, the present study considers the water balance of a regional scheme by incorporating a physically based model.

In the present study, the Soil and Water Assessment Tool (SWAT) hydrological model is used because of its widespread use in predicting runoff and sediment yield (Arnold et al., 1998). Herein, SWAT is used to estimate the streamflow at the headwork of the main canals. These streamflow data are then used to evaluate the deficit of water resources in the irrigation project area. The present results could help to identify the root of the water shortages that occur frequently not only in the irrigation project area but also across the river basin.

OBJECTIVE

This study aimed to define the available stream water to the irrigation project area and identify the extent to which the water supply of the system is in deficit and/or excess. The specific objectives are (i) to assess the surplus (excess) and deficiency of IW from the Sangker River at the Kang Hot headwork point and (ii) to evaluate the actual IW uses and the demand in the Kang Hot Irrigation Project area.

METHODOLOGY

Study Site

The present study was conducted in the Sangker River basin situated in the Battambang province of Cambodia and with a total drainage area of 6,053 km^2 (Department of Hydrology and River Works, n.d.). The elevation ranges from 13 to 1,400 m above sea level, and the annual rainfall ranges from 695 to 1,787 mm. The focus was on a 3,062-km^2 area to the southwest of the city of Battambang that covers the middle and upper basin of this river system (Fig. 1). The Kang Hot Irrigation Project is only one of the huge numbers of water uses in the study area, with a total command area of 72,000 ha. However, the water is taken from the Sangker River to the project area at the Kang Hot headwork and transported to the paddy fields through the left and right main canals, where the irrigated areas are only 11,200 ha and 42,000 ha (Kodoma, 2018), respectively (Fig. 2).

To assess the surplus and deficiency of IW, the balance between the available water supply from the river and the IW demand was analyzed at the Kang Hot headwork from 2014 to 2018. The actual IW use in the Kang Hot Project area was also evaluated by comparing the difference between the actual volume of water intake from the river and the IW requirement from June 2018 to October 2019.

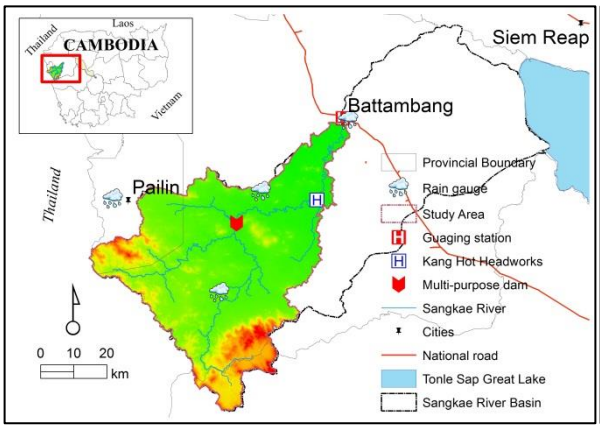

Fig. 1 Location map of study area

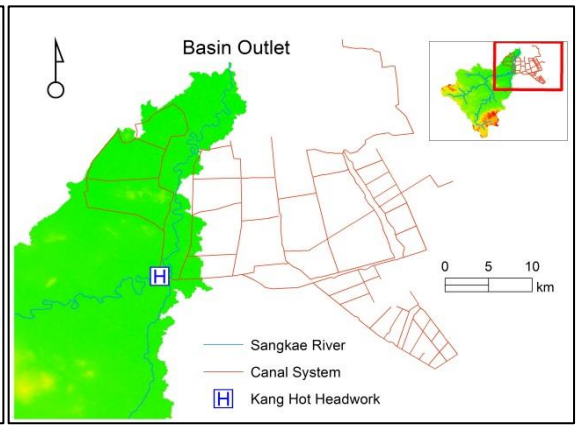

Fig. 2 Kang Hot Irrigation Project area

Availability of Stream Water

In the study area, the supply of agricultural water depends on irrigation from the river source. For the latter, the available volume of stream water was estimated using the SWAT hydrological model.

SWAT Modeling

SWAT is a river-basin-scale model developed to predict the impact of land management practices on water, sediment, and nutrient yield, including agricultural activity, in large, complex watersheds with varying soils, land use, and management conditions over a long period of time (Winchell et al., 2013). In the present study, SWAT was set up with the basin outlet at the Samdach Hun Sen Bridge as a gauging station located in Battambang City (Fig. 1). The watershed and sub-basins were delineated within the basin using 30-m-resolution DEM data (ASTER-GDEM 2) in the ArcSWAT2012 interface. The 3,062 km^2 of the catchment area accounts for 51% of the entire Sangker River basin (Fig. 2). A sub-basin was defined as a drainage area with a threshold of 5,000 ha, resulting in 26 sub-basins that were subdivided further into 123 hydrological response units based on slope, soil, and land use, the data for which were retrieved from the FAO-UNESCO Soil Map and the Mekong River Commission (MRC-2010), respectively. The available meteorological data of daily rainfall and temperature data at four stations obtained from the Ministry of Water Resources and Meteorology (MOWRAM) for 14 years (2007–2018) had to be preprocessed by the model. The observed streamflow data collected from MOWRAM at the Samdach Hun Sen Bridge between 2007 and 2018 were used for model calibration (2007–2013) and validation (2013–2018). The SWAT model was calibrated manually by editing the most sensitive parameters based on recommendations by Abbaspour et al. (2015). In addition, the SUFI-2 algorithm packaged in SWAT-CUP was used for automatic model calibration and validation and sensitivity and uncertainty analyses (Abbaspour et al., 2007). The model performance was evaluated using the quantitative statistics of the Nash–Sutcliffe efficiency (NSE) and the ratio of the root mean square error to the standard deviation of measured data (RSR) suggested by Moriasi et al. (2007). After fixing the SWAT for the Sangker River at the Samdach Hun Sen Bridge gauging station, the flow rate at the Kang Hot headwork was extracted from the database of model results.

Irrigation Water (IW) Demands

The IW demands were calculated mainly for rice-based farming in the Kang Hot Project area. Based on its cropping calendar, the unit IW requirement was estimated with a 5-d time step using

$$IR = (ETo \times Kc + PR + Lp - ER) / IE, \quad (1)$$

where (i) IR is the unit IW requirement, (ii) ETo is the crop reference evapotranspiration (calculated using the Penman–Monteith equation with different time steps using meteorological data), (iii) Kc is the crop coefficient following the FAO's guideline for the case of rice paddy fields (Allen et al., 1998), (iv) PR is the percolation rate (because of the absence of field measurement records, this was collected from the Master Plan Study Team of JICA in 2007, which applied a dial gauge and open-ended-cylinder method in the study site), (v) Lp is the land preparation requirement (needed to saturate the root zone and depends on soil type and rooting depth, which was estimated by assumption (i.e., sandy loam = 250 mm, clay loam = 200 mm, clay = 170 mm)], (vi) ER is the effective rainfall calculated by following empirical relationships developed in Japan (Dastane, 1974), and (vii) IE is the irrigation efficiency, which refers to the conveyance efficiency of the distribution system and was collected from MOWRAM and the Master Plan Study Team of JICA in 2009. The IW demand comes from the unit IW requirement multiplied by the area to be irrigated, which gives a volume of IW needed per unit time. The IW demand is computed as

$$ID = IR \times A, \quad (2)$$

where ID is the IW demand and A is the area.

Estimation of Actual IW Supply

The actual continuous flow rate for each of the main canals was estimated by three steps. (1) Water-level loggers were installed in the left and right main canals near the Kang Hot headwork during the study period from June 2018 to October 2019. (2) Each canal flow rate was calculated directly from the mean canal-flow velocity (using a current meter over ten time differences) and the flow canal cross-sectional area. The water level in each canal at the moment of measurement was also recorded. These measurements were then integrated into a rating curve (H–Q curve) of the water level and the canal flow rate for each canal (Buchanan and Somers, 1976). (3) By using this H–Q curve, the records of the daily water level were converted into the daily canal flow rate and aggregated at a monthly volume.

RESULTS AND DISCUSSION

SWAT Calibration and Validation

Figure 3 shows the results of the observed and simulated streamflow at the Samdach Hun Sen Bridge gauging station in Battambang City (Fig. 1) with a monthly time step in the periods of calibration (2007–2013) and validation (2014–2018). The graphs show that the SWAT model tracked the observed data accurately both calibration, and validation periods. This was confirmed by NSE values of 0.58 and 0.69 in the calibration and validation periods, respectively (Moriasi et al., 2007). From the SWAT results at the gauging station, the available water resources at the Kang Hot headwork could be estimated for 2014–2018 from the database of the simulation results.

Analysis of Balance Between Available Stream Water and IW Demand

To evaluate the excess and deficiency of IW from the Sangker River at the Kang Hot headwork point, Fig. 4 shows the monthly averages of available stream water and IW demand at the headwork, and Fig. 5 shows the observed deficit rate for the 5-year study period (2014–2018). The results show that the availability of stream water varies over a year and from 1 year to the next. With regard to both the irrigation area and cropping patterns in the Kang Hot Project area during this study period, they were supposed that the IW demands did not change much. If the water shortage is less than 10–20% of the monthly requirement, then the production losses are not very serious (Brouwer et al., 1992).

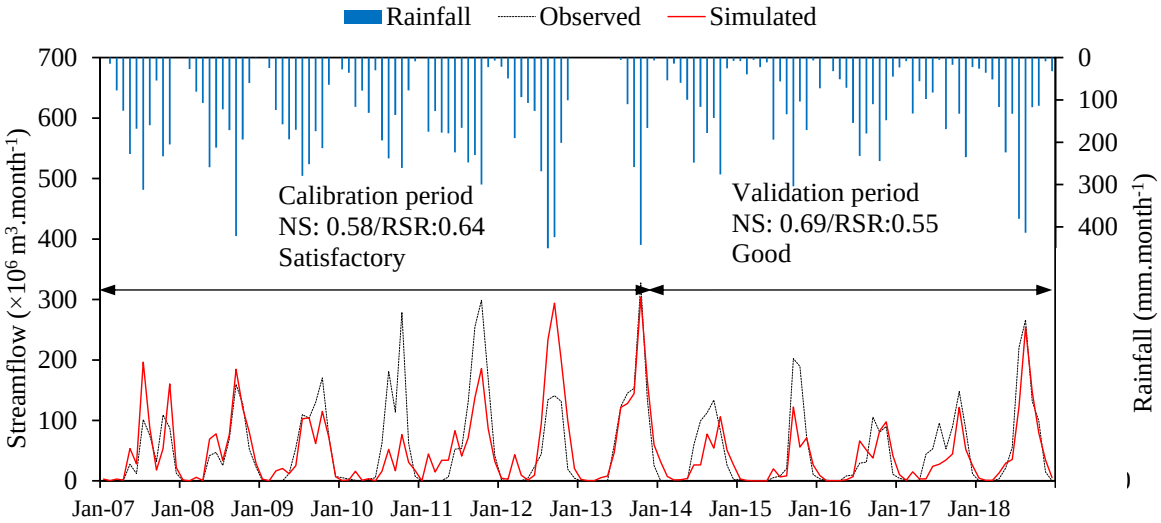

Fig. 3 Monthly simulated and observed flow rate for calibration and validation period in Samdach Hun Bridge gauging station of Sangker River

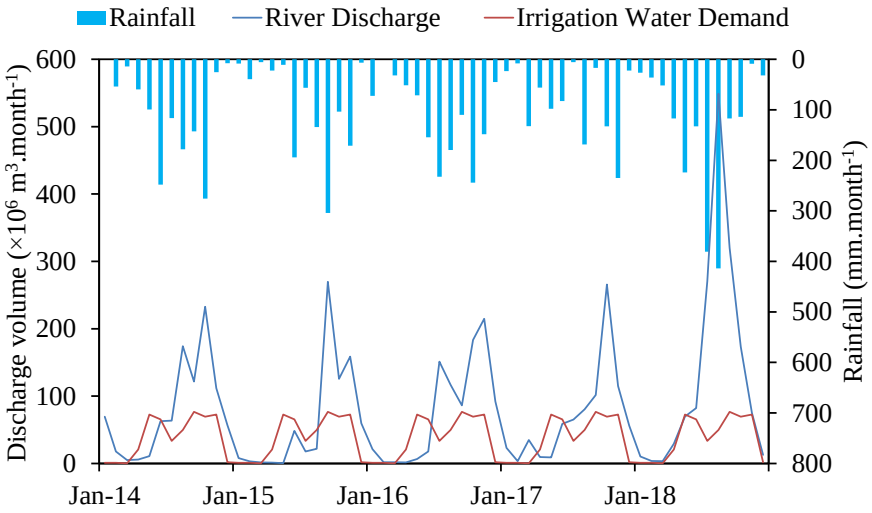

Fig. 4 Balance of available stream water and irrigation water demand at Kang Hot headwork

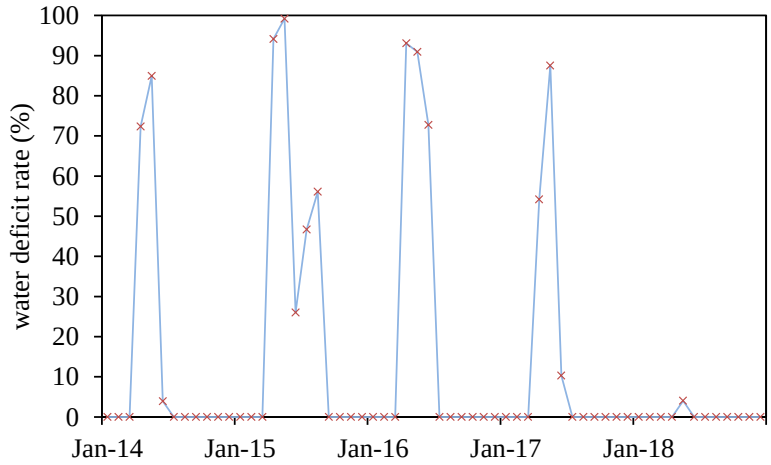

Fig.5 Monthly water deficit rate at Kang Hot headwork

The water balance calculation in Fig. 4 indicates that water deficit always occurred during the April–May dry season every year from 2014 to 2017, with shortage rates of 50–99% of monthly requirements. In the dry year of 2015, the area faced 5 months of subsequent water scarcity (with deficiency rates of 30–99%). Each year, the stream water was surplus in the July–November wet season. In 2018, heavy rainfall increased the streamflow volume, which means that the stream water could meet the IW demand in a given area for the whole year.

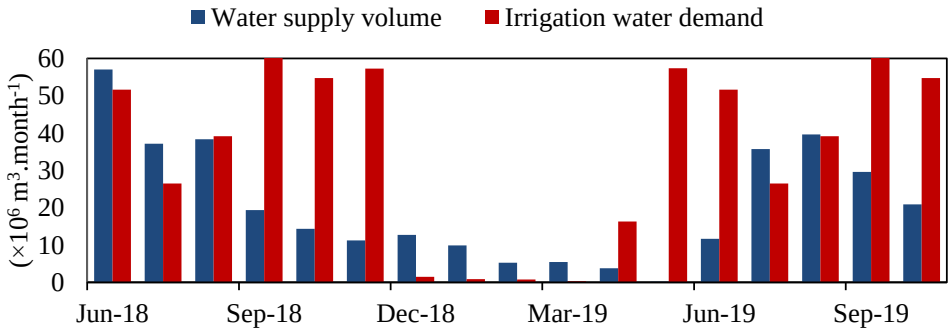

Fig. 6 Actual irrigation water (IW) in right main canal

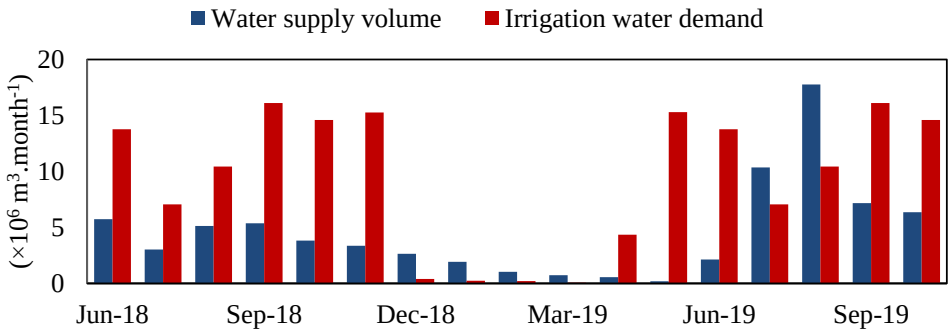

Fig. 7 Actual irrigation water (IW) in left main canal

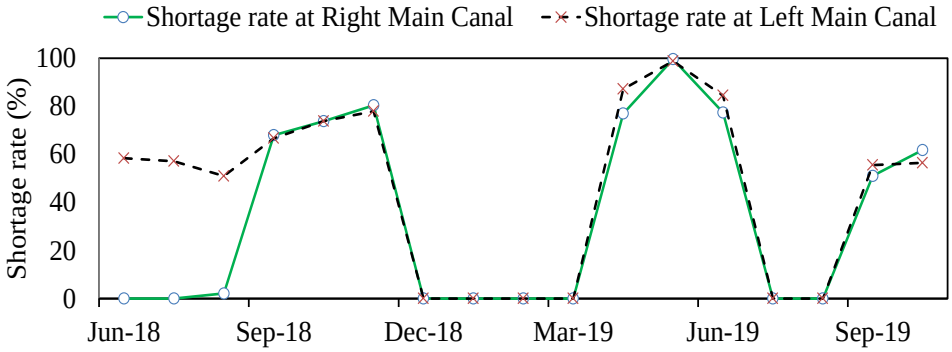

Fig. 8 Water shortage rate in right and left main canals

Evaluation of Actual IW Use

The actual volume of water supply from the Sangker River and the IW demand are shown in Figs. 6 and 7 for the right and left main canals, respectively, as monthly averages from June 2018 to October 2019. Figure 8 shows the water shortage rate in each month for both main canals.

The results for the actual water supply and demand balance for the right main canal (Fig. 6) show a maximum supplied water volume of around 57×10^6 m$^3 \cdot$ month^{-1} in 2018, decreasing to 40

$\times 10^6$ $m^3 \cdot month^{-1}$ in 2019. Meanwhile, the highest IW demand was approximately 60×10^6 $m^3 \cdot month^{-1}$, corresponding to the extreme lack of water in 2019. As shown in Fig. 8, large water shortages occurred in both 2018 (70–78% from September to November) and 2019 (over 77% from April to June). In those 2 years, the water supply was always less than the water demand in September and October, with the shortage rate exceeding 50%. However, the IW demands in every July and August during this study period were met. Overall, we conclude that the right main canal can supply around 59% of the required monthly IW.

Figure 7 shows that the maximum supplied water volume by the left main canal was around 5×10^6 $m^3 \cdot month^{-1}$ in 2018, increasing to 17×10^6 $m^3 \cdot month^{-1}$ in 2019. Meanwhile, the maximum water demand was around 16×10^6 $m^3 \cdot month^{-1}$. Similar to the right main canal, water was also scarce in September and October for those 2 years, with shortage rates of 56–74% (Fig. 8). Figure 7 also shows that water deficiency occurred between June and November, with 50–78% in 2018 and over 80% from April to June in 2019. By 2018, the water supply in July and August was inadequate, with a shortage rate of around 51%. However, compared to that in 2019, it is increased at 7×10^6 $m^3 \cdot month^{-1}$ and 12×10^6 $m^3 \cdot month^{-1}$, thereby meeting the water demands of those 2 months. The water volume of the left main canal can supply only 48% of the requirement.

Cropping Pattern

To minimize the water deficiency, an analysis is conducted by modifying the existing cropping pattern against the available IW. In the revised cropping pattern, the cultivated area is changed as follows: (i) early-wet-season rice is reduced from 40 to 10%; (ii) transplanting-wet-season rice is increased from 60 to 80%; and (iii) direct sowing-wet-season rice is increased from 10 to 20%. The results of this analysis show that the water shortage rate was reduced from 20 to 100% between April and May (2014–2017), which is at the beginning of the irrigation season.

CONCLUSION

The results of this study show that SWAT performed well in predicting the streamflow by providing good agreement between the observed and simulated monthly flow, which is based on the statistics of NSE = 0.58 and NSE = 0.69 in the calibration and validation periods, respectively. With such good performance, SWAT can be used to estimate the river discharge at the Kang Hot headwork point as needed.

The balance between the available volume of stream water and the IW demand at the Kang Hot headwork indicates that the water shortage rate was 50–99% of the monthly requirement, which occurred mostly in April–June, and the excess water was in August–November. This surplus should be controlled to compensate for the deficiencies in other months. By revising the current cropping-pattern calendar, the water deficits could be diminished from 20 to 100% of the monthly shortage rate in those shortfall months.

The actual IW use during the study period was 52% and 41% have experienced the lack of water in the left and right main canals, respectively. Also, water deficits occurred in September and October in both 2018 and 2019.

The results of this study will be useful for policy makers and field technicians for irrigation planning and for developing and managing the water resources in the river basin, in particular for the sustainability of agricultural development.

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Research article

Influence of Meteorological Parameters on Population of Whitefly, *Bemisia tabaci* on Greenhouse-grown Tomatoes

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Abstract Whiteflies (*Bemisia tabaci* (Gennadius)) are important vectors of diseases of tomato crop production. Outbreaks of whiteflies can cause decreased productivity and transmit pathogens. The purposes of this study were to compare the degree of white fly infestation in two varieties of tomatoes, Shiny Queen and Ninmanee, and to investigate whitefly population responses to weather-related environmental parameters. The study was conducted in a green house. Whitefly population was counted every two days on three positions of the plant; the upper part, middle part and lower part. The results indicated that the Shiny Queen variety was infected with significantly higher numbers of white fly than was the Ninmanee variety. Whitefly numbers observed on Shiny Queen variety were significantly related to temperature, relative humidity, solar radiation and dew point. A mathematical model was developed to predict the relationship of environmental conditions to white fly population.

Keywords weather parameters, abiotic factors, Aleyrodidae

INTRODUCTION

The whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is an important pest on tomato. It can cause direct damage to the crop by puncturing the leaf tissue and feeding on the phloem resulting in reduced growth rate and yield. In addition, it can transmit tomato yellow leaf curl virus (TYLCV) (Liu et al., 2013). The common cultivated tomato (*Solanum esculentum*) is very susceptible to TYLCV. Infected tomato plants show symptoms of yellowing, curling, and cupping of leaves. Additionally, this virus causes a severe stunting and abortion of flowers and fruits, leading to 100% yield loss (Yan et al., 2018). The production of honeydew by the whitefly can causes stickiness and promotes growth of mold. *B. tabaci*, eggs nymphs and adults are found on the underside of leaves where they are protected from applications of insecticides. Production of vegetables in greenhouses is practiced worldwide and it can protect crops from abiotic factors such as wind, rain, and temperature that may damage to the crop. It may protect crops from many diseases, and some common field pests. The largest area of greenhouse cultivation occurs in Asia, with China having 55% of the total world's plastic greenhouse acreage (including large plastic tunnels) and over 75% of the world's small plastic tunnels (Peet and Welles, 2005).

Because of seasonal climatic variations in agricultural areas, insect pests show varying trends in their incidence in nature. There some reports that the population of whitefly depends upon certain abiotic factors such as temperature, relative humidity, rainfall and sunshine hours (Janu and Dahiya, 2017; Jha and Kumar, 2017). Therefore, if the correlation of whitefly abundance and abiotic factors is understood, that knowledge can applied in designing a pest management program for tomato production in the green house.

OBJECTIVE

The objectives of this study were to compare the degree of white fly infestation in two varieties of tomatoes, and to investigate how whitefly population changed with meteorological parameters.

METHODOLOGY

The experiment was conducted in a greenhouse at the agricultural experimental area at Khon Kaen University. Seedlings (20 days old) of the tomato varieties Shiny Queen and Ninmanee were transplanted from nursery to the field. Meteorological data, temperature (ºC), relative humidity (%) wind speed (km/h), rainfall (mm), solar radiation (wat/m^2) and dew point (ºC) were recorded daily using a 2000 series Watch Dog weather station.

The population of whitefly was first observed when plants were 25 days old. The number of whiteflies was directly counted every other day between 16:00 and 17:00 from 23 tomato plants of each variety. Whiteflies were observed on three leaves (on upper, middle and lower parts of plant) using hand len of 10x magnification. Analysis of variance was conducted for testing the significance if one of the weather variables was linearly related to the whitefly population. The null hypothesis states that $\beta1=\beta2=\ldots\ldots\beta i = 0$. If alternative hypothesis is accepted ($\beta \neq 0$), then, a mathematical model of biting black flies can be analysed by logistic regression.

RESULTS AND DISCUSSION

Population dynamics of whiteflies from the two tomato varieties were similar during the vegetative and flowering stages. In the vegetative stage, the number of whitefly from both tomato varieties was lowest. Then, whitefly population gradually increased in the late flowering stage. Abundance increased by up to 18.3 and 2.39 insects/plant in Shiny Queen and Ninmanee, respectively. During fruiting and harvesting stage, the number of whitefly gradually increased in Shiny Queen variety, but it decreased in Ninmanee (Fig. 1). There were significant differences between the mean number of nymphs and adults of whitefly on the two tomato varieties. Shiny Queen was more infected with whitefly than was the Ninmanee variety (Table 1). The results of this study corresponded with the reports of Arnal et al (1998) and Patra et al. (2016) who found that whitefly were present throughout the growing period in tomato.

Abiotic parameters were separately analysed by logistic regression for each tomato variety (Table2). The results revealed that the whitefly abundance on the Ninmanee variety was not related to abiotic parameters whereas it was on the Shiny Queen variety. This result may related to the small number of whitefly infections in the Ninmanee variety. When each abiotic parameter was separately analysed by logistic regression for the Shiny Queen variety, four of six parameters; temperature, relative humidity, solar radiation and dew point, were significantly related to the whitefly population with r^2 0.31-0.47 (Table 3). The results indicated that solar radiation and temperature were negatively related to the abundance of whitefly populations. These results were corroborated with the previous studies of Jha and Kumar (2017) who reported that sunshine hours was negatively correlated whitefly population on tomato. There was a positive relationship between whitefly abundance and dew point, and dew formation is a meteorological and hydrologic phenomenon which can provide an important water input. There is a report indicating that nutrients in dew can be assimilated by certain insect

pests (Xu et al., 2015). The results differ from some previous studies where maximum temperature was found to be positively correlated with whitefly abundance (Bala et al., 2019).

Umar et al. (2003) have reported that the correlation of whitefly population abundance and temperature, relative humidity and precipitation was negative for whitefly populations on some varieties of cotton. However for certain other varieties, a positive correlation of abundance with temperature and relative humidity was observed. Janu and Dahiya (2017) found that weather parameters from different years show different levels of correlation. Therefore, the difference of host plant varieties or the duration of the experiment gave different results in respect to weather correlation. During this experiment, there was no rain and no wind speed because the experiment was done in a controlled greenhouse.

The regression equation of whitefly population with all weather parameters; temperature, relative humidity, wind speed, rainfall, solar radiation and dew point was analysed. Statistical analyses indicate that no weather variable was related to the number of whiteflies in the Ninmanee variety. However, there was statistically strong evidence that at least one of weather variables was related to the number of whiteflies in Shiny Queen. The regression model revealed a significantly positive association with only dew point, ($p<0.05$), but not with any other of the weather variables ($p>0.05$). The following regression model was selected as shown in Table 3 with r^2 =66. This result differed from the previous report of Sharma et al. (2013) that six weather parameters played a significant role in whitefly abundance on tomato; maximum and minimum temperature, sunshine hours, maximum and minimum relative humidity, and rainfall. The differential results may depend on environmental conditions such as plant varieties, natural enemies, and cultural management.

Table 1 Mean number of nymphs and adults of whitefly on tomato varieties Shiny Queen and Ninmanee.

Varieties*	Mean ± SD**		
	adult	nymph	nymph + adult
Shiny Queen	2.93±3.01a	4.56±5.6a	7.49±8.03a
Ninmanee	0.95±0.6b	0.50±0.80b	1.46±1.24b

* *n=23 (for each tomato varieties)*

** *Mean within a column followed by different small letters differ significantly ($p<0.05$)*

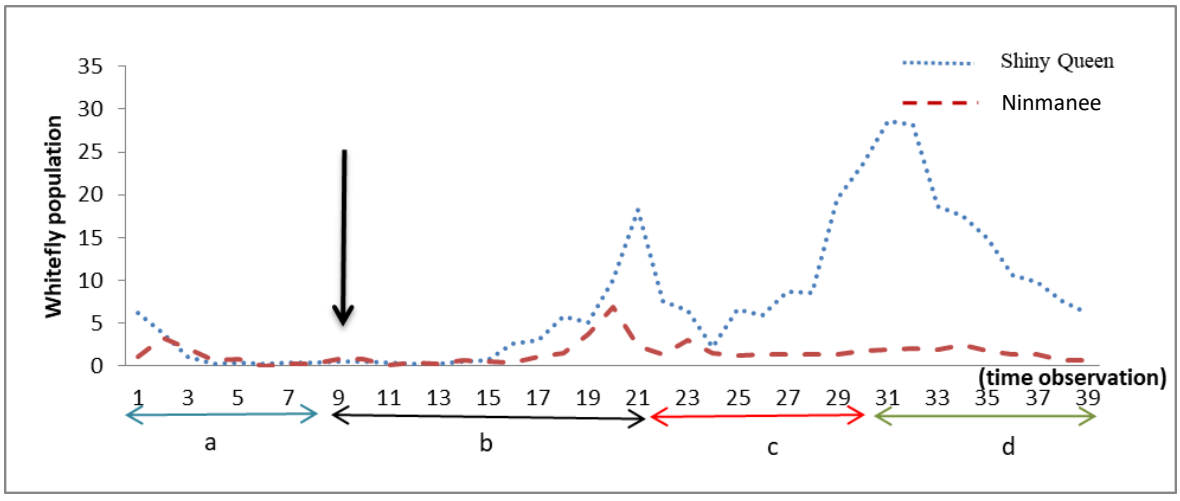

Fig. 1 Population dynamics of whitefly on tomato leaves during, a= vegetative stage, b=flowering stage, c=fruiting stage, d= havesting stage, arrow indicates insecticide application

Table 3 Meteorological parameters data from tomato greenhouse during the experiment

Checked date	Temperature (°C)	RH (%)	Solar Rad (wat/m^2)	Dew Point (°C)	Rainfall (mm)	Wind Speed (km/h)
1	28.87	56.77	67.33	21.53	0	0
2	30.75	39.8	141	19	0	0
3	32.4	33.6	144.33	18.67	0	0
4	31.21	40.87	124.33	20.2	0	0
5	33.12	34.3	113.33	18.83	0	0
6	32.71	30.47	158.33	17.87	0	0
7	33.45	27.77	138	17.77	0	0
8	34.04	28.07	161.67	18.53	0	0
9	33.86	27.93	170.33	18.73	0	0
10	30.86	45.13	76.33	20.8	0	0
11	29.21	49.63	114.33	21.63	0	0
12	27.94	55.93	78	21.9	0	0
13	32.72	27.63	150	17.3	0	0
14	29.73	43.3	138	19.9	0	0
15	28.32	48.67	128.67	19.5	0	0
16	30.63	32.13	158.67	15.7	0	0
17	31.54	38.47	152.67	19.17	0	0
18	33.71	32.53	163	17.4	0	0
19	30.3	60.57	71	22.67	0	0
20	31.54	45.7	108.67	21.33	0	0
21	29.2	64.7	66.67	23.37	0	0
22	31.49	55.23	127.33	22.5	0	0
23	31.83	40.33	92.67	19.2	0	0
24	33.15	48.53	102.33	20.9	0	0
25	31.28	40.7	100.33	19.07	0	0
26	30.22	61.33	95	23.27	0	0
27	30.58	65.27	60.67	22.5	0	0
28	27.88	69.57	81.33	23	0	0
29	30.32	58.43	69.33	22.83	0	0
30	28.73	60.67	61	21.93	0	0
31	16.88	66.7	27.33	67.47	0	0
32	28.52	65.4	59.33	74.1	0	0
33	30.8	52.87	90.33	72.7	0	0
34	30.88	64.33	28	72.9	0	0
35	30.25	54	106	71.43	0	0
36	32.13	38.9	117	66.3	0	0
37	30.94	46.93	119.33	67.97	0	0
38	32.44	36.57	129.67	64.8	0	0
39	31.42	46.1	117.67	68.27	0	0

Table 2 Regression equations of weather variables related to whitefly population

	Shiny Queen		Ninmanee	
	Regression Equation	R^2	Regression Equation	R^2
temperature (ºC)	$y = 56.54 - 1.59X$	0.31	-	-
relative humidity (%)	$y = -12.2 + 0.42X$	0.44	-	-
solar radiation (wat/m^2)	$y = 23.30 - 0.15X$	0.47	-	-
dew point (ºC)	$y = 0.06 + 0.24X$	0.38	-	-
wind speed (km/h)	-	-	-	-
rainfall (mm)	-	-	-	-
Pooled weather parameters	$y = 15.36 + 0.16 dew\ point$	0.66	-	-

CONCLUSION

This experiment provided information on the population of whitefly infesting two varieties of tomato; Shiny Queen and Ninmanee. The statistical significance of whitefly numbers indicated that the Shiny Queen was more infested by whitefly than the Ninmanee variety. Some weather variables; temperature, relative humidity, solar radiation, and dew point, were related to whitefly population in Shiny Queen. Those parameters were used to create a mathematical model for white fly population in the greenhouse.

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Research article

Effects of Crimping by Oggun Tractor-mounted Roller/crimper on Cover Crop Termination, Soil Strength, and Soil Moisture in Upland Cambodia

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Abstract Rolling/crimping technology for terminating cover crops is essential to ensure that the rolled plant residue benefits both soil and succeeding cash crops. Cambodia has also adopted this technology, but it is still at the initial stage due to limited rolling services. The objectives of this study were to compare different roller-crimpers with the Oggun-mounted USDA roller-crimper in terminating sunn hemp (*Crotalaria juncea L.)* and to determine their effects on soil strength and soil moisture. The experiment was conducted in Rattanak Mondul, Battambang province in the wet season of 2019, using a randomized complete block design with three treatments having four replicates, each of which was 14 m x 34 m and spaced 5 m. The treatments consisted of (i) a USDA roller-crimper, mounted on 19-hp Oggun tractor, (ii) a Cambodian made roller-crimper with elliptic bars, and (iii) a disc-plow, both pulled by a 75-hp tractor. Plant height and biomass before rolling; soil strength at 0-10 and 10-20 cm depths before and after rolling; field operations; and soil volumetric moisture content (VMC) evaluated on the day of rolling, and then one, two, and three weeks after rolling, along with termination rate were analyzed. The results show that the height and biomass of sunn hemp were not significantly different among the treatments, being 164 cm and 2.56 t ha^{-1}. In Oggun crimping, speed and field efficiency were lowest, being 3.5 km h^{-1} and 0.8 ha h^{-1}, but fuel use was highest. Under plow-based management, soil compaction was slightly higher and termination rate was more efficient, when compared to other treatments. Significant difference was not observed for VMC between the equipment used. However, crimping can be beneficial for cover crop termination, compared with disking that may have long-term effects on the soil.

Keywords conservation agriculture, plant biomass, sunn hemp, termination rate

INTRODUCTION

Cover crops are an integral part of conservation agriculture (CA) and are planted to benefit the soil in numerous ways (Clark, 2012). Unlike CA, conventional tillage (CT) modifies the soil, adversely affecting soil physical, chemical, and biological properties (Acar et al., 2018). Technically, CT involves plow-based practices, leaving less than 30% of crop residue on the soil surface (Vian et al., 2009). In contrast, CA is defined as a farming system whose key principles are minimal soil disturbance, permanent plant cover, and crop diversification (FAO,2016). It helps reduce soil erosion, run-off, soil temperature, and soil compaction, retain soil moistures, increase nitrogen in the soil, and

suppress weed (Balkcom et al., 2018; Mitchell et al., 2019). Because of its benefits, CA has been adopted in Cambodia since 2004 to improve soil fertility for upland crops; nevertheless, it is still considered an early stage at which rolling services remain inadequate.

There are many kinds of cover crop available in Cambodia, and sunn hemp is highly preferred. Sunn hemp (*Crotalaria juncea L.*) is a tropical leguminous crop native to India and Pakistan. It is a drought-tolerant crop that can reach 183 cm and grow on soil pH 5 to 7.5 (USDA, 2012). It produces 1 to 9 tons ha^{-1} of biomass and 122 kg ha^{-1} N in 45 to 90 days (Price et al., 2012). Seeding rates vary from 17 to 34 kg ha^{-1} (Balkcom et al., 2011). Mature sunn hemp is manageable by crimping, or herbicide, but herbicide is harmful to soil and human health (Kornecki et al., 2012).

Kornecki (2015) defined a roller-crimper as functioning to flatten cover crops on the soil surface, to kill or injure them, to create mulch through which cash crops are seeded and grow. Crimping is effective when legumes are at flowering stage, or when grass cover crops reach anthesis stages (Frasconi et. al, 2019). Cover crop termination should be done no more than three weeks before planting cash crops (Kornecki, 2009, 2012 & 2015). Crimpers consist of one or two rollers. Crimpers with one roller may have elliptic or straight bars, and the roller itself can be solid or hollow. Crimpers with one smooth roller are also common but need spontaneous operation with herbicide spray to kill the cover crop (Kornecki et al., 2012). Besides that, crimpers with two rollers use the front roller, which is usually smooth, to flatten cover crops and the rear one to crush them. Recent crimping technology is trapping and applying tractor engine heat to kill the cover crop, so the crimping mechanism is not roller-based, but like an iron (Fasconi et al., 2019).

OBJECTIVE

The objectives of this study were (1) to compare different roller-crimpers with Oggun-mounted USDA roller-crimper in terminating sunn hemp (*Crotalaria Juncea* L.) and (2) to determine their effects on soil strength and soil moisture.

METHODOLOGY

In the wet season of 2019, the experiment was conducted on clayey soil, called *Mollisol*, with pH 7 to 7.13 in Rattanak Mondul District, Battambang Province, Cambodia. The average day-time temperature and monthly rainfall were 29^0C and 148.6 mm (Climate.data.org, 2019). Sunn hemp was planted on May 12, 2019 at equal rate of 22 kg h^{-1} and terminated at the blossom stage.

Materials

The roller-crimpers tested in this experiment were a patented two-stage roller-crimper developed at the National Soil Dynamics Laboratory (NSDL), the United State Department of Agriculture (USDA), and a Cambodian made roller-crimper with elliptic bars. The USDA roller-crimper (Kornecki, 2011) had two drums with a width of 1.35 m. The first drum was smooth and the second drum had six straight crimping bars used. The Cambodian made roller-crimper had one roller a width of 2.0 m. designed its elliptic crimping bars. A disc-plow had six 2.0-m discs, functioning to cut and incorporate the cover crop into the soil, and turn over the soil. In addition, the tractors utilized to pull these implements were different. The USDA roller-crimper was mounted on the Oggun tractor; the Cambodian made roller-crimper and the disc-plow on a Ford 6600 tractor. Oggun is manufactured as an open-system tractor by the Cleber LLC located in Alabama, USA. It is hydraulically operated, weighs 0.8 ton, and has a 19-hp gasoline engine. The Ford 6600 tractor is powered by a 75-hp diesel engine, weighing 2.56 tons.

Design and Sampling Methods

Research design was based on the studies by Kornecki (2009, 2012 & 2015), but slightly modified to suit the Cambodian condition. A randomized complete block design (RCBD) was used comprising

three treatments, each with four replications. Each plot was 34 m long and 14 m wide to accommodate at least five times the roller-crimper's widths and spaced 5 m for tractor turning. The three implements were evaluated on the same day. Before rolling, sunn hemp height was measured at 9 randomly chosen locations in each plot. Sunn hemp biomass was collected from three locations within each plot area using a 1.0-m^2 area wire frame (1.0 x 1.0 m). The biomass samples were dried for 15 days at 50 to 65^0C using a solar dryer parabola dome. Before and after rolling, bulk density and soil penetration resistance were evaluated at 0-10 and 10-20 cm depths from three locations within each plot. The soil samples were dried for 24 hours at 105^0C using an oven (Universal Oven UN55 Memmert). Soil penetration resistance was evaluated using a cone penetrometer with 0-100 reading scales (model S086 proving ring penetrometer). Termination rate was evaluated 7, 14, and 21 days after rolling, using a visual method. Each rolled, or disked plot was split into five and evaluated based on 0-100% scales for mortality rate. However, the rolled residue was sprayed with glyphosate two weeks after rolling, to plant corn. Due to herbicide effects, data were collected only two weeks and then averaged. Volumetric soil moisture content (VMC) was measured using a portable TDR moisture meter with 0.12 cm long rods (Spectrum Technologies, Plainfield, IL) on the rolling day and then 7, 14, and 21 days after rolling in each plot.

The data were analyzed performing analysis of variance (ANOVA) by using the R-software 6.3.1 available online. Fisher's protected LSD test at $\alpha = 0.05$ probability level was used to show significant difference and to determine interactions between treatment means, periods before and after rolling, and soil depths.

Fig. 1 (a) USDA roller-crimper, mounted on Oggun; (b) Cambodian made roller-crimper, pulled by 75-hp diesel tractor; (c) disc-plow with six discs

RESULTS AND DISCUSSION

Sunn Hemp Height and Biomass

Significant differences in the plant height (*P-value=0.462*) and biomass (*P-value=0.823*) were not observed among the treatments, being 164 cm and 2.57 Mg ha^{-1}. The reason was that sunn hemp was planted using the same method, but crimping/disking was applied afterwards at blossom. The plant height of sunn hemp in this study was acceptable, compared to the data by USDA (2012) and Balkcom and Reeves (2004), indicating it within the range of 120 to 180 cm. However, the plant biomass was slightly low, compared to the average value of 5.6 Mg ha^{-1}, due to prolonged drought. Balkcom et al. (2011) recognized the weather as the main factor. His findings showed that the plant biomass was even lower than 2.0 Mg ha^{-1} despite different planting dates and seed rates applied.

Field Operations

There were significant differences in speed, fuel consumption, and field efficiency (*P-value<0.001*) among the treatments. Disking speed was the fastest, operated at 5.21 km h^{-1}, followed by the Cambodian made roller-crimper at 4.5 km h^{-1} and the USDA roller-crimper at 3.5 km h^{-1}. The Oggun consumed 21.35 liter ha^{-1}, greater than the 75-hp tractor that used 11.13 liter ha^{-1} for disking and 12.44 liter ha^{-1} for crimping. Oggun crimping achieved low field efficiency at 0.79 ha h^{-1}, while

disking and crimping with elliptic bars accomplished more work, equal to 1.10 and 1.27 ha h^{-1}. Low Oggun performance is most likely associated with the engine size, weight, attached equipment, rolling method and land condition. Likewise, Kornecki et al. (2009 & 2015) studied greater speed and attributed the field efficiency to speed and numbers of rolling passages.

Table 1 Sunn hemp height, biomass, and field operations by crimping/disking

Treatment	Plant height (cm)	Plant biomass (t ha^{-1})	Speed (km h^{-1})	Fuel use (l ha^{-1})	Field efficiency (ha h^{-1})
USDA-crimper	166.42 a	2.50 a	3.50 c	21.35 c	0.79 c
Cambodian crimper	167.42 a	2.66 a	4.50 b	12.44 b	1.09 b
Tillage	159.75 a	2.54 a	5.21 c	11.14 a	1.27 a
SE	6.628	0.260	0.269	1.030	0.092
CV (%)	9.87	24.8	14.96	13.75	9.95
T-test probability	0.462	0.823	<0.001***	<0.001***	<0.001***

**** significant at p < 0.001 and letters in the same column refer to the difference between treatments.*

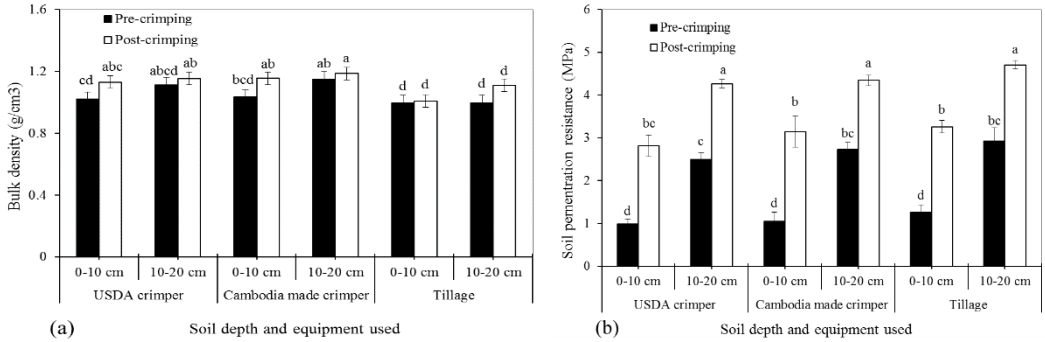

Fig. 2 Bulk density and soil penetration resistance (mean± SD) examined at different depths before and after rolling, with respect to the equipment used. Means with different letters are significantly different (LSD-Test, p < 0.05)

Bulk Density

Bulk density was examined at 0-10 and 10-20 cm depths, and then compared before and after rolling. No significant interactions between the equipment used and soil depth in both periods (*P-value=0.265*). However, significant differences were observed among the treatments with respect to depths and rolling periods (*P-value=0.043*). After rolling, bulk density increased by 0.1 to 0.2 g cm^{-3}. In disking, no significant difference was found since the soil became loose, when disked and turned over at less than 30 cm depth. Higher bulk density was observed at deeper subsoils, regardless of the equipment used. In this study, bulk density averaged 1.2 g cm^{-3}, which was categorized by Rowell (1994) and Duruaha et al. (2007) as little impacts on plant root development.

Soil Penetration Resistance

No significant interactions between the equipment and soil depth were observed in both periods (*P-value=0.917*). Although crimping/disking was not applied, soil compaction still increased as soil depth increased (*P-value<0.001*). Soil compaction was even greater after utilizing the equipment (*P-value=0.025*), indicating the effects of the equipment on the soil. Before rolling, soil penetration resistance measured at the 0-10 cm depth was similar in all treatments, being approximately 1.1 MPa, but increased to 3 MPa after rolling. At the 10-20 cm depth, soil compaction became greater when crimping/disking was applied, but was not significantly different among the equipment used. As a result, it increased from 2.7 MPa before rolling to 4.4 MPa after rolling. These values fell into the range that Bartzen et al. (2019) classified as medium limitations on plant root growth, but exceeded the threshold value of 2 MPa, that might restrict corn root elongation (Unger et al., 1994).

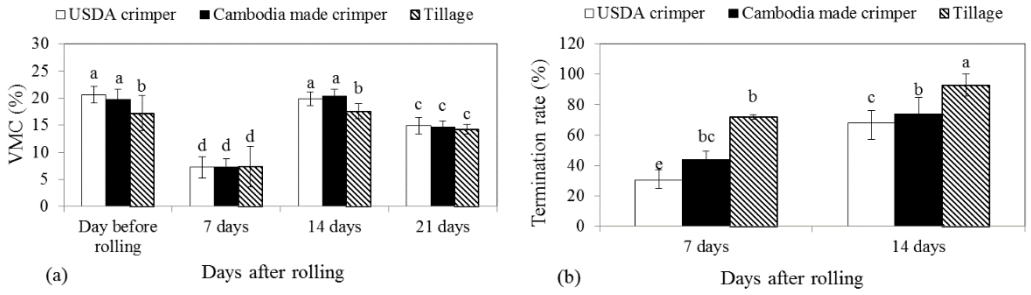

Fig. 3 Effects of crimping/disking on soil volumetric moisture content (VMC) and sunn hemp termination rate (mean % ± SD) evaluated with respect to time. Means with different letters are significantly different (LSD-Test, p < 0.05)

Volumetric Soil Moisture Content (VMC)

Soil moisture was examined on the day before rolling and after first, second, and third week, with respect to the equipment (Fig. 3). There were significant interactions between treatments and weeks ($P < 0.001$); thus, the data were analyzed weekly. On the day before rolling, significant differences in VMC were observed among the treatments ($P < 0.001$), being 21.6% in Oggun crimping, 19.8% in crimping elliptic bars, and 17.2% in disking. One week after rolling, no significant differences were detected ($P < 0.525$) and VMC averaged 7.3%. In week two, there were significant differences in VMC ($P < 0.001$), being 20.1% in both crimping types and 17.6% in disking. However, VMC were not significantly different in week three ($P < 0.188$), measured at 14.7%. It was observed that VMC fluctuated over time, but a sharp decrease in VMC was observed in week one after cover crop termination, due to sunn hemp decomposition that could not prevent water losses. In weeks two and three, VMC increased because of successive rains that replenished the soil with water. With respect to the equipment used, Effects of soil water losses caused by disking were not clearly seen due to the interference of rainfalls and low cover crop biomass production.

Sunn Hemp Termination

Mechanical termination was evaluated, analyzed and compared in two weeks only. There were significant interactions between treatments and weeks ($p<0.001$); thus, the data were compared by week. In both weeks, significant differences in sunn hemp termination rate were observed among the treatments ($p<0.001$). In week one, termination rates for oggun crimping, crimping with elliptic bars, and disking were 30.5, 44.1, and 71.5%, respectively. The value increased sharply in week two, but remained significantly lower in Oggun crimping, compared to operation by the 75-hp tractor. In that week, Oggun crimping obtained the termination rate at 67.8%, tractor crimping at 74%, and disking at 92.9%. Highest termination rate was found in disking because sunn hemp was subject to damage, when cut, crushed and buried in the soil. The termination rate obtained in this study were lower than the recommendations by Kornecki (2015), reporting that achieving 90% in two weeks is critical for succeeding cash crops and profitable.

CONCLUSION

Two different roller-crimpers were compared with disking in terminating sunn hemp in upland Cambodia. The USDA roller-crimper consumed more fuel amounts but had lower field efficiency, when compared to other treatments. Termination rate by Oggun crimping was also lower than 75-hp tractor operations. Tractor weight, engine size, rolling method, and soil condition tend to be the main cause. Bulk density, soil penetration resistance, and VMC in all treatments seem not to be different. Despite that, it can be observed that the disked plots had disturbed soil with less crop residue, leaving it exposed to the sun and prone to moisture losses, when compared with crimping.

ACKNOWLEDGEMENT

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Research article

Evaluating Changes in the State of Organic Matter Present in Agricultural Soils based on Loss on Ignition Method

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Abstract Loss on ignition (LOI) method is widely regarded as a quick, inexpensive method for evaluating organic matter characteristics in terrestrial soils and littoral sediments. Previous studies examined the LOI method alone to evaluate the state of organic matter, finding that changes in the state of organic matter in littoral sediments could be represented by LOI method-based indices related to combustion temperature: $(LOI_{300}-LOI_{200})/LOI_{600}$ and LOI_{300}/LOI_{600}. However, these new indices have not been applied to agricultural soils. In this study, laboratory experiments were conducted to examine the validity of our proposed indices for evaluating the state of organic matter in agricultural soils. Paddy soil, Andosol, and cow manure compost were allowed to decompose over three months. Measurements of pH, redox potential (ORP), and weight LOI at 200, 300, and 600 ºC were measured at one and three months after the experiments started. Temporal decreases in ORP were observed, highlighting the decomposition of organic matter present in each material. The $(LOI_{300}-LOI_{200})/LOI_{600}$ metric changed over time for all materials, whereas the LOI_{300}/LOI_{600} values were almost constant. We concluded that $(LOI_{300}-LOI_{200})/LOI_{600}$ can represent changes in the state of organic matter in agricultural soils. Furthermore, we discovered that LOI_{200}/LOI_{600} can represent changes in the state of organic matter with reasonable accuracy, rather than the more complicated $(LOI_{300}-LOI_{200})/LOI_{600}$. This finding should make LOI measurements easier and more affordable.

Keywords loss on ignition, organic matter state, decomposition, combustion, agricultural soils

INTRODUCTION

Soil organic matter (SOM) is any plant or animal material, including leaf litter, microbial biomass, water-soluble organics, and humus at different stages of decomposition (Stevenson, 1994; Brady and Well, 1999). SOM has a major impact on the physicochemical properties of soils (Tisdall and Oades, 1982). For example, SOM has been shown to affect the cation exchange capacity, structure, water infiltration rate, water-holding capacity, erodibility and conversion, and pesticide adsorption of soil (Schulate, 1995; Ding et al., 2002).

Several methods have been proposed to measure the organic matter of terrestrial soils and littoral sediments. For instance, the Walkley-Black method is a wet oxidation method used to determine the amount of organic matter from the organic carbon content of the soil (Swift, 1996; Kerven et al., 2000). Another method, loss on ignition (LOI), uses dry combustion method to directly determine the amount of organic matter (Cambardella et al., 2001; Konen et al., 2002). Automated CHNS analysis conducted on gas chromatographs has been used to quickly determine the elemental contents (i.e., C, H, N, and S) with high precision (Telek and Marshall, 1974). With advancements in technology, it is now possible to accurately analyze the organic matter characteristics of a sample based on molecular weight measurements, thermogravimetric analysis, and spectrometric analysis (Cuypers et al., 2002; Hong et al., 2010). To the best of our knowledge, the LOI method is the most

economical method that is suitable for rapidly analyzing large numbers of samples with the advantage of time and cost savings, it does not require a measurement expert, and it is an accessible method for developing countries.

To date, some authors have evaluated the amount and state of SOM on the basis of the LOI method, alone. For instance, the ratio of weight losses on ignition at 300 °C (LOI300) and at 600 °C (LOI600) was found to describe the state of organic matter present in littoral sediment (Hibino et al., 2014). Subsequent refinement revealed that (LOI300−LOI200)/LOI600 metric more accurately represents the state of organic matter in littoral sediments than LOI300/LOI600 metric, especially, changes in the state of organic matter due to decomposition (Touch et al., 2015; Touch et al., 2017). However, these metrics have not been used to evaluate the state of SOM in agricultural soils, so their validity should be tested in that setting.

OBJECTIVES

This study aims to examine the validities of LOI_{300}/LOI_{600} and $(LOI_{300}-LOI_{200})/LOI_{600}$ metrics in evaluating changes in the state of organic matter present in paddy soil, andosol, and cow manure compost. These materials are allowed to decompose over three months, and changes in their pH and redox potential (ORP) are measured for understanding the decomposition of organic matter present in each material. Then, the association between temporal changes in LOI_{300}/LOI_{600} and $(LOI_{300}-LOI_{200})/LOI_{600}$ metrics and the decomposition of organic matter is investigated for examining the validities of these metrics. Furthermore, this study also aims to propose a more economical metric for examining the state of organic matter present in organic agriculture materials.

METHODOLOGY

Materials and Experimental Procedures

The paddy soil used in experiments was collected from a rice field (Ebina, Kanagawa, Japan) during the agricultural off-season. Approximately 150 mm of the surface soil was collected and transported to the laboratory. Approximately 200 mm of the surface soil of an andosol was collected from a farmland (Nakai, Kanagawa, Japan) during the agricultural off-season. Finally, commercial cow manure compost was purchased and used in this study. All of the materials were used in the experiment without any pre-treatment. Each material was placed in the experimental device as shown in Fig. 1.

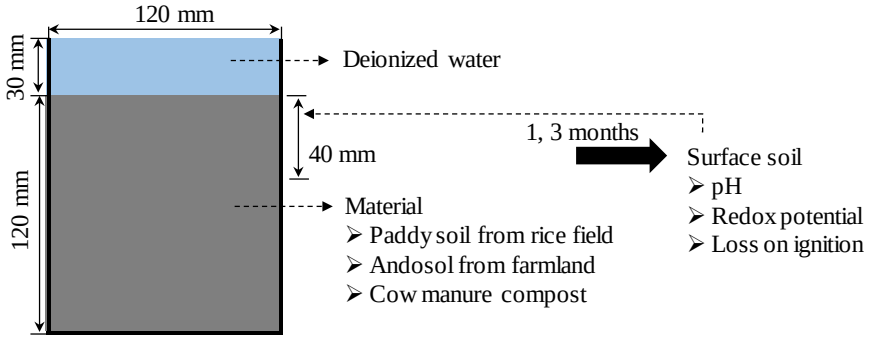


Fig. 1. Diagram of the experimental device and some procedural details used in this study

The experimental device comprised a cylindrical bottle with an inner diameter of 120 mm and a height of 150 mm. The bottle was filled with each material to a depth of 120 mm. The bottle was then filled the rest of the way with deionized water (Fig. 1), and placed under ambient conditions for three months. After one and three months, the top 40 mm of the surface soil was collected from the bottle for measurements of pH, ORP, and weight LOI.

Soil Analysis

Each collected sample (paddy soil, andosol, or cow manure compost) was mixed before pH and ORP were measured. A D-50 pH/ORP meter (Horiba, Japan) was inserted directly into the sample. After the pH and ORP measurements were completed, samples were prepared for the measurement of weight LOI. Each sample was oven-dried at 50 ± 5 °C for more than three days, and the dried weight was then measured. A temperature of 50 °C is suitable for drying samples before determination of organic matter content (Takata et al., 2017). An electronic muffle furnace (Advantec, KL-420) was used to burn each of the dried samples for 4 h at each of three temperatures: 200, 300, and 600 °C according to Saito et al. (1977). The sample was weight after burning at each temperature. LOI for each stage was determined by comparing these values with the 50 °C oven-dried weight. The measurements of LOI were performed in triplicate and had an error of ± 6 $mg.g^{-1}$.

RESULTS AND DISCUSSION

Temporal Decomposition of Organic Matter

Figure 2 shows the temporal changes in pH and ORP for each material while under ambient conditions. The ORP values started at 304±4 mV, 318±1 mV, and 96±9 mV for the andosol, paddy soil, and cow manure compost, respectively. The OPR of the paddy soil decreased to 93 mV over one month, and to −241 mV over three months. Decreases in the ORP of andosols and cow manure compost were also found. After three months, the ORP was −226 mV for the andosol, and −437 mV for cow manure compost.

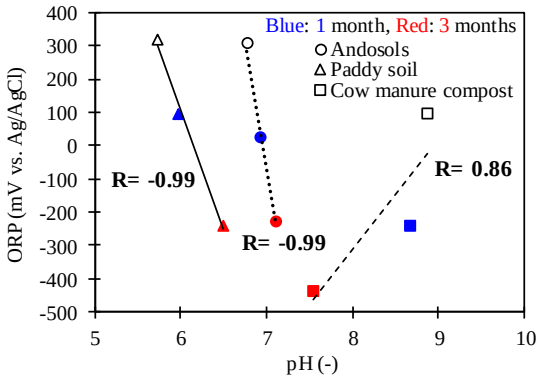
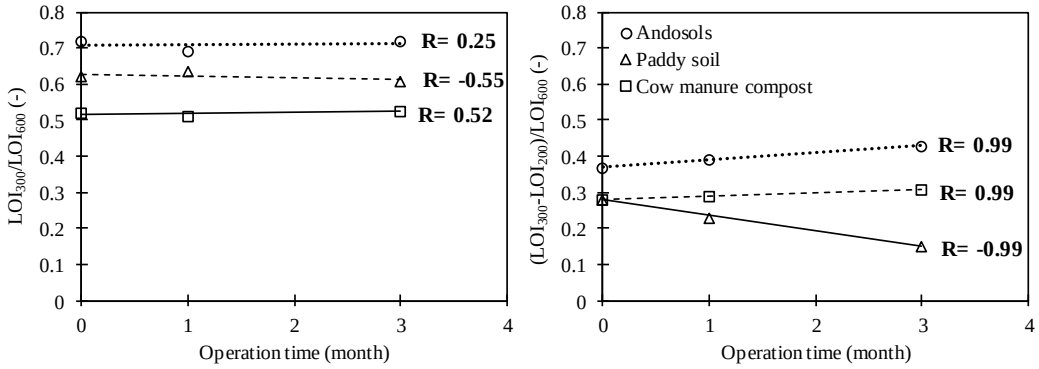


Fig. 2 Temporal changes in pH and redox potential (ORP)

Variations in pH and ORP can represent the decomposition of organic matter present in littoral sediments (Touch et al. 2015). A decrease in ORP indicates the decomposition of organic matter because oxidants are used in the decomposition processes. Thus, our results showed clear signs of decomposition of organic matter over time, as was found by Touch et al. (2015).

Validities of LOI_{300}/LOI_{600} and $(LOI_{300}-LOI_{200})/LOI_{600}$

As revealed by Fig. 2, the decomposition of organic matter present in each material decomposed over time. This means that a correlation between the proposed indices and operation time should be observed. Figure 3 depicts the temporal patterns of LOI_{300}/LOI_{600} and $(LOI_{300}-LOI_{200})/LOI_{600}$ metrics. Low correlation between LOI_{300}/LOI_{600} metric and operation time was confirmed, with this matric remaining nearly constant for each material over the span of experiment (Fig. 3a). This finding suggests that LOI_{300}/LOI_{600} metric is unable to reflect the decomposition of organic matter present in andosol, paddy soil, and cow manure compost.



(a) LOI_{300}/LOI_{600} **(b) $(LOI_{300}-LOI_{200})/LOI_{600}$**

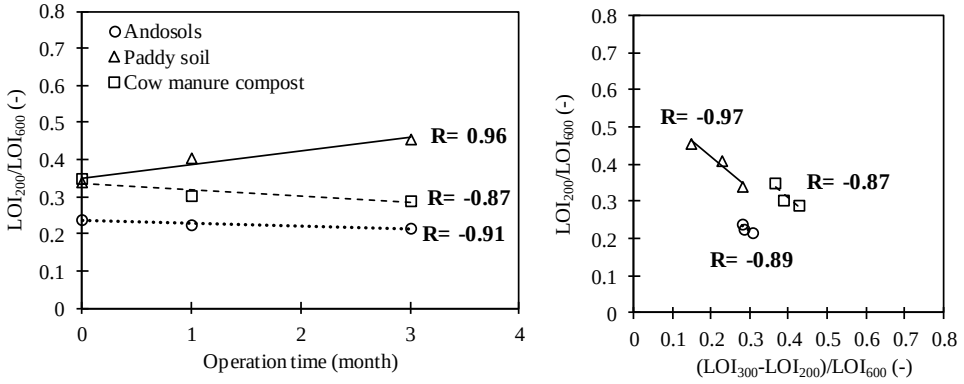
Fig. 3 Temporal variations of LOI_{300}/LOI_{600} and $(LOI_{300}-LOI_{200})/LOI_{600}$

On the other hand, the $(LOI_{300}-LOI_{200})/LOI_{600}$ metric for each material had a strong correlation (R = 0.99 for all samples) with operation time (Fig. 3b). This demonstrates that $(LOI_{300}-LOI_{200})/LOI_{600}$ metric can indicate the decomposition of organic matter present in these materials. When combined with the findings of previous research (Touch et al., 2017), we concluded that the $(LOI_{300}-LOI_{200})/LOI_{600}$ metric can represent the decomposition of organic matter either in littoral sediments or in agricultural soils, including compost materials.

Interestingly, different tendencies in the variation of $(LOI_{300}-LOI_{200})/LOI_{600}$ metric were observed among the materials used. Specifically, $(LOI_{300}-LOI_{200})/LOI_{600}$ metric increased in the andosol and paddy soil samples, while it decreased in the case of cow manure compost (Fig. 3b). This reflects differences in organic matter decomposition characteristics among these materials due to a difference in the initial pH-ORP (Fig. 2) and organic matter content (e.g., Fig. 3a) of each material.

New Index for Evaluating the Decomposition of Organic Matter

To explore the source of the difference in the performance between $(LOI_{300}-LOI_{200})/LOI_{600}$ metric and LOI_{200}/LOI_{600} metric, Figure 4 shows the behavior of LOI_{200}/LOI_{600} metric. This metric had a strong correlation (R > 0.87) with operation time for each material (Fig. 4a), but was not as strong as $(LOI_{300}-LOI_{200})/LOI_{600}$ metric (R = 0.99). Furthermore, it was observed that LOI_{200}/LOI_{600} metric had a strong correlation (R > 0.87) with $(LOI_{300}-LOI_{200})/LOI_{600}$ metric (Fig. 4b), suggesting that LOI_{200}/LOI_{600} metric can be used instead of $(LOI_{300}-LOI_{200})/LOI_{600}$ metric. This means that LOI_{200}/LOI_{600} metric can be viewed as a new index for evaluating the decomposition of organic matter in these materials. This may provide an advantage in terms of cost and time savings, because only the weight losses on ignition at 200 and 600°C must be measured for this simplified metric.



(a) Operation time and LOI_{200}/LOI_{600} **(b) $(LOI_{300}-LOI_{200})/LOI_{600}$ and LOI_{200}/LOI_{600}**

Fig. 4 Relations between operation time and $(LOI_{300}-LOI_{200})/LOI_{600}$ with LOI_{200}/LOI_{600}

As noted earlier, we observed different tendencies in the variation of $(LOI_{300}-LOI_{200})/LOI_{600}$ metric (Fig. 3b). According to Cuypers et al. (2002), the burning temperature of organic matter increases as the organic matter becomes more humified. For the cow manure compost, $(LOI_{300}-LOI_{200})/LOI_{600}$ metric decreased (Fig. 3b), while LOI_{200}/LOI_{600} metric increased (Fig. 4a). This suggests a loss of the organic matter burned at 200−300°C ($OM_{200-300}$) and the release of the organic matter burned at 50−200°C (OM_{50-200}). The other two samples, however registered a loss of OM_{50-200} and a formation of $OM_{200-300}$.

Generally, cow manure compost contains the organic matter that readily decomposes, while the organic matter in paddy soils and andosols tends to be humified. Hence, these results reflect decomposition of $OM_{200-300}$, leading to the release of OM_{50-200} in cow manure compost, while the humification of OM_{50-200} leads to the formation of $OM_{200-300}$ in paddy soils and andosols. It can be said that the tendency of the temporal change in each metric reflects the decomposition characteristic of organic matter.

CONCLUSION

Our laboratory experiments examined the validities of LOI_{300}/LOI_{600} and $(LOI_{300}-LOI_{200})/LOI_{600}$ metric in evaluating changes in the state of organic matter present in paddy soil, andosol, and cow manure compost. Temporal changes in LOI_{300}/LOI_{600} metric were not observed, while $(LOI_{300}-LOI_{200})/LOI_{600}$ metric had a strong correlation with operation time. This reinforced the idea that $(LOI_{300}-LOI_{200})/LOI_{600}$ metric can represent the decomposition of organic matter, either in littoral sediments or agricultural soils, including compost materials. Furthermore, we found out that LOI_{200}/LOI_{600} metric had a strong correlation with $(LOI_{300}-LOI_{200})/LOI_{600}$, suggesting that this matric can be used as a simpler proxy for $(LOI_{300}-LOI_{200})/LOI_{600}$ metric. Finally, the proposed metrics, i.e., $(LOI_{300}-LOI_{200})/LOI_{600}$ and LOI_{200}/LOI_{600}, were used to identify the decomposition and humification of organic matter. For example, the humification of organic matter caused a decrease in LOI_{200}/LOI_{600} metric and an increase in $(LOI_{300}-LOI_{200})/LOI_{600}$ metric. The tendency of the temporal change in each metric reflected the decomposition characteristic of organic matter.

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Research article

Vegetable Farming Practices in Cambodia: Case study of Small-scale Vegetable Farmers in Kandal, Kampong Chhnang and Battambang Provinces

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Abstract Cambodia shifted from an agrarian-based to a service- and production-based economy through its fast-economic growth. However, agriculture is still a backbone of the Cambodian economy because 80 percent of the population lives in rural areas, and around 37 percent of the total workforce remains directly engaged in the agricultural sector. Even though the Royal Government of Cambodia (RGC) considered the enhancement of the agricultural sector as a high priority in its national development agenda for 2014 to 2018, Cambodia remains a net vegetable importer. Approximately USD 200 million of vegetable products are imported informally from Thailand and Vietnam each year. Several research studies have been conducted to identify farmers' constraints. However, challenges faced by small-scale vegetable farmers have yet to be clearly characterized. This research aimed to identify the farming practices and challenges of small-scale vegetable farmers in Cambodia. There were 40 households, selected by homogeneous purposive sampling method, surveyed from the Kandal, Kampong Chhnang and Battambang Provinces. The results of the study are divided into three parts, with the first component focused on farming practices. There were 12 types of vegetables that were identified as being grown in the studied areas. However, only 5 types of vegetables were commonly grown by farmers. Chinese mustard (55%) was the most popular vegetable being grown in the areas, followed by green mustard (50%), pak choi (45%), leafy mustard (37.5%) and Chinese kale (27.5%). Due to small production size, almost all interviewed farmers harvested their products by sickle, knife, and/or scissors, and manual harvest is still in practice by some farmers. Post-harvest activities such as grading, sorting and cleaning products after harvesting and before selling are not commonly practiced by farmers. Second, the majority of vegetable products are sold to collectors; a small quantity of remaining products is sold to retailers, farmers' groups/cooperatives and direct consumers in the areas. Third, the study revealed three main challenges faced by farmers. Insect pests and disease infestation (87.5%) was the most prominent issue of vegetable farmers, followed by climate change (e.g. flooding, drought) (77.5%). Low selling price and considerable fluctuation in prices were equally problematic (both 57.5%). Other notable issues included post-harvest losses especially in peak seasons of oversupply (45%), lack of power in the market chain (42.5%), and lack of pest control information (40%), while lack of information about market prices (37.5%) and poor market information systems (37.5%) were the minor issues in vegetable production.

Keywords vegetable farming, marketing, post-harvest, value chain

INTRODUCTION

Cambodia has experienced rapid agricultural growth, among the fastest in the world. The annual growth of agricultural gross production was 8.7 percent from 2004 to 2012. However, the contribution of this sector in the Cambodian economy has been decreasing and is being replaced by manufacturing and services (World Bank, 2015). Even though the Royal Government of Cambodia (RGC) considered the enhancement of the agricultural sector as a high priority in its national development agenda (National Strategic Development Plan, 2014), the development of the Cambodian agricultural sector has been slow. Cambodia is a net agricultural importer. Their imported commodities include vegetables (about USD 200 million of vegetable products was informally imported annually), agricultural inputs and finished products primarily from Thailand and Vietnam (USAID, 2019). Several issue which have been hampered the small-scale vegetable production are lack of agricultural techniques, unreliable supply and demand, and competition with informal imported vegetables. Even though there have been various research studies conducted in the vegetable sector, the practices and challenges of small-scale vegetable farmers have remained ambiguous.

OBJECTIVE

This research aimed to identify the farming practices and challenges of small-scale vegetable farmers in Cambodia.

METHODOLOGY

Mixed methods, quantitative and qualitative, were used to conduct this study. The total sample was 40 households, selected by homogeneous purposive sampling method, from the Kandal, Kampong Chhnang and Battambang provinces. The selection of study location based on two reasons. First, these provinces are among Cambodian vegetable production's zones. Second, characteristic of smallholders in these provinces represents the farmers in all location in the country. Ensuring accuracy in sample selection, researchers reviewed literature, screened names in the list of vegetable farmers provided by the local authority, and then discussed and finalized the selected sample with the local authority. The collected data was analyzed by using descriptive statistics.

RESULTS AND DISCUSSION

Table 1 Household demographics

Items	N	Minimum	Maximum	Mean	Std. Deviation
Family members	40	2	9	4.85	1.545
Children ≤ 15 years old (male)	18	1	3	1.56	0.784
Children ≤ 15 years old (female)	14	1	2	1.21	0.426
Adults 16 – 60 years old (male)	36	1	4	1.67	0.956
Adults 16 – 60 years old (female)	39	1	5	1.77	0.931
Elderly >60 years (male)	9	1	1	1.00	0.000
Elderly >60 years (female)	11	1	1	1.00	0.000
Valid N (listwise)	0				

*Source: Authors, *multiple answers will not add up with 100*

To understand the current practices and various challenges faced by small-scale vegetable farmers in Cambodia, 40 smallholder vegetable farmers were interviewed in 18 villages in 5 districts of Kandal, Kampong Chhnang and Battambang provinces. The household demographics are shown in Table 1.

The gender and age distribution as well as the family size between the villages surveyed were similar. Of the respondents, 67.5% were male, 32.5% were female, and the average age of respondents was 47.30 years old. Ninety-five percent of respondents were able to read and write Cambodian language, while 5% were illiterate. The majority of interviewed household (95%) were nuclear families[1], while 5% were jointly family[2]. The average family size was 4.85 members.

Table 2 Household land use

Distribution of household land in hectares	Kandal	Kampong Chhnang	Battambang
Main dwelling land	0.007	0.005	0.008
Other dwelling land	0.074	0.136	0.070
Agricultural land	0.611	1.569	3.204
Total owned cultivable area in 2018	0.884	1.569	3.170
Total rented cultivable area in 2018	0.051	-	0.600
Own areas under vegetable farming	0.308	0.199	0.293
Rented areas under vegetable farming	0.017	-	-
Total owned land	1.884	3.478	6.745

Source: *Authors*

The household land distribution is shown in Table 2. The household land size and agricultural land size differed between provinces. Farmers in Battambang province owned on average 6.745 hectares, which was greater than Kampong Chhnang (3.478 hectares) and Kandal (1.884 hectares) provinces. Similarly, farmers in Battambang had the most agricultural land (3.204 hectares), followed by 1.569 hectares in Kampong Chhnang province and 0.611 hectare in Kandal province. In contrast, the average area under vegetable cultivation in Kandal province was 0.325 hectare, which was higher than Battambang province (0.293 hectare) and Kampong Chhnang province (0.199 hectare).

Table 3 Types of vegetables grown in the studied areas

No	Name of Vegetable	Frequency	Percent
1	Pak choi	18	45.00
2	Leafy mustard	15	37.50
3	Chinese mustard	22	55.00
4	Cabbage	2	5.00
5	Chinese cabbage	1	2.50
6	Green mustard	20	50.00
7	Lettuce	10	25.00
8	Spring onion	1	2.50
9	Crown daisy / Chrysanthemum green	0	-
10	Chinese Kale	11	27.50
11	Gallic chives	0	-
12	Culantro	4	10.00

**multiple answers will not add up with 100; ** N=40.*
Source: Authors

There were 12 types of vegetable identified as being grown in the studied areas (Table 3). However, only 5 types of vegetable were commonly grown by farmers. Chinese mustard (55%) was

[1] ''A nuclear family, elementary family or conjugal family is a family group consisting of two parents and their children (one or more). It is in contrast to a single-parent family, the larger extended family, and a family with more than two parents. Nuclear families typically center on a married couple; the nuclear family may have any number of children'' (Wikipedia '' Nuclear family'' accessed by January 22, 2020: https://en.m.wikipedia.org/wiki/Nuclear_family).

[2] ''A joint family or undivided family is an extended family arrangement prevalent throughout the Indian subcontinent, particularly in India, consisting of many generations living in the same household, all bound by the common relationship'' (Wikipedia '' Hinu Joint Family'' accessed by January 22, 2020: https://en.wikipedia.org/wiki/Hindu_joint_family).

the most popular vegetable being grown in the areas, followed by green mustard (50%), pak choi (45%) and leafy mustard (37.5%). Chinese kale and lettuce were grown by 27.5% and 25% of farmers, respectively. Culantro, cabbage, spring onion and Chinese cabbage were not commonly grown by farmers in the studied areas. Post-harvest activities such as grading, sorting and cleaning products after harvesting and before selling were rarely implemented by farmers. There are three main reasons encounter the postharvest practices of farmers: interviewed farmers do not have knowledge and experiences on postharvest activities; the required materials are not accessible in the target, and no requirements for grading, sorting and cleaning products from collectors, retailers, agricultural cooperative, and customers.

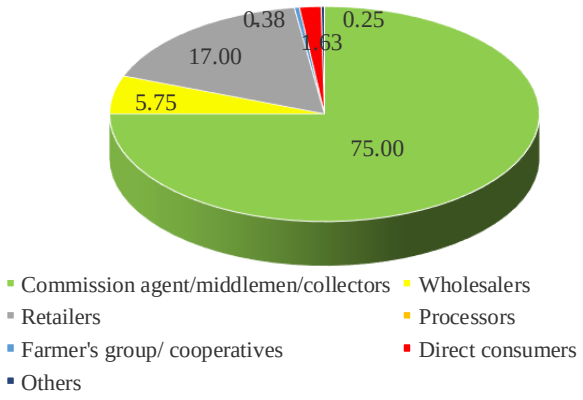

Fig. 1 Vegetable distribution channels

The produced vegetables were distributed to 6 channels: commission agents/middlemen /collectors, wholesalers, retailers, processors, farmers' groups/cooperatives, and direct consumers (Fig. 1). The majority of products (75%) were sold to collectors in the area and retailers (17%) in Phnom Penh, Battambang, Kampong Chhnang and Siem Reap provinces, while some vegetables (5.75%) were sold to wholesalers in the areas. Vegetables were less commonly sold to consumers, farmers' groups and other channels because the quantity of product was small and some producers have supplied contracts with collectors and retailers.

Table 4 Challenges of vegetable producers

No	Challenges	Frequency	Percent
1	Insect pests and disease infestation	35	87.5
2	Climate change (e.g. flooding, drought)	31	77.5
3	Low selling price	23	57.5
4	Considerable fluctuation in prices	23	57.5
5	High price of inputs	21	52.5
6	Post-harvest losses, especially in peak seasons of oversupply	18	45.0
7	Lack of power in the market chain	17	42.5
8	Lack of pest control information	16	40.0
9	Lack of information about market prices	15	37.5
10	Poor market information systems	15	37.5

**multiple answers will not add with 100; ** other challenges consisted of: lack of technical skills, poor shelf life of vegetables, differentiated price based on quality difference, labor shortages during critical times, lack of access to cold chain facilities, lack of storage facility, poor coverage and quality of extension services, lack of consumer preference for quality vegetables, high temperature especially at night, insufficient and lack of quality seed, lack of incentive for grading, lack of packaging, long distance to market, poor transport network, lack of access to credit, difficulty finding a buyer, and lack of quality seed ** N=40.*

There were 10 prominent challenges faced by vegetable producers in the studied areas (Table 4). Insect pests and disease infestation (87.5%) were the key issue of vegetable farmers, followed by

climate change (e.g. flooding, drought) (77.5%). Low selling price and considerable fluctuation in prices were equally problematic (57.5%). Post-harvest losses, especially in peak seasons of oversupply (45%), lack of power in the market chain (42.5%), and lack of pest control information (40%) were considered as important challenges; while, lack of information about market prices (37.5%) and poor market information systems (37.5%) were the minor issues of vegetable farmers. Sokhan et al. (2018), in their study on the effect of agricultural cooperatives on smallholders' incomes in Svay Chrum commune, Svay Rieng province, Cambodia, found that vegetable farmers faced several similar challenges, including high production cost, disease infestation and prevention techniques, and fluctuation of market price. More than half (59%) of interviewed vegetable farmers, non-members of Svay Rieng Agro-Products Cooperative (SAC), did not know market information. Therefore, price setting for their products depended on vegetable collectors. Ibeawuchi et al. (2015) who conducted a study on Fruit and Vegetable Crop Production in Nigeria revealed that pest and disease was one of important issues that affected fruit and vegetable in the field. More specifically, it reduced shelf life and appearance of vegetable and fruits.

CONCLUSION

The study on current practices of small-scale vegetable famers was conducted in three provinces of Cambodia to identify the farming practices and challenges faced by small-scale vegetable farmers. The results of study found that twelve types of vegetables (pak choi, leafy mustard, Chinese mustard, cabbage, Chinese cabbage, green mustard, lettuce, spring onion, crown daisy / chrysanthemum green, Chinese kale, gallic chives and culantro) were being grown in the provinces. However, only five types of vegetable were prominently grown, including Chinese mustard, green mustard, pak choi, leafy mustard, and Chinese kale. As production size is small, the majority of farmers used sickle/knife/scissors to harvest their products, and manual harvest is still being practiced by some farmers. Post-harvest activities such as grading, sorting and cleaning products after harvesting and before selling are rarely implemented by farmers. In terms of product marketing, majority of products are sold to collectors; while, a small quantity of remaining products is sold to retailers, farmers' group/cooperatives and direct consumers in the areas. The study also identified that three main challenges faced by farmers were insect pests and disease infestation, climate change (e.g. flooding, drought), and considerable fluctuation in prices. Other issues e.g. high input price, low price of products and post-harvest losses, especially in peak seasons of oversupply, also hamper the vegetable production in the studied provinces. Introduction of contract farming model is the best option to tackle the current issues of farmers. First, vegetable smallholders need to integrate into the agricultural cooperatives in the areas. These cooperatives collect all farmers' produce and then contract with retailers and other marketing actors in and outside Cambodia. Second, producer's group need to form in order to monitor the farming practices of members. Finally, vegetable hand-on trainings are required for producers to ensure that required quality and quantity of vegetable are produced.

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Research article

Feeds and Feeding Practices for Dairy Cattle Farming in Selected Areas of Myanmar

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Abstract This study was carried out to evaluate the feeds and feeding practices of dairy cattle farming in Yangon, Mandalay and Sagaing regions. The secondary data and questionnaires were assessed from 60 farmers of 60 households in the study area and made discussion with them. According to the findings of this study, zero grazing was the main production practices used by smallholder dairy farmers in the study area. Most of farmers used locally available feed resources such as cut and carry grass, forage crops, crop residue after harvesting and local feedstuffs. Common feedstuff used by dairy farmers in the studied areas are broken rice, rice bran, wheat bran, beer cake, bean cake, oil cakes, cotton seed cake, sorghum, yellow corn, soybean meal, mineral block, and sugar syrup. Feeding input among the farmers in the studied areas is similar. However, the availability and quality of these resources are varied, but farmers are properly selected and combined according to their nutritional characteristics, adequate and productive diets had been provided all year round for sustainable production and productivity. There are generally two feeding practices: compound cattle feeding and home-mixed feeding in the studied areas. Among the respondents, 84.77% preferred to use compounded cattle feeding and others 15.23% used home- mixed feeding. Most of the farmers in the study area used natural mating methods than artificial insemination method (AI). Over 90% of the respondents had knowledge on the signs for oestrus detection. The average 7.45liter and 6.48liter of milk per cow per day was recorded in wet and dry season from the study area. Seventy three percent of dairy farmers used concentrate to their animals based on milk production.

Keywords dairy, feedstuff, forage, fodder, feeding, grazing

INTRODUCTION

In Myanmar, dairy farmers face many feed constraints such as inadequate feeding, quality and quantity of feed, price of feed, poor storage facilities for feed conservation as well as insufficient water supply. Feed and feeding practices among dairy farmers are different due to lack of information on composition and utilization of locally available feed resources, poor access to the market and high cost of feed inputs and low income from production. Dairy development in Myanmar has played a vital role in improving the nutritional standards, generating employment opportunities and increasing the level of income of dairy farmers in rural areas. Nowadays scarcity of feed and rising feedstuff prices affect the dairy farming especially for small scale farmers. Farmers used seventy percent of total production cost for feed and feeding practices. There is a limited access to adequate grazing pastures and fodder production during the dry season. Many researchers have conducted feeding trials to solve the feed problems to improve the utilization of crop residues and optimal feeding practices. There are several approaches to improve the nutritive value of crop residues for dairy cattle feeding including improved handling and processing to increase palatability, feed intake and digestibility to release nutrients to animals. But the challenge to researchers is to work with farmers to identify improved practices that improve productivity and are feasible, profitable and acceptable for farmers to adopt. Selection of proper feeding standards, using the right combination of feeds in

adequate quantity along with other related practices are some of the ways which will enable the farmers to increase the milk production and make dairying more profitable. Therefore, the present study was undertaken to ascertain the prevailing feeding practices of dairy animals in the selected areas.

METHODOLOGY

The study was conducted in Rangoon, Mandalay and Sagaing Regions. Two locations were randomly selected from each region and 10 dairy farmers were randomly selected from each village, making the total sample of 60 dairy farmers. Questionnaire was prepared in light of the objective. The data was collected through interview method and personal observations for only one year i.e. 2018-2019. The structured questionnaire was used to collect information on individual household's characteristics (e.g. age, gender, education and family size, etc.). Other information collected included food and cash crop production, livestock herd structure, livestock production practices, husbandry activities, reproductive performance, livestock feeds and feeding practices, sources of feeds, major feeding constraints and milk yield were also recorded. Secondary data such as Demographic, climate and feeding constraints, were collected using reports from Project of non - governmental organization. The collected secondary data provided additional information to understand the dairy cattle performance in the study area.

Data Analysis

Statistical Package for Social Science (SPSS, 2003) was used to analyze the data obtained from baseline survey. Descriptive statistics analysis for percentages, means, ranges, cross tabulation were employed to assess household characteristics, feed and feeding practices, breeding and milk yield.

RESULTS

General Observations

Zero grazing was the main production practices used by smallholder dairy farmers in the study area. Under zero grazing, farmers were confined dairy cattle in their backyard. Feeds and drinking water were regularly offered to them. Most of farmers hired labour to do dairy farming activities as they had other income generating activities i.e, crop farming, civil service and other businesses. Dairy farmers who did not own land for forage cultivation, brought forage bundles from different feed sources such as communal grazing lands, around the road side and river banks. Farmers, who own land, cultivated the grass and sorghum to feed their animals. During the dry season when there was a shortage of forages, farmers used rice straw, grass hay, silage feed and beer cake as supplement to feed dairy cattle. These crop residues were mainly offered to milking cows purposely for increasing milk yield. However, during the dry season, these feeds were not enough for normal production performances, since most of these roughages had low nutritive values due to high lignification.

Demographic Characteristics

Table 1 Demographic Characteristics of Sample Households

Parameter	Unit	Average	Max.	Min.
Household age of farmer	Year	54.00	74.00	45.00
Household head's education	Year	7.00	14.00	1.00
Household head's farming experience	Year	8.00	12.00	4.00
Household's family size	Number	6.00	8.00	4.00
Farmers received training in dairy cattle	Number	1.20	3.00	1.00
Farmers who did not received training in dairy cattle	Percent	31.67	0.00	0.00
Total land owned	Hectare	0.96	3.20	0.40
Land owned under established fodder	Hectare	0.94	1.60	0.20

Table 1 shows the household characteristics of smallholder dairy farmers in studied areas. The mean age of farmers was 54 years. The respondents comprised of both male and female headed-households. The level of education of dairy farmers varied from one household to another, ranging from primary school, middle school to high school level. Majority of heads of households had middle education, followed by high school level. Information from the formal survey also indicated that 68 % of the farmers had training in dairy cattle husbandry. In the current survey, farmers had owned an average of 0.96 ha. The land owned under established fodder by farmers was 0.94 hectare.

Sources of Feeds for Dairy Cattle

Table 2 Sources of Feeds for Dairy Cattle as Indicated by Respondents in Studied Areas

Type of feeds	Sources		
Roughages	**Own Farm %**	**Outside %**	**Do not Used %**
Local pasture grass	10	90	0
Fodder grass	20	10	70
Rice straw	60	40	0
Silage	25	0	75
Concentrates			
De Heus/CP	0	100	0
Cotton seed cake	20	60	20
Bean cakes	15	85	0
Bean and rice powder	20	80	0
Sorghum	15	0	85
Maize bran	30	70	0
Beer cake	0	85	15
Rice bran	10	90	0
Oilseed cakes (cotton, sesame)	0	100	0
Mineral block	0	80	20
Sugar syrup	0	80	20

Table 2 shows the main sources of feed materials for dairy cattle. The main source of local pastures in the study area was outside lands. Other sources were farmers' own farms. The main sources of ingredients for concentrates and minerals were from shops and milling machines.

Feeding Practices of Dairy Animals Followed by Dairy Farmers in the Studied Areas

Table 3 showed the feeding practices of dairy animals followed by dairy farmers in the studied areas. All the smallholder dairy farmers used zero grazing. Ninety two percent of farmers practiced individual feeding while only 7.97 % used group feeding. Among the respondents, 84.77% preferred to used compounded cattle feed and others 15.23% used homemade mixture. In the study area, 65.57 % of the respondents fed the animals thrice or more daily followed by 34.43 % who fed their animals two times in a day. More than half of the respondents (78.21%) used rice straw, 10.06% green fodder and 11.73% used maize straw as dry fodder. The dairy farmers (89.91%) fed concentrate feed separately while 10.09% respondents mixed with fodder. Seventy three percent of dairy farmers used concentrate to their animals based on milk production while remaining 14.82 and 11.87 percent of the respondents fed it on flat rate and body weight. Dairy farmer (62.54 %) fed concentrate to their animals after milking followed by 28.76% during milking and 8.70 % before milking. More than half of respondents 57.35% and 56 % did not feed mineral mixture and salt to their animals respectively.

Breeding System of Dairy Cattle

Breeding system of dairy cattle is shown in Table 4. Most of the farmers in the study area used Natural mating methods than Artificial Insemination method (AI). There were some limitation of AI methods, i.e. storage of frozen semen, transportation, communication and availability of frozen semen. Over 90% of the respondents had knowledge on signs for oestrus detection i.e. changes in cows' behaviour (shouting, mounting and restlessness) followed by mucus discharges. However, there were no records kept by farmers relating to reproductive performances.

Table 3 Feeding Practices of Dairy Animals Followed by Dairy Farmers in the Studied Areas

No.	Feeding Practices	Percentage
1.	**Feeding system**	
a.	Zero grazing	100
b.	Grazing	0
2.	**Feeding of animal**	
a.	Individual feeding	92.03
b.	Group feeding	7.97
3.	**Frequency of feeding**	
a.	Twice	34.43
b.	Thrice or more	65.57
4.	**Fodder availability**	
a.	Green fodder	10.06
b.	Rice straw	78.21
c.	Maize straw	11.73
5.	**Type of concentrate**	
a.	Homemade mixture	15.23
b.	Compound cattle feed	84.77
6.	**Methods of feeding concentrate**	
a.	Mixed with fodder	10.09
b.	Separately	89.91
7.	**Feeding standard based on**	
a.	Milk production	73.31
b.	Body weight	11.87
c.	Flat rate	14.82
8.	**Time of feeding concentrate**	
a.	During milking	28.76
b.	After milking	62.54
c.	Before milking	8.70
9.	**Feeding mineral mixture**	
a.	Yes	42.65
b.	No	57.35
10.	**Feeding salt**	
a.	Yes	44.00
b.	No	56.00

Table 4 Percentage of respondents indicating breeding of dairy cattle

Breeding Method	Unit	Yes	No
AI	%	45	55
Natural mating	%	65	35
Use of signs of oestrus			
Change in feed intake	%	40	60
Change in cows behaviour	%	90	10
Change in milk production	%	25	75
Mucus discharge	%	80	20

Milk Yield (litres/day/cow) of Lactating Cows as Reported by Respondents

The results for milk production, milk prices and feed cost reported by respondents during baseline survey were summarized in Table 5. Average milk production was highest in Monywa industrial zone (10.79 Liter) followed by Mingaladon (8.45Liter) and Patheingyi (6.29Liter). The availability of feed and feeding system was affecting the milk yield. It is consistent with the previous study reported by Gillah et al., 2012, which said feeding systems and calving season were affect milk yield. Milk prices were varied within and among the regions between US $0.42 and US $ 1.00 with an average of US $ 0.66/ Liter. At and around Yangon region was about 1.0 US$/ L. Price for raw milk around Mandalay was 0.56 US$/ L. Raw milk price at and around Sagaing regions was about 0.42

US $/ L. Sagaing and Mandalay farmers were always complaining on the low milk price given by the collectors in their regions. Value added technology and contract farming were urgently needed in the studied areas. The higher demand of milk in urban population, consumption pattern, seasonality and calving season will affect the price of milk. Feed costs used by farmers were different between US $ 0.23 and 0.57 US $ with an average cost of US $0.38/liter milk. The feed cost and availability of feed resources depends on season in the studied areas. Feeds are generally not available in sufficient quantities owning to overgrazing of lands and uncertain weather conditions. However, concentrate feeds, crop residues and conserved forage are used both in wet and dry seasons. Sintayehu et al.,(2008) said that feed shortage problems in terms availability of quality, quantity and costs of feeds were also noted as major constraints in development of dairy production.

Table 5 Milk yield (litres/day/cow) of lactating cows as reported by respondents

Location	Mean Milk Yield Liter/cow/day	Milk Prices Liter / US $	Feed Price US $/day/cow	Feed Cost US $/liter milk	Gross Margin US $/liter milk
Mingaladon (Yangon)	8.45	1. 00	3.57	0.57	0.43
Patheingyi (Mandalay)	6.29	0.56	2.69	0.35	0.21
Monywa Industrial Zone (Sagaing)	10.79	0.42	2.71	0.23	0.19
Average	**8.51**	**0.66**	**2.99**	**0.38**	**0.28**
Max	11.00	1.00	4.00	0.57	0.43
Min	6.00	0.42	3.00	0.23	0.19

Source: Own Calculation based on Farmer from studied areas

DISCUSSION

The present feeding management practice adopted by dairy farmers are feeding on crop residue, additionally grain by-products are provided only to the lactating animal during milking stage. However, the nutritional availability for productive animals is much lower than the requirement. Extension of fodder cultivation can contribute significantly to dairy farmer to feed their animals. Integrated fodder production and feeding management demonstrations from NGOs and INGOs can assist the dairy farmers to improve the feeding practice. The farmers' expenditure on feeding of the productive animal is influenced by the price of milk and the cost of concentrate feed. Cost effective feeding practice for productive animal can be done by reducing the used of concentrates and increasing fodder production. Therefore, demonstration plot such as nutrient rich Azolla production farm, use of byproducts from crop farming, field training, and motivation of farmers to take up fodder farming (i.e. providing seed and planting materials) in their own lands can assist nutrient availability for optimum productivity. Education level of most dairy farmers had primary and middle school education. It is also very important to farmers to handle the farm management practices to attend the training and to use the information regarding dairy cattle farming (Luhosi, 1998). Educated farmers had the ability to keep record on the reproduction and production, the performance of dairy cattle and identify area of weakness for improvement (Gimbi, 2006). In the current study, it was revealed that dairy farmers practiced crop farming apart from dairy farming. Rice cultivation can provide not only food for dairy farmers but also income generation for the family as a supplementary income obtained from dairy farming. Husbandry practices such as feeding, collection of feeds, cleaning, milking and health management were performed by both family and hired labour. The main sources of forages given to dairy cattle were Para grass, Mombasa grass, Mulato, Millet, Rhodes and Seteria. Natural growing leguminous species such as Leucaena spp., Stylosanthes spp., Arachis spp., and Sorghum and Centrosema pubescens were available in the study area. Feeding grasses alone without combining with other forage species do not meet the nutrient requirements of dairy cattle for maintenance and production. Similar observation was reported by Mlay (2001) that dairy farmers in Morogoro were feeding their animals largely on natural grass and that these feeds were unable to

meet nutritional requirements of the animals for both maintenance and production. Feeding one type of forage to dairy cattle attributed to lack of knowledge on proper feeding of dairy cattle for achieving higher performance. It can happen true since most of respondents interviewed had no training in dairy cattle husbandry. Training of these farmers on how to feed their animals properly could bring greater improvement in animal performance. Therefore, regular training of farmers on various methods of improving quality of crop residues could be one of the strategies of supplementing nutrients to cattle during dry season and hence reduce the problem of underfeeding. Mlay, (2001) and Mtamakaya, (2002) reported that molasses and urea supplementation and treating of the straws using wood ash and urea are some of the feeding strategies to improve utilization of crop residues.

CONCLUSION

Farmers should establish enough fodder during the rainy season when there is adequate moisture and conserve them in the form of silage ready for being utilized in the dry season. Farmers know the importance of feeding fodder grasses to cows especially during dry season area but they were neither conserving forages nor natural grasses in form of silage or hay due to lack of enough knowledge and skills in silage and hay making and conservation methods. Therefore it can be concluded that optimal feeding of dairy cattle in zero grazing is not attained probably due to lack of knowledge on proper feeding. Feeding mixture of local pasture grasses and legumes, proper mixing of concentrates, proper utilization of crop residues, use of fodder grasses and feed conservation could be the good strategies to be used by farmers to improve the existing feeding practices for better animal performance. Research and extension activities are recommended to find a way to reduce the problem of shortage of fodder during dry season.

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Research article

Environmental Effects from Contamination of Agricultural Soils via Spraying and Dust Application to Crops and Animals

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Abstract Salinity from spraying may be important with crop cultivation and pasture for grazing. Soil guidelines can indicate salinity build up in soil. Effects on cultivated crops and soil cumulative contaminant loading limit trigger values are generally available for salinity, heavy metals and pesticides (kg/ha) for long-term application of irrigation water to soil. In additional, metal levels in meat from livestock and fowl species can be compared against food standard guidelines. The air quality guidelines of the World Health Organization (WHO), European Commission (EC) and United States Environmental Protection Agency (USEPA) are based on studies of health effects undertaken globally. However, little detail exists on effects of air particulates on terrestrial animals. Animals breathe air and may ingest deposited particles on soil surface or via ingestion of grass or other plants. Soil contamination guidelines are well developed for the ecological health case but may require extensive assessment for soil and the native/wild species that are not characterized. The German metal deposition guidelines (TA Luft) are useful in this case. In contrast to native/wild species, domestic animal effects from soil contamination and particularly pasture grazing by cattle, sheep, pigs and fowl are well understood. Such guidelines provide a basis for developing site specific criteria for spray deposition to farm land. Particle dispersion and deposition for prediction of environmental effects from spraying using risk assessment can be developed. Guidelines for air particulates and fall out may be relevant to assess if spraying is significant to humans or animals but limitations of guidelines for contaminants can occur. Risk-based assessment for environmental management of spray dispersion and deposition of agricultural wastewater can be undertaken as such contaminants may be significant if they are dispersed at sufficiently high concentrations.

Keywords crops, animals, spraying, contaminants, risks, management

INTRODUCTION

Particulate matter (PM) is defined by diameter (µm) or size based on its physical property (NEPC, 2016). PM_{10} (diameter 10 µm) and $PM_{2.5}$ (diameter 2.5 µm) can be mixtures of solid particles and liquid droplets in air (NEPC, 2016). Particle sizes <10 µm and 2.5 µm can penetrate deep into the human lung and transfer to the bloodstream. $PM_{2.5}$ approximate the fine mode particles giving alveolar deposition, while PM_{10} is the thoracic aerosol component (Raunemaa, 2002). Particles from mechanical means have larger-sized particles (>$PM_{2.5}$) compared with particulate matter generated during combustion (high temperature) processes having a higher percentage of fine particles < $PM_{2.5}$ to ultrafine particles. Particles generated from spraying activities can also be fine to ultrafine. Particles that fall out of suspension under gravity are collected using a dust deposition gauge and described as 'deposited matter'. People exposed to particulate contaminants in food, air and water receive background exposure primarily from food and water. The potential pathways for exposure of humans to contaminants are dermal, inhalation and ingestion (eNHealth, 2012). Only <PM_{250} (diameter 250 µm) fall out material can be ingested by humans or animals (Ng et al., 2015) as deposited larger particles on ground do not readily adhere to hands. Particle size dependence and oral exposure have specific associations (eNHealth, 2012).

Fall out guidelines in Australian are limited to nuisance soiling of property (Noller, 2018). The German air pollution control regulation and guidelines (TA LUFT, 1990 and Annex 2, 1999) provide metal and arsenic deposition guidelines for assessing deposition or spraying (Table 1). Higher deposition rates require additional evaluation using Annex 2 (TA LUFT 1999).

Table 1 Arsenic and metal deposition guidelines for fall out

Arsenic or metal	Standard ($\mu g/m^2$.day)	Averaging period
Arsenic	4	1-year
Cadmium	2	1-year
Lead		1-year
Protection of human health	100 (1990)	
Protection of crop land integrity	185 (1999)	
Protection of grassland integrity	1900 (1999)	
Nickel	15	1-year

Source: TA LUFT (1990, Annex 2 1999).

The Australian National Environmental Protection Measure (NEPM) soil contamination guidelines are well-developed, risk-based Health and Ecological criteria for respective receptors, and an alternative to fall out monitoring (Tables 2 and 3). Deposition to soil is assessed by measuring specified constituents in soil to a surface depth (e.g. 1 cm) per unit area and comparing concentrations against the NEPM soil contamination guidelines (NEPC, 2013). Soil cumulative contaminant loading limit (CCL) trigger values for metals and arsenic (kg/ha) (NWQMS, 2000) are applicable for long-term application of irrigation water to soil (Table 4). Excessive salinity from spraying or dust deposition may affect crop cultivation and pasture for grazing (Table 5). Comparison with soil guidelines can indicate salinity build up in soil and if soil cumulative contaminant loading limit trigger values for salinity and heavy metals (kg/ha) are occurring for long-term application of irrigation water to soil.

Table 2 Soil Health Investigation Levels for various land use

Arsenic or metal	Health Investigation Levels (HIL) for soil (mg/kg)			
	HIL Level A Urban residential with garden	HIL Level B Urban residential without garden	HIL Level C Public open space	HIL Level D Commercial and industrial
Arsenic	100	500	300	3,000-
Cadmium	20	150	90	900
Copper	6,000	30,000	17,000	240,000
Lead	300	1,200	600	1,500
Nickel	400	1,200	1,200	6,000
Zinc	7,400	60,000	30,000	400,000

Source: NEPC (2013) Australian soil contamination guidelines for health risk assessments.

Table 3 Soil Ecological Investigation Levels in soil for various land uses

Arsenic or metal and age of contamination (fresh/aged)	Ecological Investigation Levels (EIL) for soil (mg/kg) and various land uses		
	Area of ecological significance	Urban residential/ public open space	Commercial and industrial
Arsenic	20/40	50-100	80/160
Copper	15-60/20-80	30-120/60-230	45-200/85-340
Lead	110/470	270/1100	440/1800
Nickel	1-25/5-95	10-170/30-560	20-350/55-800
Zinc	7-130/15-280	25-500/70-1300	15.64

Source: NEPC (2013) Australian soil contamination guidelines for ecological risk assessments.

Table 4 Soil cumulative contaminant loading limits (CCL) and preferred level in soil

Element	Soil cumulative contaminant loading limit (CCL) (kg/ha) (NWQMS, 2000)	Preferred level in soil (mg/kg) (NSW Soil, 2011)
Arsenic	20	<20
Cadmium	2	<1
Copper	140	2-50
Lead	260	<35
Nickel	85	1-20
Zinc	300	1-200

Source: Soil cumulative contaminant loading limit (CCL) (NWQMS, 2000) and preferred level in soil (NSW Soil, 2011)

Table 5 Soil guidelines associated with salinity

Test	Agriculture Victoria (2017)	Rural Solutions SA (2016)	NSW Soil (2011)
Available sulfur (KCl 40 test)	>8 mg/kg	>10 mg/kg	
Total sulfur			10-20 mg/kg
Exchangeable Calcium	>5meq/100g 65-80% Total Cation	65-75% Total Cation	>5meq/100g
Exchangeable Magnesium	>1.6meq/100g 10-20% Total Cation	10-15% Total Cation	>1.6meq/100g
Exchangeable Potassium	>0.5meq/100g <1% Total Cation	3-8% Total Cation	>0.5meq/100g >0.5% Total Cation
Exchangeable Sodium	<0.1meq/100g <1% Total Cation	<6% Total Cation	>1.0meq/100g <0-1% Total Cation
Soil salinity (dS/m)	<0.2% dS/m	Many plants affected 4-8 dS/m Tolerant plants affected 8-16 dS/m	Plants tolerant <8.6 dS/m Tolerant plants affected 8-16 dS/m

Source: Agriculture Victoria (2017), Rural Solutions SA (2016) and NSW Soil (2011) Soil guidelines for sulfur, calcium, magnesium, potassium, sodium and salinity.

Contributions to human diet are assessed by comparing contaminant levels with food guidelines (FSANZ, 2009). Metal and arsenic levels in meat from livestock and fowl species can be compared against food standard guidelines. Wild (game) animals for consumption as food can also be compared similarly. However, wild species that are part of the ecosystem generally have no guidelines for estimating exposure to specific contaminants. Although particulate matter effect is not normally assessed for domesticated terrestrial animals, wild animals also breathe air and may ingest deposited particles on soil surface or via grazing of grass or other plants (Arslan and Aybek, 2012; Serita, 1999). Wild animals may also be exposed when air particulates drift over natural open land or forest (Isaksson, 2010). In contrast, domestic animal effects from soil contamination and particularly pasture grazing by cattle, sheep, pigs and fowl are well understood.

OBJECTIVE

The Objective is to use a risk-based approach to examine contamination of agricultural activities in selected studies from air particulates and fall out produced from spray-base activities with irrigation waters or other dust-generating agricultural activities, to provide a means to assess the significance of effects to humans via uptake in crops, domesticated animals, and potentially for wild animals.

METHODOLOGY

Details from published papers, reports and other sources were summarized. Selected data for salinity, arsenic and heavy metals was used as case studies from Australian locations. Monitoring data for air particulates and fall out for ambient air quality in Australia (NEPC 2016) is described (Noller, 2018). Deposition of metals and arsenic to soil is assessed by collecting fall out and by measuring specified constituents in soil for comparison against guidelines (Table 1). Soil requires sufficient characterization of the site (Standards Australia, 2005); selection of appropriate guidelines ensures that meaningful and appropriate comparison is made (Tables 1 4). Salinity from spraying may also be important with crop cultivation and well as pasture (Table 5) and give rise to a buildup in soil affecting cultivated crops. The tolerances of pasture and other plant species to various forms of salinity can be low but salinity build-up is likely when existing soil levels are high (Table 5). Data for various livestock body weight, peak water intake and peak food intake is summarised (ANZECC/ARMCANZ, 2000 p 9.3-16). Peak food intake assumes importance with cattle and sheep from grazing and involuntary ingestion because (Thornton and Abrahams, 1983): (i) cattle ingest up to 20% as soil (2kg); and (ii) sheep ingest up to 30% as soil (0.7kg). Spraying deposition over open farmlands used for grazing may be significant if contamination occurs.

RESULTS AND DISCUSSION

Data from case studies is examined to demonstrate how deposition to soil by fall out or via irrigation can be assessed using guidelines given in Tables 1-5. Background concentrations of metals and arsenic in the soil from natural mineralisation of the Line of Load at Broken Hill, NSW, Australia (AARC, 2011) are given together with fall out data for the deposition of lead in Broken Hill city, nearby the Rasp Mine (Rasp Mine, 2010). Comparison of soil concentrations in Table 6 with the Soil Health Investigation Levels (Table 2) shows that HIL Level A (urban residential) is exceeded for arsenic, cadmium, lead and zinc, and HIL Level C (public open space) is exceeded for lead and zinc. Comparison with the Soil Ecological Investigation Levels for various land uses (Table 3) shows that all categories of land use are exceeded for arsenic and all metals. Comparison of lead in fall out at Broken Hill for both high and low deposition exceed the guideline for protection of crop land but not grassland (Table 1). Thus the extent of contamination is indicated.

Table 6 Background concentrations of metals and arsenic in the soil with natural mineralisation of the Line of Load at Broken Hill, NSW, Australia and deposition of lead

Element	Concentration (mg/kg) Mean ± sd (n) (AARC, 2011)	Fall out (µg/m^2.day) (Rasp Mine, 2010)
Arsenic	290±51 (9)	
Cadmium	89±45 (6)	
Copper	585±254 (6)	
Lead	8317±10161 (65)	High deposition 822 Low deposition 274
Zinc	45,510±76943 (20)	

Source: AARC (2011) background concentrations of metals and arsenic in Line of Lode at Broken Hill and data for fall out in Broken Hill (Rasp Mine, 2010).

Potential build-up of salinity from a mining operation within a cattle station in Northern Australia is given in Tables 7 - 8 (Noller, 2017). Total and water soluble sulfate, salinity based on EC are all very low (Table 7). Similarly water soluble calcium, magnesium, potassium and sodium are also very low (Table 8). The location is in the wet-dry tropics receiving high rainfall during the annual monsoonal wet season in excess of 1500 mm. Comparison with guidelines (Table 5) shows the soil is highly leached by rainfall and shows no buildup of salinity. In fact the soil is deficient in sulfur for pasture growth for cattle feed and requires addition of supplement.

Table 7 Total and water soluble sulfate and electrical conductivity (EC) of water extract of soil from cattle station

Test	Total Sulfur (mg/kg)	Soluble Sulfur (mg/kg)	Electrical conductivity (1:5) (dS/m)
Within Mine Lease 1			
Surface (0-10 cm)	<100	<10	0.025
Depth (100 cm)	<100	<10	0.0085
Within Mine Lease 2			
Surface (0-10 cm)	130	<10	0.0164
Depth (100 cm)	<100	10	0.0089
Property Lot 1			
Surface (0-10 cm)	300	<10	0.0353
Depth (100 cm)	<100	<10	0.007
Property Lot 2			
Surface (0-10 cm)	100	<10	0.0324
Depth (100 cm)	<100	<10	0.0573

Source ANZECC/ARMCANZ, 2000 (p 9.3-16 and explanation) Electrical conductivity measured in a 1:5 water extract.

Table 8 Water soluble calcium, magnesium, potassium and sodium in soil from cattle station

Test	Calcium (meq/100g)	Magnesium (meq/100g)	Potassium (meq/100g)	Sodium (meq/100g)
Within Mine Lease 1				
Surface (0-10 cm)	<0.05	<0.082	0.033	<0.043
Depth (100 cm)	<0.05	<0.082	<0.026	<0.043
Within Mine Lease 2				
Surface (0-10 cm)	<0.05	<0.082	<0.026	<0.043
Depth (100 cm)	<0.05	<0.082	<0.026	<0.043
Property Lot 1				
Surface (0-10 cm)	0.10	<0.082	0.052	<0.043
Depth (100 cm)	<0.05	<0.082	<0.026	<0.043
Property Lot 2				
Surface (0-10 cm)	0.0850	<0.082	<0.026	<0.043
Depth (100 cm)	0.15	<0.082	<0.026	<0.043

Source ANZECC/ARMCANZ, 2000 (p 9.3-16 and explanation) meq/100g = milli-equivalents per 100 grams soil. Electrical conductivity measured in a 1:5 water extract.

CONCLUSION

The use a risk-based approach to examine contamination of agricultural activities from air particulates and fall out in two dust-generating studies is able to provide a means to assess the significance of effects to humans via uptake in crops and domesticated animals. For terrestrial species, NEPM soil contamination guidelines for ecological effects are able to provide a comprehensive assessment procedure to follow. In contrast to native/wild species, domestic animal effects from soil contamination and particularly pasture grazing by cattle and sheep are well understood. Thus application of such guidelines provides a basis for developing site specific criteria for fall out from dust and spray deposition to farm land.

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Research article

Effects of Different Percentages of Sorghum Silage and Napier Grass on Nutrient Intake and Growth Performance of Goats

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Abstract This study was to evaluate the growth performance of goats fed different proportions of sorghum silage and Napier grass. A total of fifteen local male goats were divided into five groups on the basis of Completely Randomized Design (CRD). The dietary treatments were: T_1 (100% Napier grass); T_2 (75% Napier grass + 25% sorghum silage), T_3 (50% Napier grass + 50% sorghum silage); T_4 (25% Napier grass + 75% sorghum silage); and T_5 (100% sorghum silage).The experiment ran for 98 days. The average daily nutrient intake of dry matter, crude protein, organic matter, neutral detergent fibre, acid detergent fibre and cumulative live weight gain of the goats fed on T_1, T_2, T_3, T_4 and T_5 diets were not significantly different ($p>0.05$) from each other throughout the experimental period. Based on these results, regardless of the inclusion of Napier grass in the diet, 100% sorghum silage could be favourable feed for local goat in Myanmar especially dry zone area where goats are populated and sorghum is available in planting.

Keywords sorghum silage, Napier grass, feed intake, growth performance, goats

INTRODUCTION

Ruminant production is largely limited by the availability and the high cost of quality feed. Low quality feeds are considered to be a major constraint in farm animal production. The availability of feed significantly decreases in the dry season when natural pastures are mature and highly fibrous and has low nutritive value due to low crude protein content (Moyo et al., 2012). Silage, anaerobically fermented green fodder, is widely valued as a source of animal feed. The primary goal of silage making is to maximize the preservation of original nutrients in the forage crop for later food for livestock (Stewart, 2011). Thus, surplus and cultivated quality forage is conserved during the wet season for use during the dry season. Kung and Shaver (2001) reported that corn silage can be used not only as a main source of feed for cattle but also in combination with other forage types, including pasture grass. Silage, which is anaerobically fermented green fodder, is valued throughout the world as a source of animal feed. Thus, feeding of ruminants with conserved forage has become an important feeding strategy since this can be made available throughout the year. Napier grass (*Pennisetum purpureum*) is recommended as a basal forage for intensive cattle production because of its high biomass fresh dry matter yield of 40 t/ha compared to other grasses (ILRI 2001).Tesfaye et al., (2016) observed that 100% *Pennisetum purpureum* silage had better feeding value as compared to the natural grass hay fed *ad libitum* in crossbred lactating dairy cows. In Myanmar, locally available crop residues such as rice straw, sorghum stover, maize stover, groundnut straw and pigeon pea residues, sesame residues, butter bean residues, chick pea residues are used as feed resources for ruminant in central dry zone area (CDZ) (Min Aung et al., 2015; Soe Min Thein et al., 2016). Among these crop residues, sorghum stover is used as common based feed mixture for ruminant because sorghum stover production is higher than other crop residues. The dry sorghum stover production was 800-3200kg/acre depend on soil type and nutrient quality in CDZ area of Myanmar. Farmers in

CDZ area used three types of dried chopped sorghum stover based diets (50%, 60% and 70% dry chopped sorghum stover) (Soe Min Thein et al., 2016). Feeding value and animal performance of sorghum stover based diets were lower than that of Mombasa grass based diets because of low crude protein contents and high fiber contents (Soe Min Thein et al., 2019). Nowadays, the farmers in dry zone of Myanmar grew sorghum, which were fed to ruminant animals as both fresh and dry feed mix (Soe Min Thein et al., 2014). There is still need to do research related to effective usage of fresh forage sorghum and sorghum silage for ruminant animal. There is a little information concerning with the effects on different percentage of sorghum silage on growth performance in goats**.**

OBJECTIVES

This study was undertaken to determine feed intake and growth performance of goats fed different proportions of sorghum silage to Napier grass.

METHODOLOGY

Preparation of Napier Grass and Sorghum Silage

The sorghum forage and Napier grass were planted at the same time in the research field at Yezin Agricultural University. The sorghum was harvested at the stage of maturity around 60 days. Harvested and wilted green sorghum was cut into approximately 2-4 cm pieces, using a chaff cutter machine. The chopped green sorghum chaff was compacted in the pit silo. After filling the pit silo with sorghum chaff, it was tightly covered with plastic covers and weighted down with sand bags to keep the pit silo watertight and airtight. The silage remained sealed and in the pit silo, except to take food once daily for the goats. The Napier grass was harvested after 90 days. This was then cut into pieces around 2-4 cm by the chaff cutter machine and air-dried at room temperature until constant weight was obtained.

Experimental Animals and Diets

The experiment was carried out from April 2018 to August 2018 at the goat farm of Animal Science Department, Yezin Agricultural University. A total of fifteen (locally bred) male goats at a similar age of around six months and with weights ranging from12 kg to18 kg, were purchased from Myanmar C.P Livestock Production Co. Ltd. These animals were randomly assigned into five treatment groups, with three goats each group. Initially, Ivermectin was administered by subcutaneous injection to prevent internal and external parasites. The five treatment groups were based on the various proportions of Napier grass (G) and whole sorghum silage (SS): T_1 (100% G); T_2 (75% G + 25% SS), T_3 (50% G + 50% SS); T_4 (25% G + 75% SS); and T_5 (100% SS). The length of the feeding trial to determine the relationship between feed intake and growth performance was 84 days, with an initial adaptation period which lasted 2 weeks, in which no data was collected. The goats were fed with the treatment diets *ad libitum,* with feed replenished twice daily, at 08:00 am and 4:00 pm. Water was accessed freely by the animals. Feeding and drinking buckets were cleaned every morning to prevent contamination with detrimental microorganisms such as yeasts and moulds and the spread of undesirable bacteria that could have formed on the silage. During the feeding trial, the body weight (BW) of each goat was measured weekly, before that morning's feed was offered.

Chemical Analysis

The chemical analysis determined the value of dry matter (DM), organic matter (OM) and crude protein (CP) by the AOAC (1990) method. The levels of neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined as outlined in Goering and Van Soest (1970). The feed samples were analyzed at the Department of Physiology and Biochemistry, University of Veterinary Science, Yezin, Nay Pyi Taw.

Statistical Analysis

The chemical composition of Napier grass and sorghum silage were analyzed by Students' t test. The data were subjected to the one-way analysis of variance (ANOVA) using SPSS software (version 16, SPSS Inc, Chicago. USA). Mean values were compared by Duncan's Multiple Range Test (DMRT). If $P<0.05$, the differences were considered as significance.

RESULTS

The chemical compositions of feedstuffs and experimental diets used in this experiment are shown in Table1 and 2. The dry matter content of Napier grass was significantly higher ($p<0.05$) than those of sorghum silage. The organic matter and crude protein of sorghum silage was significantly higher ($p<0.05$) than those of Napier grass respectively. There was no statistically difference between Napier grass and sorghum silage for ADF, NDF and Ash. The feed intake and cumulative live weight gain of goats fed the experimental diets containing different proportions of Napier grass and sorghum silage at 84 days are shown in Table 3 and 4. The nutrient intake of dry matter, crude protein, organic matter, neutral detergent fibre and acid detergent fibre by goats fed T_1, T_2, T_3, T_4 and T_5 diets were not significantly different ($p>0.05$) within the five treatments at 84 days. The cumulative live weight gain of goats fed the experimental diets were not significantly different ($p>0.05$) among the treatment groups during the experimental period.

Table 1 Chemical composition of feedstuffs (DM basis) except DM

Item	DM %[1)]	OM (%)	CP (%)	NDF (%)	ADF (%)	Ash (%)
Napier grass	56.63*	88.67	3.49	69.48	41.83	11.33
Sorghum silage	23.39	91.70*	7.56*	67.73	39.07	8.30

1) Fresh basis

*All values except DM are on DM basis. DM = dry matter, OM = organic matter, CP = crude protein, NDF = Neutral detergent fibre, ADF = Acid detergent fibre, *Comparison within each column and p<0.05 tested by Students' t test*

Table 2 Chemical composition of experimental diets (DM basis)

Parameters	T1	T2	T3	T4	T5
Dry matter %	94.38	76.63	58.89	41.14	23.39
Organic matter %	88.67	89.43	90.19	90.94	39.07
Crude protein %	3.49	4.51	5.53	6.54	7.56
Neutral detergent fibre %	69.48	69.04	68.61	68.17	67.73
Acid detergent fibre %	41.83	41.14	40.45	39.76	39.07
Ash %	11.33	10.57	9.82	9.06	8.30

T_1; Napier grass: Sorghum silage (100: 0), T_2; Napier grass: Sorghum silage (75: 25), T_3; Napier grass: Sorghum silage (50: 50), T_4; Napier grass: Sorghum silage (75: 25), T_5; Napier grass: Sorghum silage (0: 100)

Table 3 Effect of experimental diets on average daily nutrient intake at 84 days of goats

Nutrient Intakes	T1	T2	T3	T4	T5	SEM	p (value)
Dry matter intake (kg/day)	0.54	0.72	0.80	0.68	0.44	0.03	1.00
Crude protein intake (kg/day)	0.02	0.03	0.04	0.04	0.03	0.002	0.38
Organic matter intake (kg/day)	0.48	0.64	0.72	0.61	0.17	0.05	0.20
Neutral detergent fibre intake (kg/day)	0.38	0.49	0.55	0.46	0.29	0.02	0.08
Acid detergent fibre intake (kg/day)	0.23	0.30	0.32	0.27	0.17	0.01	1.00

All mean values are not significant different 5% level (p>0.05).

Table 4 Effect of experimental diets on cumulative live weight gain at 84 days of goats

Live Weight Changes	T_1	T_2	T_3	T_4	T_5	SEM	p (value)
Initial body weight (kg)	18.33	18.33	17.33	18.33	16.33	0.87	0.57
Final body weight (kg)	24.07	23.97	23.98	24.11	23.36	0.58	0.75
Total live weight gain(kg)	5.64	5.74	6.65	6.72	7.03	0.35	0.31

All mean values are not significant different 5% level (p>0.05).

DISCUSSION

The dry matter content of the Napier grass used in this experiment was 56.63%, which is higher than that of 23.4 % (Khaing et al., 2015).The CP content of Napier grass was 3.49% which is a lot lower than that of 7.3% (Rahman et al., 2013). A possible reason for these variations might be that in previous, trials the Napier grass was harvested about 45-60 days after planting, when the grass was about 1m high. In this experiment, the maturation stage of Napier grass was around 90 days and the whole plant was cut. The harvesting time is, therefore, an important factor for the nutritional management of forage such as grasses and leguminous trees. The amount of OM in the Napier grass was 88.67% which was in the same range with the values of 89.8% (Rahman et al., 2013) .The Ash content of Napier grass was 11.3% which is higher than 10.2 % (Rahman et al., 2013). The NDF and ADF contents of Napier grass were 69.48% and 41.83% respectively. In this case, for these detergent fibres, the values were lower than those of 74.8 % and 42.6 % (Khaing et al., 2015). In respect to the sorghum silage, the dry matter (DM) content in this study was 23.39%, which is similar to Khaing et al., (2015) at 23.30%, while lower than that of 56.3% in the (Muhamad et al., 2018) trial. The crude protein (CP) value of sorghum silage was 7.56% which is lower than those of 12.6% in Muhamad et al., (2018) and 8.1% (Khaing et al., 2015). The contents of NDF and ADF in sorghum silage were 67.73% and 39.07%, which is higher than those of Khaing et al., (2015) at 58.60% and 35.10%, but lower than those of Muhamad et al., (2018) at 81.4% and 42.5% respectively. The content of organic matter in sorghum silage was 91.70% which is higher than the 88.5% obtained by Muhamad et al., (2018) but lower than that of 96.10% reported by Khaing et al., (2015.) In the current study, Ash content in sorghum silage was 8.30% which is lower than that of value 11.5% (Muhamad et al., 2018).Von Keyserlink et al., (1996) reported that chemical composition and mineral content of feedstuffs are affected by many factors such as growth, maturity, species or variety, drying method, growth environment and soil type. Similar factors would explain the variation in this experiment. The Napier grass contained higher NDF and ADF content than the whole sorghum silage although other chemical parameters were relatively similar. The inclusion of increased proportions of sorghum silage relative to Napier grass has thus contributed to a reduction in NDF and ADF contents in the experimental diets. Intake of dry matter, crude protein, organic matter, neutral detergent fibre and acid detergent fibre by goats fed T_1, T_2, T_3, T_4 and T_5 diets were not significantly different ($p>0.05$) across the five treatments at 84 days. The goats fed the T_2, T_3, T_4 and T_5 diets showed high values for the intake of dry matter, crude protein, organic matter, neutral detergent fibre and acid detergent fibre, than those of the goats fed the T_1 diet. The increase in the DM content of the feed might be due to the chemical composition of the whole sorghum silage. This has a lower cell wall content resulting in increased the dry matter composition of the sorghum silage compared to Napier grass. Okoruwa et al., (2012) reported that the fermentation process by rumen microorganisms of high fibre diets takes longer compared to low fibre diets. Similar results were obtained by (Khaing et al., 2015). They reported increased growth performance of goats fed diets with a higher proportion of corn silage to Napier grass, when the various proportion of Napier grass (G) and whole corn plant silage (CS) were as follows: 100:0 G: CS, T2/75:25 G: CS, 50:50 G: CS, 25:75 G: CS and 0:100 G: CS and this was fed to male Boer cross goats. This is because sorghum silage contains high amounts of fermentable carbohydrate that increase nutrient intake by animals. The diets with a greater proportion of sorghum silage have a lower content of indigestible fibre portion due to the fermentation process involved in the silage production, compared to a diet solely of Napier grass. In contrast, Browne et al., (2004) stated that voluntary intake and growth performance were negatively affected by the substitution of high amounts of corn silage to the basal diet of the grass silage, due to the accumulation of high level

of fermentation acid which depressed the activity of cellulolytic bacteria in the rumen. However, in the current experiment, the basal diet was not grass silage but Napier grass. Widiawati and Thalib (2009) and Kariuki et al., (2001) stated that cell wall content of Napier grass degraded slowly in the rumen and was more resistant to rumen microbial fermentation. Inclusion of corn silage to the grass silage had a positive effect on feed intake as observed by (Browne, 2000). In addition, high concentration of lactic acid in silage may be metabolized into propionic acid by rumen microorganisms (Abedol et al., 2013). The soluble carbohydrate can be used by the animal as an energy source for maintenance and production activities (Hariadi and Santoso, 2010). The goats fed the T_2, T_3, T_4 and T_5 diets showed higher numerical values for total weight gained than the goats fed T_1 diet. The results also mirror those of Khaing et al., (2015). They reported increased growth performance of goats fed diets with a higher proportion of corn silage to Napier grass when the various proportion of Napier grass (G) and whole corn plant silage (CS): 100:0 G:CS, T2/75:25 G:CS, 50:50 G:CS, 25:75 G:CS and 0:100 G:CS fed to male Boer cross goats. Generally, the diets containing a higher percentage of sorghum silage and which had higher CP content result in higher weight gain as the animal performance is the product of nutrient concentration, intake and digestibility of absorbed nutrients.

CONCLUSION

According to this finding, 100% sorghum silage could be fed to goats without detrimental effect on the growth performance. Since Myanmar farmers could not access Napier grass easily, making sorghum silage for small ruminant will be advantages for small and large scaled farmers. Family labour would be used to keep costs for feeding. Sorghum silage could be fed to form a balanced ration. Therefore, it can be concluded that sorghum silage is a high potential feed comparable with Napier grass and with positive growth response when fed to small ruminants.

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Research article

Bending Strength and Toughness Properties of Pavement Concrete Reinforced with Bamboo Fiber

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Abstract The problems of neglected bamboo forest have been actualized in association with the aging of the people owning bamboo forest in recent years in Japan. Then it becomes imperative to establish the methods of effective utilization of the bamboo. Some bamboo has enough tensile strength as construction material, and studies and experiments on bamboo have been increasing gradually. The purposes of authors are to make short fiber of bamboo ("BF" for short) from Moso- bamboo, one of most popular bamboo in Japan, by ourselves, and to develop the concrete for pavement which matrix are reinforced with BF. A cross-linked effect between concrete surface on crack by BF had been expected as same as other kinds of short fibers. The purpose of this paper is to confirm the reinforcement effect by BF, and cement mortar was the object in order to simplify the experiments, in which the basic properties were investigated. The experiment factors are the amount of BF, water cement ratio, fiber length and distribution method of BF. These influence on compressive strength, bending strength and bending toughness was investigated experimentally. As the results, the followings were obtained. The strength does not increase only by a cross-linked effect by BF. The coefficient of toughness can be improved greatly by BF, and this effect is shown even in little quantity of fiber. Influence of water cement ratio on the toughness improvement is small. In case of random mixing of BF, each strength become lower without depending on fiber length, toughness coefficient can be improved. In case of spreading of BF, the strength and toughness coefficient can be improved even in little quantity of fiber.

Keywords bamboo fiber, short fiber, bending toughness, strength

INTRODUCTION

In recent years, the problems of neglected bamboo forest have been actualized in association with the aging of the people owning bamboo forest in Japan. Then it becomes imperative to establish the methods of effective utilization of the bamboo. Actually, bamboo has enough tensile strength as shown in Table 1 and studies and actions about the bamboo has been increasing gradually. Authors has made short bamboo fiber (see Photo 1, BF for shot) by ourselves from Moso-bamboo, and it is the final purpose to develop the concrete for pavement which matrix is reinforced by this BF. The purpose of this study is to confirm the reinforcement effect by BF. Mortar was intended to simplify the experiments, and its basic properties were investigated. The factors of experiment were fiber

amount, water cement ratio, fiber length and casting method of fiber, and the influence of them to compressive strength, bending strength and bending toughness was acquired experimentally.

Table 1 Tensile strength of Moso-bamboo

No.	width (mm)	thickness (mm)	cross section (mm^2)	fracture load (N)	tensile strength (N/mm^2)
1	10.2	7.80	79.6	11400	143.3
2	13.5	8.00	108.0	12700	117.6
3	11.1	8.40	93.2	10000	107.3
4	12.7	7.80	99.1	13850	139.8
5	11.9	8.13	96.7	11950	123.5
6	9.2	8.33	76.4	9600	125.7
7	9.7	8.63	83.5	8150	97.7
8	9.5	8.43	79.8	10250	128.4
9	9.6	7.57	72.9	8100	111.1
10	11.3	8.13	91.6	11350	123.9
		average		10735	121.8

Photo 1 Handmade bamboo fiber

METHODOLOGY

a) Making of Bamboo Fiber and Materiasls

As a result of trial and error, the bamboo was molded into a fiber form by the next process. (1)split by circular wedge (2)unfastened by compressor for concrete (3)struck by mallet and unfasted again (4)cut to predetermined length. The moisture state of bamboo was determined as that it had been dried in laboratory over 1 year after the felling (air-dried state).

The materials were high early strength Portland cement, JIS standard sand, BF and tap water. Size of specimen was 40×40×160mm and they were taken out of molds on the next day of the casting. After curing in water, the tests were carried out at 7 days of material age.

b) Series I

The purpose in series I was to find the appropriate mixing ratio of BF which length was 20mm (aspect ratio was 13.3). In previous experiment, W/C was 50%, mixing ratio of BF (outer percentage based on the mass of mortar) was 0, 1, 3 and 5%. As the results, the workability decreased remarkably at 5%, so it was concluded that 3% was upper limit. Then, W/C was varied with 50, 55 and 60%, and BF mixing ratio was varied with 0, 1, 2, and 3%. These mix proportions are shown in Table 2 as the mixing weight. The compressive strength and bending strength of BF mortar was obtained in accordance with "Cement Strength Test" to confirm the strength improvement effect by BF. Furthermore, the bending toughness was calculated based on the JSCE concrete standard specifications (See Figure1), expecting the toughness improvement effect by BF.

c) Series II and III

In series II, the BF length was changed to 30 and 40mm to increase adhesion. W/C was 55%, and BF mixing ratio was 0, 1, 2, and 3%. Table 3 shows the mix proportion of series II.

A method to spread BF in tensile domain was adopted in series III. Because when BF is mixed simply, the placement of BF becomes random in three-dimensionally and the two-thirds waste should occur in a direction of stress. In actual construction, it will be effective to induce a direction of BF by a container which has slits (see Photo 2). Firstly, specimens were made in the cover of 0mm, mixing ratio of 0.5%, fiber length of 30, 60 and 90mm and the strength was evaluated by bending strength. As the result, fiber length of 60mm, which had increased the bending strength most, was

adopted, and the specimens with the cover of 5 and 10mm were made in this fiber length. Table 4 shows the mix proportion of series III.

Table 2 Mix proportion of series I

W/C (%)	BF (%)	fiber length (mm)	mixing weight (g)			
			W	C	JIS Sand	BF
50	0	20	225	450	1350	0
	1					7.7
	2					15.5
	3					23.2
55	0		247.5	450	1350	0
	1					7.9
	2					15.9
	3					23.8
60	0		270	450	1350	0
	1					8.1
	2					16.2
	3					24.4

Table 3 Mix proportion of series II

W/C (%)	BF (%)	fiber length (mm)	mixing weight (g)			
			W	C	JIS Sand	BF
55	0	–	247.5	450	1350	0
	1	30				7.9
	2					15.9
	3					23.8
55	1	40	247.5	450	1350	7.9
	2					15.9
	3					23.8

Table 4 Mix proportion of series III

W/C (%)	BF (%)	fiber length (mm)	mixing weight (g)			
			W	C	JIS Sand	BF
55	0.5	30	247.5	450	1350	4.0
		60				
		90				

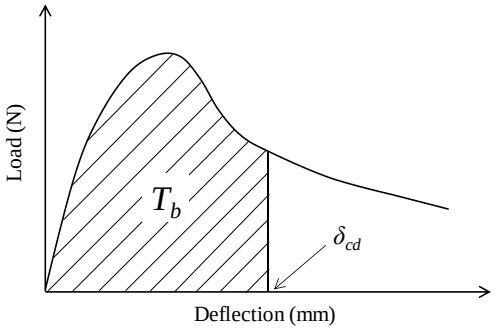

Fig. 1 Calculation of T_b

Photo 2 Casting of BF in series III

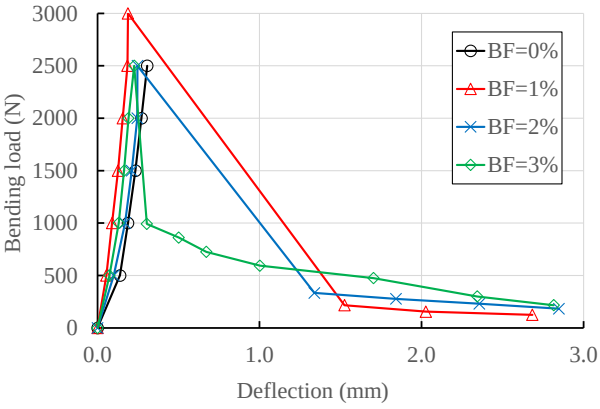

Fig.2 Load and deflection curve of series I (W/C=55%)

Calculation of Toughness

Figure 2 shows the load-deflection curve in series I (W/C=55%). Bending toughness could be evaluated by toughness coefficient, and when this is large, the toughness at destruction could be improved, which leads the restraint of disasters and accidents.

The spans of beam specimens were 45cm and loads were applied at the 2 points of 3 equal parts. In order to obtain the details of data for toughness coefficient, the loads were applied slowly until the deflection became 3mm by the confirmation of data logger. After the measurement, load-deflection

curve was described in the procedure of JIS. The toughness coefficients were calculated by formula (1) using the area from 0 to 1mm of the deflection by the curves.

$$\sigma = \frac{T_b}{\delta_{cd}} \cdot \frac{L}{bd^2} \qquad \cdots\cdots\cdots\cdots (1)$$

Here,

- σ: bending toughness (N/mm^2)
- T_b: Area to δ_{cd} (N·mm)
- δ_{cd}: deflection (=span/150; mm)
- L: span (=120mm)
- b: width of section (=40mm)
- d: height of section (=40mm)

RESULTS AND DISCUSSION

a) Series 1

Figure 3 and 4 show the relationships between BF mixing ratio and compressive strength or bending strength. Both strength decreased in comparison with non-mixing of BF. According to the observation of the fractured section of mortar, every BF slipped out without being cut, which means that the adhesion of BF and mortar was not enough and the primary tensile strength of BF was not shown.

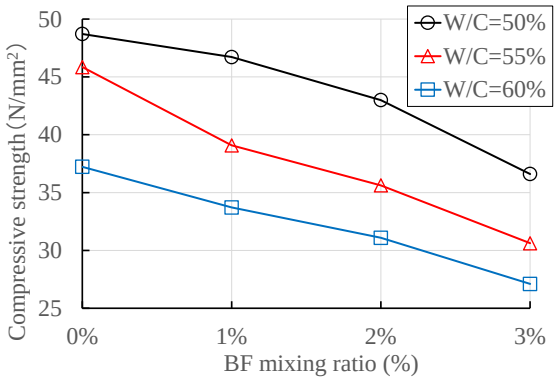

Fig. 3 Relationship between BF mixing ratio and compressive strength in series I

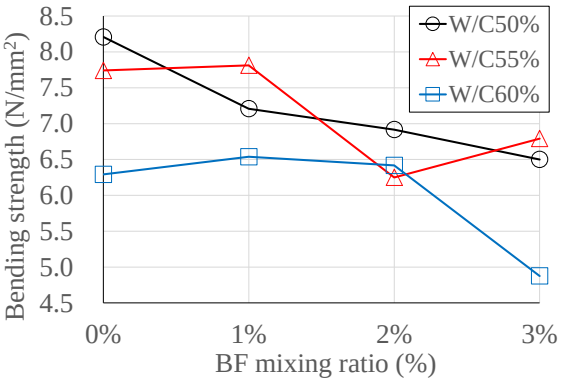

Fig. 4 Relationship between BF mixing ratio and bending strength in series I

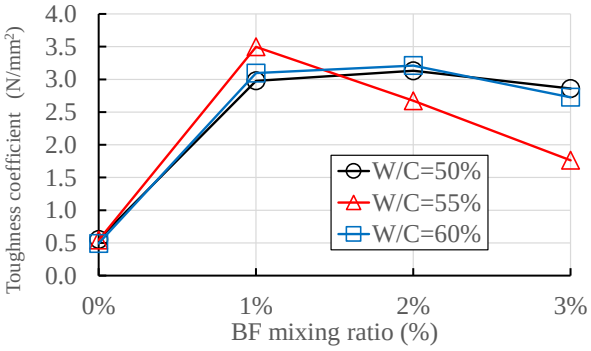

Fig. 5 Relationship between BF mixing ratio and toughness coefficient in series I

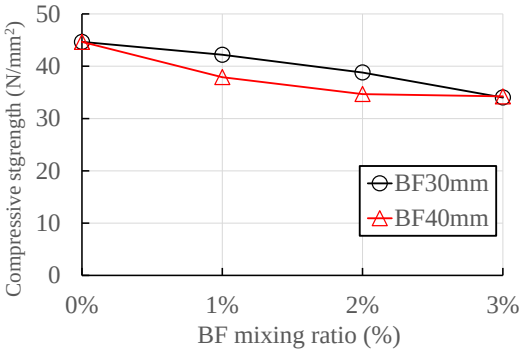

Fig. 6 Relationship between BF mixing ratio and compressive strength in series II

Figure 5 shows the relationship between BF mixing ratio and toughness. Improve of toughness coefficient by BF can be confirmed. It is effective even in low BF mixing ratio, and the influence of W/C on the effect is small. It is estimated that the cross-linked effect by BF increased the toughness coefficient according to the above-mentioned observation results.

b) Series II and III

Figures 6 and 7 show the relationships between BF mixing ratio and compressive strength or bending strength. Figure 8 shows the relationship between cover and bending strength in series III. Bending strength and compressive strength decreased by mixing BF. However, in the case that BF was spread with little cover and the fiber length was 60mm, the effect of BF was shown most, and the bending strength was stronger than non-mixing, nevertheless the mixing amount was only 0.5%. When BF is mixed at random, it is estimated that the effect as the fiber cannot be shown, even if fiber length and mixing amount are changed, because the adhesion between fiber and mortar are not enough.

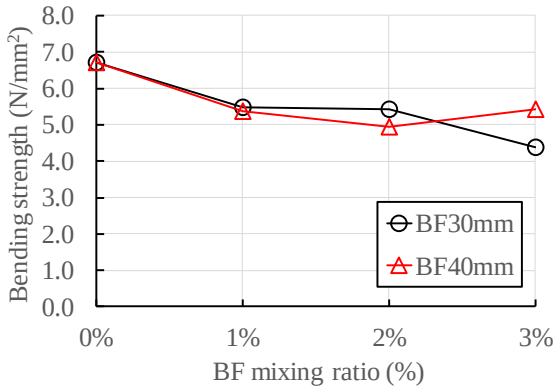

Fig. 7 Relationship between BF mixing ratio and bending strength in series II

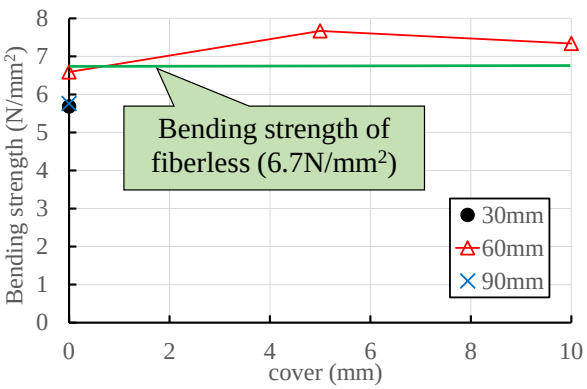

Fig. 8 Relationship between cover and bending strength in series III

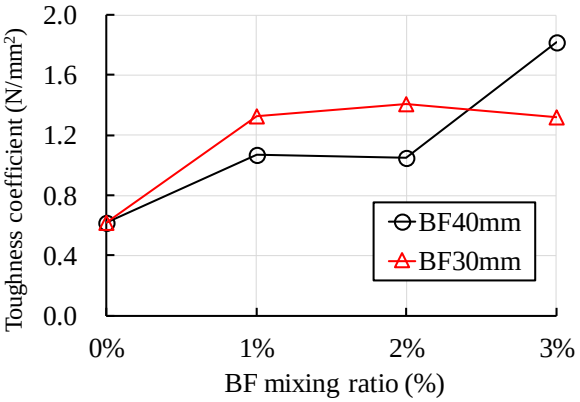

Fig. 9 Relationship between BF mixing ratio and toughness coefficient in series II

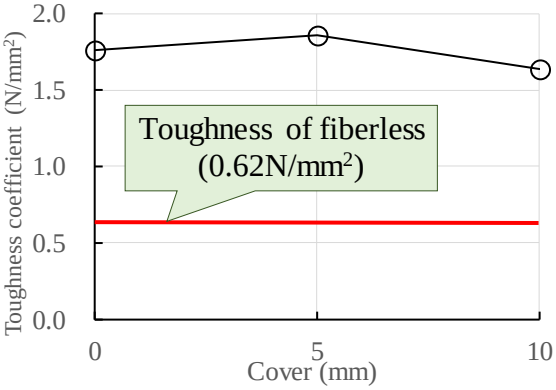

Fig. 10 Relationship between cover and toughness coefficient in series III

Figure 9 shows the relationship between the mixing ratio and toughness coefficient with various fiber length. The toughness coefficient improved with the increase of mixing ratio generally in series II, however, the effect by the change of fiber length could not be confirmed. Figure 10 shows the relationship between cover and toughness coefficient in series III. The toughness coefficient of the mix proportion with the fiber length of 60mm and the cover of 5mm improved most even the mixing amount was only 0.5%.

CONCLUSION

The summary of this study on the concrete for pavement which short bamboo fiber was mixed with is as follows:
(1) The strength does not improve only by a cross-linked effect.
(2) Toughness coefficient greatly improves, and the effect is shown even if the amount of fiber is little.
(3) The influence of W/C on the effect of toughness improvement is small.
(4) When bamboo fiber is mixed at random, each strength decreases, and toughness coefficient increases regardless of fiber length.
(5) In case of spreading construction of bamboo fiber, both strength and toughness coefficient improves even by little amount of fiber.
(6) As a contrivance to align the same direction of bamboo fiber easily in large scale on actual road, the sieve with slit in one direction could be effective, practicable and economical.

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Research article

Richness of Horticultural Crops with Emphasis on Mango Species in Selected Home Gardens in Myanmar

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Abstract This study aims to explore the relationship between home gardens' sizes and species richness of horticultural crops and to study the distribution of mango varieties in the selected area. Sixty home gardens were studied from September, 2018 to October, 2019 in Nay Pyi Taw Union Territory, Myanmar. Drone was used to generate geographical information. Coordinate points of each mango variety was collected. Information on compound dimensions and crop plants namely local names, growth stages, numbers of individual, leaf attitudes and characters were collected. Shannon-Wiener' index was employed to determine species richness. Distribution maps of mango varieties were developed. The compound areas could be classified into three classes as small, medium and large; were not correlated with species richness of all horticultural crops, but there had significant correlation with richness of mango varieties ($p=0.01$, $r=0.32$). Potential area for home garden development was highest in large gardens (41%) followed by medium (16%) and small (9%). Out of total 480 species, richness was highest in ornamentals (46%) followed by vegetables (10%), fruits (8%), shade-trees (8%), medicinal-plants (6%), spices (3%) and unidentified species (20%). Among fruit trees, mango was the most dominant species and 90% of home gardens were growing a total 361 plants (young 37% and adult 63%) of 15 local varieties namely Ma Chit Su (39%), Sein Ta Lone (24%), Sein Sar Thee (20%), Yin Kwe (9%), Ma Naw Nwe (3%), Waso, Padamyar Nga Mauk, Mya Kyauk and 4 unknown varieties (1% each) and Wet Ta Kaut, Pan Swae and Pyo Ta Ngone (0.3% respectively). Three types of leaf attitude and 8 different leaf characters of mango varieties were identified. Diversity index of total species was 1.57 and 1.40 for mango varieties. It was concluded that species distribution was sufficient; however, there is remaining available space to extend home gardening in the study area.

Keywords drone, species diversity, potential area

INTRODUCTION

Home gardens (HG) are sites of plant species diversity and also serve to conserve different species and varieties. Richness of horticultural crops species can be attained not only for self-sufficiency in food production but also nutritional status by diversification to those crops. Saving and exchanging seeds/planting materials from home gardens with neighbours are able to conserve a considerable amount of crop species. Being labour-intensive, horticultural crops provide job opportunities, besides having great export potential and therefore create more income for rural people. In order to promote the growth of horticulture sector, there are necessities to document the existing horticultural crops, to calculate the richness of those crops species and also to assess potential area for further expansion. To know the richness of horticultural crops species and the potential areas for home gardens development, the existing kinds of crops species and sizes of home gardens are needed to investigate.

The potential area for home garden development is the basic unit of species conservation in rural sustainable development. Therefore also the exploration of relationship between the home gardens areas and species richness has becoming importance for developing of the home gardens. Scientific investigations on richness of species and sizes of home gardens are severely lacking in the country.

In a statement of Helen Keller International/Asia-Pacific program, 2010, "the vegetables and fruits in the home gardens contribute considerably to increased consumption of these types of foods in many Asian countries". Among fruit trees, mango is one of the most important commercial crops in Myanmar and peoples' choicest fruit due to its agronomic and cultural value. Myanmar mangoes are assumed to be traditional varieties as they has historical origins, distinct identity, are genetically diverse, locally adapted and associated with traditional farming systems (Hirano et al. 2011). The total planted area of mango in Myanmar was 93,890 hectares and was 30% of total cultivated area for fruits (MFFVPEA, 2013). There are about 300 different mango varieties and 20 kinds of mango species in Myanmar. Leaf morphology of the mango species is highly variable depending on the cultivar. There is broad genetic diversity of mangoes in Myanmar that needs to be identified (Hirano et al., 2008). Research based on genetic resources of mango is very scarce in Myanmar. Moreover, there have been no reports of detailed information on spatial varietal distribution and identification on land-usage. By analysing the spatial distribution, the current land use of this area can be identified and has great potential in efficient utilization of land (Sana Iftikhar and Hafiz Zahid Mahmood, 2017). The determination of spatial distribution will help in determining the ecological suitability of an area for fruit growing. Geospatial technology such as Global Positioning System (GPS) and Geographical Indicating System (GIS) is one of the most widely used tool to provide updated information in identifying suitable sites for various crops and mapping for fruit trees distribution (Singh et al., 2017).

OBJECTIVE

The aims of this study were to explore the relationship between the size of home gardens' and species richness of horticultural crops and to study the distribution of mango varieties in the selected area.

METHODOLOGY

The study was conducted in 60 selected home gardens out of total 370 in Kyee-Inn village, Nay Pyi Taw Union Territory, Myanmar from September, 2018 to October, 2019. Drone (DJI Phantom 4PRO) was flown above 50m to generate geographical information. The location of each selected home garden and mango varieties were recorded by Global Positioning System (GPS) GARMAN, GPSMAP 62 device. Drone photos were merged and arranged with Pix 4D software to determine the base map of the study area. ArcCatalog and ArcMap softwares (10.3.1 version) of ArcGIS were used to map the distribution of selected home gardens and mango varieties.

The composition of each home garden such as compound and building areas were measured; residential (social) and crops covered areas were visually estimated by drone images and the potential areas for home garden development were calculated. Primary data were gathered by both direct observations to acquire information on all horticultural crops especially mangoes: including local names, growth stages and number of individuals, and by interviewing people with semi-structured questionnaire sets. Descriptive statistics of the Statistical Package for Social Scientists (SPSS), version 23 was used to examine the relationship between the home gardens areas and species richness. The Shannon-Wiener' index was employed to determine the species richness by use of the following equation.

$$H' = -\sum_{i=1}^{s} pi \; ln \; pi$$

where H′equals diversity index, *s* equals the number of species and *pi* equals the ratio of individuals of species *i* divided by all individuals *N* of all species.

For growth stages of mangoes, less than 5 year-old trees were regarded as young and those above 5 years were regarded as adults. Finally, three representative leaf samples of each mango variety were collected and leaf attitudes and leaf characters such as shapes of blades, apexes, bases and margins, were evaluated using mango descriptors (International Plant Genetic Resources Institute, IPGRI, 2006). Leaf lengths and widths were measured manually.

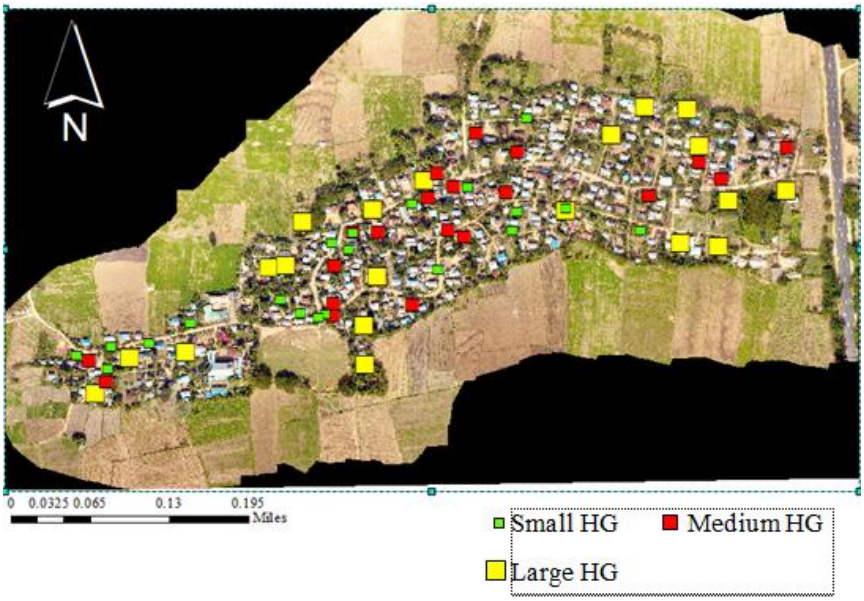

Fig. 1 Distribution of selected 60 home gardens (small, medium, large) in the study area

RESULTS AND DISCUSSION

Fig. 2 shows three groups of home gardens (n=20) categorized from small (1400-4000 ft^2), medium (4001-6400 ft^2) to large (6401-21,500 ft^2). Potential area for home garden development was highest in large home gardens group (41%) followed by medium (16%) and small (9%).

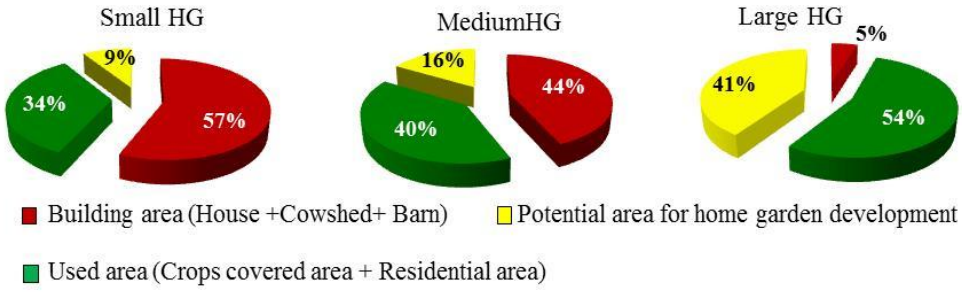

Fig. 2 Different areas that comprised home gardens in the 3 categories (n= 20)

The observed horticultural species were categorized into 7 groups. Of the 480 species that were observed, species richness was highest in ornamentals (46%) followed by vegetables (10%), fruits (8%), medicinal plants (8%), shade trees (6%), spices (3%) and unidentified species (20%) (Fig. 3).

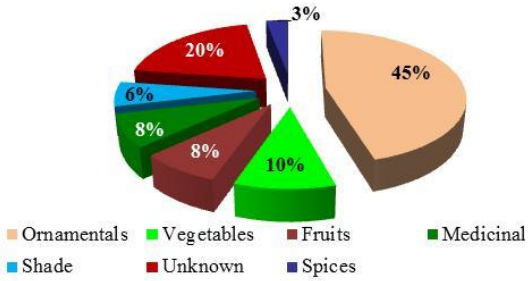

Fig. 3 Classification of horticultural crops identified in selected home gardens

Among fruit trees, mango species were the most dominant and 90% of home gardens were growing a total of 361 trees which included 15 local varieties: namely, Ma Chit Su (39%), Sein Ta Lone (24%), Sein Sar Thee (20%), Yin Kwe (9%), Ma Naw Nwe (3%), Waso, Padamyar Nga Mauk, Mya Kyauk and four unknown varieties (1% each) and Wet Ta Kaut, Pan Swae and Pyo Ta Ngone (0.3% respectively). These respective proportions in each group of home gardens are presented in Fig. 4 (a). A base map of the village was produced and then the distributions of the 15 mango varieties are shown in Fig. 5. Mango varieties were well distributed over the whole study area. Out of a total 361 mango trees, mostly propagated by seeds, 37% were at the young stage and the remaining 63% were adult (Fig. 4 (b)). Almost in all varieties, the juvenile period usually ended after 4th years and flowering started in the 5th year. This finding is consistent with the report by Mukherjee and Litz, (2009) who stated that the juvenile period of seedling trees usually ranged from 3 to 7 years.

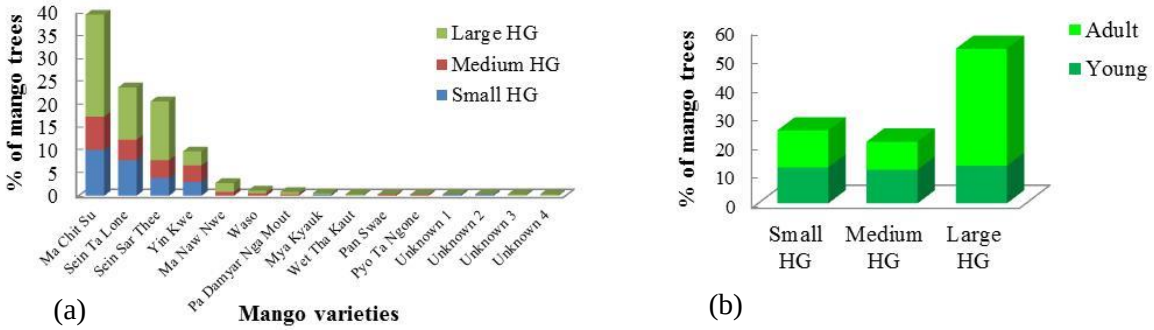

Fig. 4 Fifteen mango varieties identified in 3 groups of home gardens (a), growth stages (b)

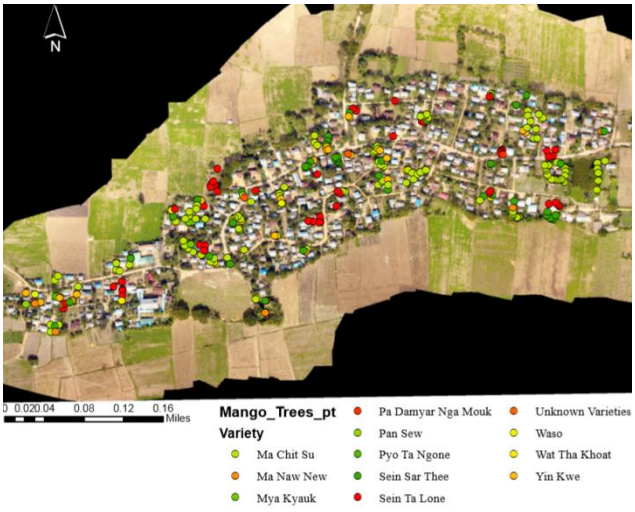

Fig. 5 Distribution map of 15 mango varieties

The evaluated leaf characters of 11 known and 4 unknown varieties are shown in Table 1. Three types of leaf attitudes and leaf characters (blade, apex, base) were observed. Both wavy and entire margins were found in all varieties. Lengths and widths of leaves ranged from 16.5-25.0 cm and 3.0-4.4cm respectively. Fig. 6 shows the comparison of different leaf characters of the observed mango varieties.

Table 1 Leaf descriptors of 11 mango varieties and 4 unknown varieties

No.	Variety	Attitude	Blade	Apex	Base	Margin	Length (cm)	Width (cm)
1	Unknown 1	semi-dropping	oblong	acute	obtuse	wavy	19.5	4.0
2	Unknown 2	horizontal	oblong	acute	obtuse	entire	18.0	4.1
3	Unknown 3	horizontal	lanceolate	acuminate	acute	wavy	21.0	3.0
4	Unknown 4	horizontal	lanceolate	acuminate	acute	wavy	24.0	3.2
5	Yin Kwe	semi-erect	elliptic	acute	acute	wavy	19.3	3.8
6	Ma Chit Su	semi-dropping	lanceolate	acuminate	acute	entire	20.5	4.0
7	Ma Naw Nwe	horizontal	oblong	acute	obtuse	wavy	16.5	4.4
8	Pan Swe	semi-dropping	lanceolate	acuminate	obtuse	wavy	18.3	3.6
9	Pa Damyar Nga Mouk	horizontal	lanceolate	acuminate	obtuse	wavy	21.0	3.8
10	Pyo Ta Ngone	horizontal	lanceolate	acuminate	acute	entire	25.0	3.4
11	Mya Kyauk	horizontal	oblong	obtuse	acuminate	entire	20.8	4.0
12	Sein Ta Lone	semi-erect	oblong	acute	obtuse	wavy	21.5	4.0
13	Wat ThaKout	horizontal	lanceolate	acuminate	acute	entire	19.5	3.6
14	Sein Sar Thee	horizontal	lanceolate	acuminate	acute	wavy	23.0	3.2
15	Waso	horizontal	oblong	obtuse	acuminate	entire	20.8	4.0

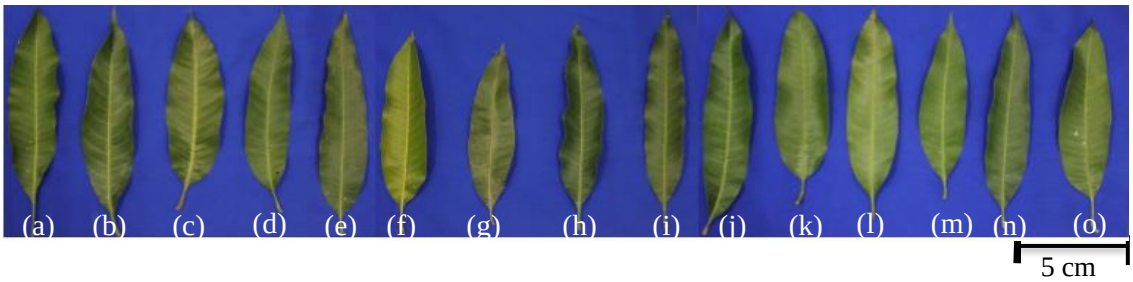

Fig. 6 Leaf characters of (a-d) 4 unknown varieties, (e) Yin Kwe, (f) Ma Chit Su, (g) Ma Naw Nwe, (h) Pan Swe, (i) Pa Damyar Nga Mouk, (j) Pyo Ta Ngone, (k) Mya Kyauk, (l) Sein Ta Lone, (m) Wat Tha Kout, (n) Sein Sar Thee and (o) Waso

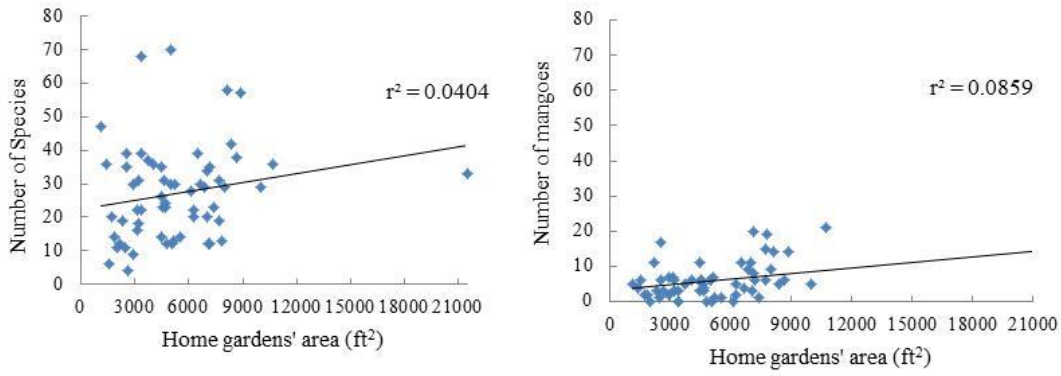

Fig. 7 Relationship between area of home gardens and number of species for all horticultural crops (a), number of mango trees (b)

Though the sizes of home gardens had no correlation with species richness of all horticultural crops (p=1.24, r=0.20), there had a significant correlation with mango varieties (p=0.01, r=0.32). Fig. 7 shows correlation coefficient for species richness of all horticultural crops (r^2=0.04) and mango trees (r^2=0.08) which mean only 4% of the variance in species richness and 8% of mango trees is explained by the change in home garden areas. Furthermore, the slope is 0.001 in both cases, indicating that for every unit increase in areas, number of species increases by only 0.001. The calculated diversity indices were H'=1.57 for all species and 1.40 for mango varieties. Typical values of diversity index are generally ranged between 1.5 and 3.5 (Magurran, A.E. 2004) and the calculated indexes of the study area were reached nearly this range.

CONCLUSION

Although the results suggest that indeed, plant species richness of home gardens in the study area is high, there were more potential areas to extend home gardening especially for large home gardens (41%) followed by medium gardens (16%) and small ones (9%) respectively. While we found no correlation between species richness and the home gardens sizes, these sizes were significantly correlated to richness of mango varieties with a higher species richness in larger than in smaller-sized home gardens. This might be because large-sized gardens tend to focus on fruit tree type species and allocate more of their land to food crops, while small gardens can afford to include different types of crop species. Mango varieties were well distributed and adaptable with agro-ecology of the study area; therefore, the gardeners should try to replace with the marketable and exportable quality mango varieties in spite of existing local varieties. Home gardeners need to be made localized efforts to conserve rare native species by promoting more widespread cultivation.

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Research article

Impact of Forest Cover Change in Phnom Kulen National Park on Downstream Local Livelihoods along Siem Reap River, Cambodia

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Abstract National parks play important roles in the conservation of biodiversity, environmental protection, and provision of resources for local livelihoods. This research aims at examining the effect of forest cover change in Phnom Kulen National Park (PKNP) on water quality and downstream local livelihoods along the Siem Reap river. Forest cover change in the park was collected from the United States Geological Survey from 2000 to 2016 through the Multi-Temporal Satellite Imagery (MTSI). The study used livelihood approach to interview with 120 households and four key-informants to elicit local perceptions on effect of forest lost on their livelihoods. The research found the forest cover in PKNP decreased by 22% from 2000 to 2016. The loss of forest cover has affected downstream local people whose daily livelihoods depend on Siem Reap River. Scores on local perceptions were low. Livelihood capital were performed low; only 0.48 on natural capital, 0.44 on human, and 0.24 on financial capital, in which correspondent perceived their livelihood did depend significantly on those capitals. However, we found that the physical and social capitals were not significantly affected by the forest cover change because forest clearing created stable access to infrastructure and social network. As forest cover declined, crop production, fish availability, water quality and access to clean water were also declined. As local needs to adopt new skills for living, human and financial capitals were low. The study confirmed the forest cover change at national park had a serious impact on the downstream local livelihoods.

Keywords Phnom Kulen National Park, forest cover change, sustainable livelihoods approach, upstream-downstream issue, perception analysis

INTRODUCTION

Forest provides direct and indirect of good and services to human well-beings by ecosystem functions (Robert et al., 2002). Moreover, it was totally essential for water storage because when the natural forest was damaged, rainfall would be declined, reduced infiltration of water, increased run-off, and reduced water quality (Robert et al., 2002). Existence of watershed areas in protected forests and

national parks played the vital functions for water purification and water resources for both upstream and downstream livelihoods. National park was one of the great tools for forest and biodiversity conservation. The PKNP was one of famous sacred tourist places with immense spiritual, cultural, historical value. Moreover, it was the main source of water provision for downstream people almost the whole year. However, weak law enforcement and higher market demands on timber and other forest products caused serious forest lost in Protected Areas (Sanchez-azofeifa et al., 2002). Approximately 70 % of downstream local people were semi-subsistence farmers and fishers who heavily depended on river-based livelihood activities (Hayes et al., 2013). Lastly, present Siem Reap river had faced water shortage, soil fertility problems, and water pollution (UNDP, 2014).

OBJECTIVES

In overall, the study aimed to investigate the perception of local people on impact of forest cover change in PKNP on Siem Reap river and their livelihood. The specific objectives are i). analyzing the trend of the forest cover change in PKNP between 2000 and 2016; and ii). assessing the livelihood capital of downstream people affected by upstream forest cover change. The limitation of the study did not access to measure economic comparation between before and after the forest cover change due to uncertainly of household's livelihood diversity.

METHODOLOGY

Study Area

Fig. 1 showed PKNP, targeted area, located at Siem Reap province, Cambodia (Hayes et al., 2013). Over centuries, the PKNP provided not only main source of water for the city use throughout full year, but also for underground water, which support Angkor Wat temple basement and its scenery (Gaughan, Binford, & Southworth, 2009). Recently, the water from the park contributed importantly daily consumption and agriculture of provincial population. However, there were concerns on the deforestation, led to cause on both water quality and quantity from the park.

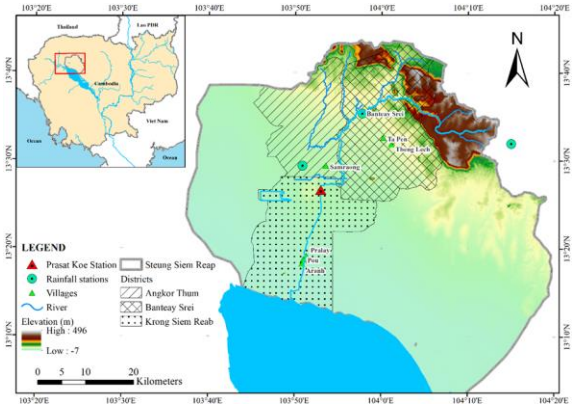

Fig. 1 Phnom Kulen National Park boundaries and administration

Forest Cover Change Detection in PKNP between 2000 to 2016

This study utilized Landsat Satellite Imagery (LSI) from 2000 to 2016. Multi-temporal satellite data were downloaded from the United Stare Geographical Satellite including Landsat 5, Landsat 7 ETM+, and Landsat 8 OLI with a 30 meters resolution. ArcGIS software (ArcGIS 10.6) was utilized for digital image processing, classification, and analysis as well as forest cover change maps generation. Two types of land use and land cover (LULC) were classified including forest, and non-forest areas. In addition, these satellite imageries were selected with less than 10 % of cloud. The band combination of mosaic and masking were used to analysis and merge the images and clip the boundary. Indeed, Regions of Interest (ROI) was used for supervising classification for forest change detection. Band Combination false color of Landsat was used, and it is easy to take ROI which is forest or non-forest. Therefore, band 4, 3, 2 was used for Landsat 5 from 2001 to 2011, and Band 7, 4, 2 was used for Landsat 7 ETM+ from 2000 to 2013 and Landsat 8 OLI from 2014 to 2016.

Accuracy Assessment

Accuracy assessment was conducted for all classification to prove the accuracy of each classified image. Moreover, it used to compare the classification from one to another, assumed to be accurate i.e. aerial photo (Parece et al., 2011). An error matrix was accomplished for this task. To assess the accuracy of classification, there were four main steps: 1) create random point on image classified in ArcGIS (100 sample), 2) convert layer to KML to assess the point in Google Earth, 3) insert the point in Google Earth and compared the classification task and Google Earth, and 4) created the error matrix table and calculate with the formula.

Cohen's kappa co-efficient was an essential component of accuracy assessment, it provided the accurate result how well our classification performed.

$$\hat{k} = \frac{\text{observed accuracy - chance agreement}}{\text{1 - chance agreement}}$$

Where, The **KHAT** value ranges from 0 to 1,**0** indicates the classification is not any better than a random assignment of pixels, **1** indicates that the classification is 100% improvement from random assignment

$$\hat{k} = \frac{N \times \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} (X_{i+} \times X_{+i})}{N^2 - \sum_{i=1}^{r} (X_{i+} \times X_{+i})}$$

Where, $\mathbf{r}$ number of rows in the error matrix, $\mathbf{X_{ii}}$ number of observations in row i and column i (the diagonal cells), $\mathbf{X_{i+}}$ total observations of row i, $\mathbf{X_{+i}}$ total observations of column I, **N** total of observations in the matrix. Source: Parece et al., (2011)

This study calculated the error matrix formulations of two years: 2010 and 2016 to verify the accuracy of forest cover change analysis. After calculating the error matrix of supervised classification in 2010, the overall accuracy of image classification is 96 % and the Kappa was 91 %. In 2016, the overall accuracy of the image classification was 91% in 2010 and 82% in 2016.

Assessment of Livelihood of Downstream Local People Affected by Upstream Forest Cover Change

120 households were selected with purposive sampling for the questionnaire survey. Four key-informants from forestry administrative office, department of environment, department of meteorological and rangers in Siem Reap province were interviewed for the confirmation of both qualitive and quantitative survey.

Adapted from Qian et al. (2017), livelihood approach has five capitals including; Physical capital which had indicators: household fixed assets (Land, Machinery, etc.); Natural capital had indicators: forest coverage (changing), necessary for forest protection (important of forest), forest protection activities in National Park, and biodiversity (quantity of water, quality of water, crop fishing in natural place); Human capital had indicators: skill and knowledge (improvement), health status (illness or not); Financial capital has indictors: household income (income of agricultural production, forest and NTFPs), and Social capital had indictors: community membership (participant), social network (relationship), and family decisions. The total scores of local livelihood assets were calculated by:

$$\text{LA} = \frac{C_{Pc} + C_{Nc} + C_{Hc} + C_{Fc} + C_{Sc}}{5}$$

Where; **LA** Livelihood Assets, $\boldsymbol{C_{Pc}}$ Physical capital , $\boldsymbol{C_{Nc}}$ Natural capital , $\boldsymbol{C_{Hc}}$ Human capital, $\boldsymbol{C_{Fc}}$ Financial capital, $\boldsymbol{C_{Sc}}$ Social capital

RESULTS AND DISCUSSION

Trend of Forest Cover in Phnom Kulen National Park

In Fig. **2** shown in 2000, PKNP covered by 31000 ha of forest area. Between 2009 and 2016[3], forest was dramatically declined about 2800ha. The forest in PKNP had lost huge amount at the same trend of forest cover in whole (ODC, 2016). According to the interview with rangers reported the main reasons of population growth (both people who migrated in and population growth naturally inside the village), people expanded land for settlement, agricultural activities. Moreover, it was because of inadequate knowledge of local people regarding forest conservation and forest management, illegal logging. The perpetrators cut trees and killed the wildlife for selling at nighttime, which was difficult for rangers to take action. In addition, limitation of logistic and incentive of ranger affected on less activities of the patrolling.

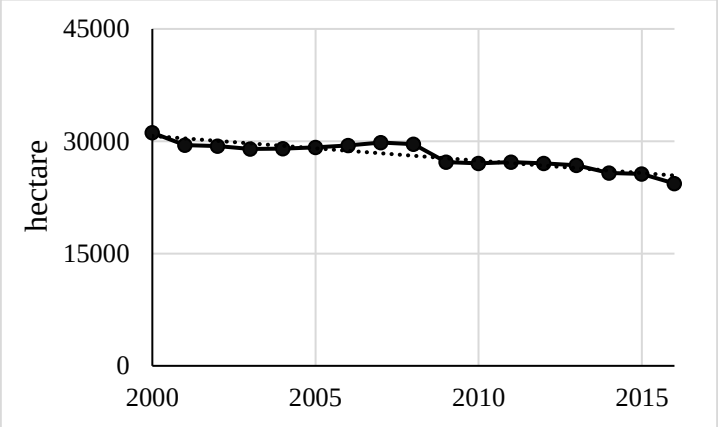

Fig. 2 Land surface of forest cover change in Phnom Kulen National Park from 2000 to 2016

Between 2009 and 2013 is the period of creating the policy on economic land concession (ELC) by the government in the National Strategic Development Plan (NSDP). The purpose of creating the ELC policy was to develop the industrial agricultural sector, sustain economic growth and reduce poverty (ODC, 2015). By contrast, our study found there was impact on the forest cover change in Siem Reap province. Based on the NGOs reported ELC was a hot very topic for land conflict including land grabs, evictions and exploitation of natural resources (ODC, 2016).

In a line, the result of forest cover from the LSI from 2000 and 2016 shown in Fig. **3**, forest lost about 22 %, equal to 6780 ha and the rate of deforestation was 1.3 %, account to big amount of forest lost that had to be consideration of the Cambodian government and development agencies. Recently, over 4,600 people had settled in PKNP, caused to forest land conversion to residential, crop cultivation mainly rice and cashew nut and the area was mainly used for rice (A&D Foundation, 2018).

The analysis found that 65 % of local people perceived that forest cover in the upstream of PKNP had decreased, while 35 % reported not. The score of forest coverage was 0.35, suggesting a significant decline. Our analysis of satellite imagery found that sharp decline in Banteay Srei district, where local people depended on most on timber and non-timber production for daily livelihoods.

The result shown in Table 3, the percentage of local people perceived the forest at upstream was declined, water quantity in the region decline is 76.7% especially. Moreover, there are 23.3% of correspondents reported water was not declined due to the forest cover change at upstream. The score of this water quantity was 0.23, which means deforestation impacted the decline of water quantity at downstream area.

[3] *In 2008, forest cover increased because of the cloud problem which made some error in calculation. In 2012 and 2013, the imagery of land 7 was selected to use because it is the clearest one but there has many gaps on the image so the research applied Shoreline Extraction (Landsat 7 ETM+) to fix it.*

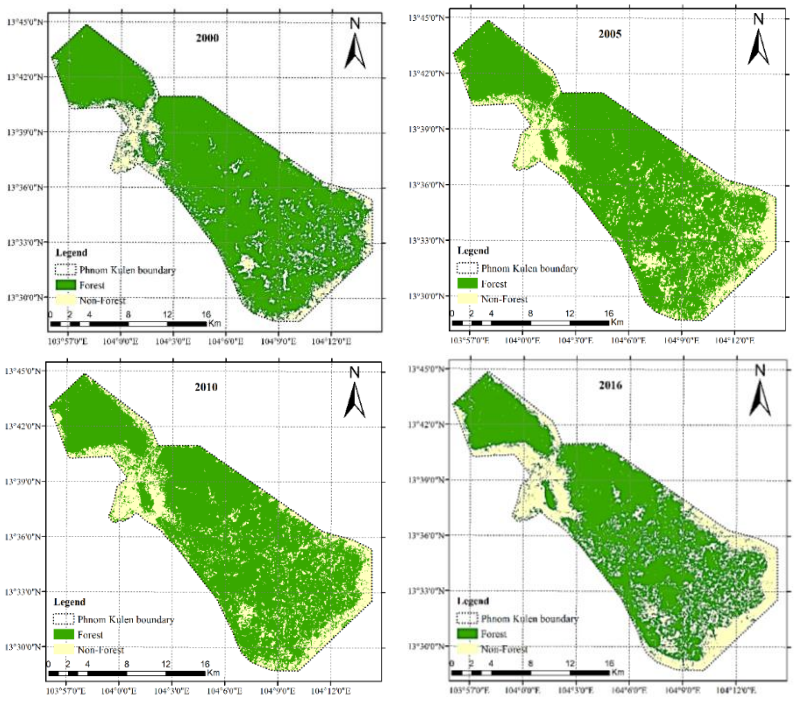

Fig. 3 Comparison of forest cover change in Phnom Kulen National in 2000 and 2016

Table 3 Percentage of correspondent on livelihood capital

Statement	Respondents (n=120)		
	No (%)	Yes (%)	Score
Do you know that forest in the upstream national park has decreased?	35	65	= 35*1+65*0 = 35 % = 0.35
Do you think that since forest from upstream declined, water quantity in your region has also declined?	23.3	76.7	= 23.3*1+76.7*0 = 23.3 % = 0.23
Do you think since forest from the upstream decreased, water quality in your region also decrease?	28.3	71.7	= 28.3*1+71.7*0 = 28.3 % = 0.28
Do you think since forest from the upstream decreased, your crop production also declined?	40.8	59.2	= 40.8*1+59.2*0 = 40.8 % = 0.41
Do you think since forest from the upstream declined, the amount of fish in the river also decreases?	25.0	75.0	= 25.0*1+75.0*0 = 25 % = 0.25
Scaling: 0.00 – 0.25 Largely decreased 0.26 – 0.50 Decreased 0.51 – 0.75 Increased 0.76 – 1.00 Largely Increased		Total score	0.30

Another result shown 71.7% of downstream people perceived the decreased forest at upstream impacted on water quality. The score of water quality was 0.28. Correspondents reported last seven years ago before 2013, water in river and lake could be used for drinking, taking shower, and using for daily. In addition, 59.2% of the downstream people perceived the decreased forest at upstream impacted on a decrease of crops productions due to water shortage, badly in dry season.

There were 75 % of the downstream people perceive the decreased forest at upstream, impacted on the decline of natural fishery in the river the decline of fishery significantly affected on income and food insecurity of the local livelihood.

Livelihood Assets of Downstream Local People in Relation to Siem Reap River Affected by Upstream Forest Cover Change

Although forest cover change occurred in upstream but physical capital was required to use for daily life. Natural capital was reported decreasing in biodiversity with 0.48 score. Local people perceived there was decreased in upstream forest cover led to decrease the water quality, water quantity, impacted on yield of crop production fish production. People in Banteay Srei, Tbaeng Lech, Ta Pen, and Samraong villages raised the same aspect on decline of water quality and quantity impacted on reduction of crop production and fishery.

As shown in Fig. 4, the result indicated, physical capital was not impacted regarding the forest cover change in upstream with score 0.61. Similar change of physical capital because people required to use for their daily live.

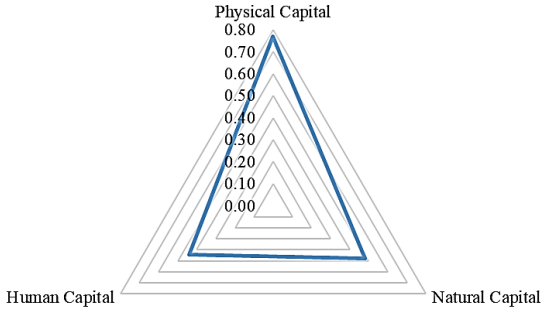

Fig. 4 Downstream local perception in term of change of livelihood capital

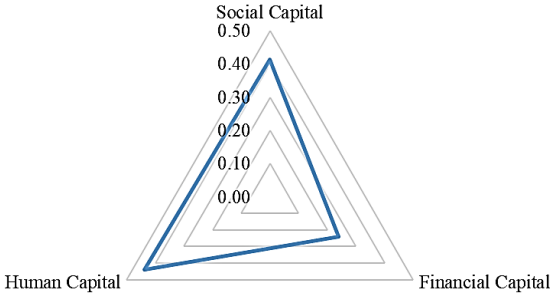

Fig. 5 Downstream local perception on the current situation of the livelihood capital

In Fig. 5, the result illustrated that the current situation shown score of financial capital was very with score 0.24, local people mostly depend on agriculture. The mean score human capital and social capital in term of current level was medium mean score 0.44 and 0.41 because people did not have any serious case of their health and both of man and woman had decided together for decision making.

CONCLUSION

The research found forest cover in PKNP was declined 22 % from 2000 to 2016 due to illegal logging, inadequate knowledge regarding forest conservation, population growth, increase in cashew nut, and rice fields. A strong link between natural capital and forest cover have found. As local people need to change to new skills in order to survive after decline of forest cover, low scores on human capital was observed, indicating the need for interventions of the local or national authority to assist local people. Similarly, for the current situation of their financial capital had low income and high expenditure.

Therefore, this study provided very important evident base of the forest cover change thought the satellite imagery maps from 2000 to 2016 and result of perceptions of local people about the impacts of the forest cover change in PKNM, which contributed direct and indirect impacts to natural capital, human capital and influenced on the current situation of financial capital.

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Research article

Study of Farmers' use of Fertilizers and Methods of Application for Rice Cultivation in Central Myanmar

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Abstract Fertilizers play an important role in the maintenance of soil fertility for rice production. The correct application of fertilizers can alleviate declining soil fertility. To improve levels of rice production in central Myanmar, it is essential to assess the current practices used in the application of fertilizers. The aim of this study is to examine farmers' knowledge and attitudes to the use of fertilizers for rice production and examine the constraints they face. A survey was conducted using structured questionnaires to interview 164 farmers, randomly selected from three villages in central Myanmar. The survey data were analyzed using descriptive statistics. Based on the survey results, commonly used fertilizers were urea and compound fertilizers. It was clear that the majority of farmers used amounts below that recommended amount in their application of urea and levels of application of mineral fertilizer varied greatly. About 23% of respondents used cow-dung manure and 12% applied pulses residues as fertilizers for rice cultivation. Although the farmers' accept that fertilizer application is necessary for better rice growing, the majority of the farmers faced financial difficulties with any increased use of fertilizers. Also, this study shows that the sampled farmers' limited knowledge on fertilizer use and the lack of access to the information related to fertilizer management, is a constraint preventing appropriate use of available fertilizers. Thus, clear improvements to increase agricultural productivity and soil fertility levels would result from the improved application of organic and inorganic fertilizers.

Keywords rice cultivation, use of fertilizers, farmers

INTRODUCTION

In Myanmar the agriculture sector is the backbone of the economy. This sector contributes to 37.8 percent of gross domestic product (GDP), accounts for 25 to 30 percent of total export earnings and employs 70 percent of the labor force (FAO, 2018). Among the cereal crops, rice is the most important source of national prosperity. Rice is not only the staple food source but also an important export crop, so successful rice production is crucial. Correctly used, fertilizers can play an important role in ensuring successful rice production.

Although Myanmar has had a long history of low fertilizer use, the fertilizer market has expanded rapidly since 2008. However, current practices in fertilizer use have resulted in the unbalanced application of nutrients. One keyway to improve fertilizer use is to enhance farmers' knowledge of the specific crop and soil nutrient needs and the fertilizer products (nutrient grades/formulations) that will best ensure the supply of these needs. Choosing which fertilizer to use

is often one of the most important decisions a farmer has to make. However, Myanmar farmers have limited knowledge of modern agricultural technologies, including fertilizers (IFDC, 2018).

The Department of Agricultural Development and Planning, Myanmar, reports that there is a declining tendency in domestic use and demand for chemical fertilizers, and that many small holder farmers have not adopted technology that ensures best use of both organic and inorganic fertilizers application, nor were farmers fully abreast of the importance of their use (DADP, 2007). This is despite the advantages of using inorganic fertilizers in boosting production and previous efforts making these fertilizers more freely available to farmers. In contrast to chemical fertilizers, farmyard manure has been used long term by Myanmar farmers to restore soil fertility. However, because of the lengthy process in processing farmyard manure so that it is ready for use, and the limited availability of animals kept by small holders, the amount of farmyard manure produced and used has always been insufficient to needs.

Myanmar faces huge food supply challenges due to the increasing population, the limited opportunities to increase arable land, and the declining yields associated with continuously declining soil fertility. In order to improve the productivity of rice farming, particularly for small holder farms in central Myanmar, it is critical to assess the current practices for the use of fertilizers, and to explore the constraints encountered by farmers with respect to both the use of organic and inorganic fertilizers.

OBJECTIVES

The main objective is to study the current methods of fertilizer application for rice production in central Myanmar, and to ascertain any problems and constraints associated with the farmers' use of fertilizers.

METHODOLOGY

General Description of Study Area

Three villages were selected, with two from the Naypyitaw area (Kyee Inn and Thit Tat villages) and the third, Chiba (Shwebo Township) from the mid-north of Myanmar. Data were collected using a structured questionnaire, with the assistance of the village-head (Table 1).

Table 1 General description of Kyee Inn, Thit Tat and Chiba Villages

Variables	Unit	Kyee Inn	Thit Tat	Chiba
Population		2160	1522	2828
Sown acre	acre	1392	550	1750
Rice sown acre (Summer)	acre	-	550	1750
Rice sown acre (Monsoon)	acre	850	550	1750
Farmer population		1000	89	230
Water availability		Irrigated	Irrigated	Irrigated
Name of Dam		Nga-like Dam	Yezin Dam	Tha Phan Seit Dam
Cropping pattern		Rice-Pulses	Rice-Rice	Rice-Rice

Survey and Data Analysis

Interviews were conducted, and farmers taking part were selected using a simple random sampling method. A total number of 164 farmers (66 from Kyee Inn, 63 from Thit Tat, 35 from Chiba) were interviewed using questionnaires which included questions on gender, marital status, farmers' age, farming experience, location of residence, educational levels, and size of area cultivated for rice. Questions specific to fertilizer use related to quantity, time of application, and type of fertilizer used for rice cultivation. The survey also identified any problems and constraints faced by farmers in

obtaining fertilizers, and what methods of application were used. All data were analyzed by descriptive statistics with the *Statistix 8th* version.

RESULTS AND DISCUSSION

Socioeconomic Background of Sampled Respondents

Agriculture is undertaken by an aging male population at all sites (80% in Kyee Inn, and 89% in Thit Tat and Chiba). This finding is in agreement with those of Lawal and Ayoola (2008). The results indicate that the majority of the farmers are about middle aged and according to Yunusa (1999) this is an economically active age for motivation and innovation.

Education facilitates the transfer and promotion of technologies meant to improve crop production (Lawal and Ayoola, 2008). The education status of the respondents in the survey areas varies greatly, with farmers who have no formal education to those who have tertiary education and university education (in this survey university education is given a separate category to education gained at other tertiary institutions). However, in general, the level of educational attainment is sufficient to support the adoption of technology through information sharing and written material. The percentage of farmers attaining a secondary education is highest in Kyee Inn (45%) followed by Chiba (43%). Thit Tat village had the highest percentage of farmers (41%), who had attained, at highest, primary education. These results correspond to those of Ifejika et al. (2008) who found that the majority of farmers had some formal education. There is a low percentage of farmers with tertiary education in all villages. A significant number of farmers with no formal education (14%) is found only in Thit Tat village. The results clearly indicate that the farmers in the surveyed villages can, in general, read extension leaflets, posters and magazines promoting innovative farming methods. Given the small percentage of illiterate farmers it can be expected that knowledge of new methods would be communicated widely in the farming community.

The amount of experience of farming relates as a key risk management factor, and Ridler and Hishamunda (2001) showed that new farmers were at a higher risk compared to experienced farmers. The survey identified five different levels of farming experience; from under 5 years, then 5 to 10 years, 10 to 15 years, 15 to 20 years and finally those with above 20 years of farming experience. Thit Tat village had the highest percentage of farmers with experience of more than 20 years, followed by Chiba and Kyee Inn. The data show that most farmers are very experienced and this would be expected to enhance effective fertilizer use.

The size of land holding of the respondents ranges from under 2 hectares, 2 to 6 hectares and above 6 hectares. However, Olayide et al. (1980) classified small-scale farmers as those having 0.1 to 5.99 hectares of farm size. Farm size determines the number of inputs, such as fertilizer, that can be purchased. Most of the respondent's farms can be classified as small scale, with this being attributable to land fragmentation with land acquisition among family members.

Types and Brand of Fertilizers used by Farmers in the Survey Area

The data show that the most common types of fertilizers used by the farmers are urea (85%, 95%, and 100%) and compound fertilizers (97%, 81%, and 71%) in the Kyee Inn, Thit Tat, and Chiba villages, respectively. This indicates that farmers in these areas have good knowledge in the use of these types of fertilizers, which can provide a greater rice yield than other types of fertilizers. However, there was little use or knowledge of other types of fertilizers such as the Phosphorus and Potash, in the surveyed villages. In respect to most popular brands, most farmers use a combination of brands with Armo brand used by 87%, followed by Awba (57%), China brand (46%), Myanmar brand (8%), while Tan Quen and Thailand brand have the same percentage use (5%), and Shwe Nagar (2%).

Methods and Time of Fertilizers Applications

According to the data in Table 2, broadcast fertilizer application methods are used by most farmers across the surveyed villages, and basal application methods are seldom used. The broadcasting method has a lower investment cost, and is popular as farmers lack the capital to invest in mechanization or even hire labor for alternate application methods. Most respondents used a top dressing application at the tillering and flowering stages. Some of the respondents from Thit Tat and Chiba, but very few from Kyee Inn, apply fertilizers after flowering.

Table 2 Methods and time of fertilizer application for rice crops

Method of application	Kyee Inn Frequency, (%)	Thit Tat Frequency, (%)	Chiba Frequency, (%)
Broadcast	57 (86)	50 (79)	34 (98)
Basal	0 (0)	13 (21)	1 (2)
Time of application			
Top dressing			
Tillering	63 (100)	59 (94)	35 (100)
Flowering	60 (95)	55 (87)	33 (94)
After flowering	3 (5)	45 (71)	22 (63)
Total amount of urea application (kg ha^{-1})	125.20	169.05	105.8

Urea Application at Different Farm Size and Education Levels

In Fig. 1, it is clear that farmers on smaller farms applied relatively low amounts of urea fertilizers in comparison to larger farms in the areas surveyed. This indicates that larger holdings relate definitely with higher use of urea. The Kyee Inn village in particular, shows this pattern, with vastly higher amounts of urea application for those areas greater than 6 hectares.

It can be seen that there is a visible progress in the amount of urea application with higher levels of education for farmers in the Nay Pyi Taw area. However, in the Chiba (Shwebo) area there is a quite difference. Here a relatively lower amount of urea is applied by those with a university level of education, while farmers who were educated to a primary level or by another tertiary institution applied high amounts of urea. In contrast, university educated farmers from Kyee Inn and Thit Tat villages apply higher amount of urea for their rice production. In Thit Tat village, farmers with no formal education or a primary level education applied the lowest amounts of urea (Fig 2.).

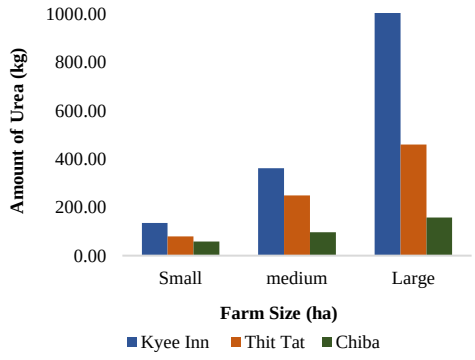

Fig. 1 Urea application and farm size

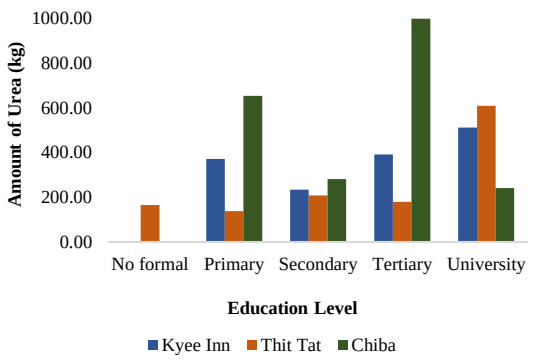

Fig. 2 Urea application and education levels

Problems and Constraints Faced by Respondents in Rice Cultivation

Farmers face many problems in growing rice. The main problem is insufficient water, followed by inadequate credit facilities, pest infestation, and problems related to seed and soil in the Nay Pyi Taw

area (that is Kyee Inn and Thit Tat villages). However, poor soil and pest infestation are clearly the main problems faced by Chiba village in their rice production (Fig 3.).

Farmers in the survey area encounter many common shared constraints in their use of fertilizers for rice production (Fig 4.). While farmers of Kyee Inn village are mainly constrained by high cost of fertilizers, lack of capital, less in weight and poor quality fertilizer, the farmers in Chiba village are more constrained by lack of capital, the high cost of fertilizers, lack of organic fertilizers, and non-availability of fertilizers for timely application. Finally, in the Thit Tat area, the major constraints on rice production are high cost of fertilizers and replacement of organic fertilizers.

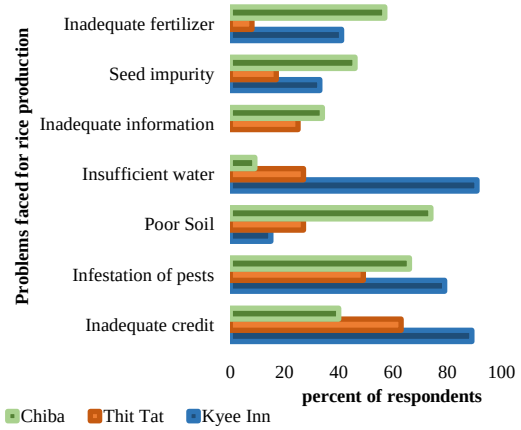

Fig. 3 Problems faced by respondents for rice production

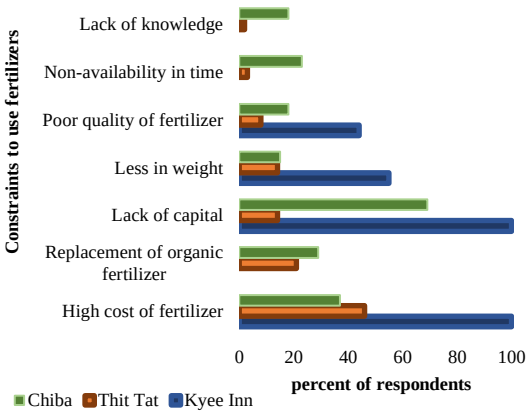

Fig. 4 Constraints on the use fertilizer for rice production

CONCLUSION

According to these results, respondents in Kyee Inn have the highest appreciation of the benefits of using fertilizers. They believe fertilizers are necessary for the crop to do well and can double yields. To a lesser extent, Thit Tat village has similar attitudes regarding the use of fertilizers, but farmers from Chiba village do not value fertilizers as much in rice production. Most farmers applied urea with two to three times of split application to be more efficient for rice production. A majority of farmers use amounts of urea below those recommended (276 kg ha^{-1} for monsoon season and 414 kg ha^{-1} for summer). In spite of the role that fertilizers play in improving rice production, lack of access to information about fertilizer management, high prices and lack of capital constrain their usage. This study shows that manure or organic fertilizer cannot be relied on to increase rice production and sustain agricultural productivity. Manure is scarce and transportation costs are high. As a result, the quantity of manure applied is likely to be low. Due to the lack of proper storage facilities the quality of manure applied is likely to be very low in terms of nutrient supply. Lack of proper management of fertilizers by farmers increases the cost of production and excessive application will probably have adverse effects on aquatic and terrestrial ecosystems. Greater education on fertilizer use and management through agricultural extension services, the media, and at the point of sale are recommended to improve sustainable use of fertilizers for rice production in Myanmar.

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Research article

Factors Causing Deficits in Traditional Rice Liquor Production in Rural Areas of Cambodia

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Abstract Adding value to agricultural products is expected to play an important role in increasing income and reducing poverty in rural areas of Cambodia. The promotion of agro-processing is one of the key strategies for the value addition. A variety of processed foods produced by individual small-scale farmers have helped generate income, with the exception of rice liquor which has been faced deficits and low profitability. This study aimed to clarify the socio-economic status of rice liquor farmers in rural areas and to examine the factors leading to deficits and surpluses in rice liquor production. Data on the economic status of rice liquor farmers and non-rice liquor farmers were collected by conducting structured interviews using questionnaires at the targeted areas in Takeo Province. Comparisons of the income structures of the two groups revealed that the rice liquor farmers mainly depended for income on agricultural activities including rice liquor production and pig rearing, whereas non-rice liquor farmers depended on non-agricultural activities such as off-farm businesses, labor work, and remittances. Rice liquor production was less profitable, and around 30% of rice liquor farmers faced deficits in this activity. A comparison of the economic status between deficit and surplus operations of rice liquor production revealed the key factors that caused deficits, such as a low sales price, high cost of rice, low productivity, and high frequency of production failure. Rice liquor farmers expected improvements in the production techniques, in the quality and productivity of liquor. Thus, modifying production techniques to improve the quality and productivity of rice liquor, and to reduce the rate of production failure are the key strategies to increase the profitability of rice liquor businesses.

Keywords agro-processing, added value, traditional product, business improvement, Cambodia

INTRODUCTION

Adding value to agricultural products is expected to play an important role in increasing income and reducing poverty in rural areas. The promotion of agro-processing in rural areas has emerged as one of the key strategies to add value to local agricultural products (Royal Government of Cambodia, 2006; Royal Government of Cambodia, 2013). In rural areas of Cambodia, individual small-scale farmers have produced a variety of processed products, such as pickled vegetables, processed fish, traditional sweets, charcoal, and rice liquor (*sraa sar* in Khmer). The production of these processed foods, with the exception of rice liquor, has helped generate income for rural households; in contrast, rice liquor production has faced deficits and low profitability (Yagura et al., 2010). Instead, such producers have obtained profit from pig farming by reducing the cost of feeding pigs by using the by-products derived from the distillation of fermented rice (Vathana and Takeya, 2004; Yagura et

al., 2010). This production system kept pig farming profitable despite rice liquor operations staying in the red (Yagura et al. 2010). However, recent sales prices of pigs have been fluctuated in the Cambodian market due to increasing the imported pigs from Vietnam and domestic pig from large-scale farms. (Tornimbene and Drew, 2012). This situation have made the small scale rice liquor farmers with pig farming difficult to sustain their businesses in rural areas. It is significantly important to examine the strategies to improve profitability of rice liquor production.

The cultural norms and general production methods of alcoholic beverages from rice in Southeast Asian countries such as Vietnam and Laos have been clarified (Kozaki et al., 2002; Kozaki et al., 2005). The production methods of traditional brewed and distilled rice liquor in Cambodia were revealed by Kozaki (2007). Yamamoto and Matsumoto (2011) identified the production methods and raw materials of starter cultures for rice wine and rice liquor in Cambodia. However, there have been no studies which examined the economic issues and possibilities of the improvements in rice liquor productions.

OBJECTIVE

This study aims to clarify the socio-economic status of rice liquor farmers in rural areas and to examine the factors that lead to a deficit or surplus to come up with the strategies of the development in rice liquor production.

METHODOLOGY

This study attempted to clarify the socio-economic status of rice liquor farmers by comparing the farmers who were engaged in rice liquor production (rice liquor farmers) and those who were not (non-rice liquor farmers). Then, a detailed analysis was conducted by focusing on rice liquor production, including its economic and technical issues, to examine the factors that lead to deficit and surplus operations based on the economic analysis and the farmers‘ awareness.

In September 2008, structured interviews were conducted to understand the socio-economic status of farmers in six targeted communes consisting of 93 villages in Takeo Province, one of the areas where rice cultivation is most popular, given the region’s high productivity and quantity of produce (Hamano et al., 2013). The most popular communes in rice liquor production were selected as surveyed areas according to the key informant interview results to the officers of the provincial department and the district offices, commune chiefs, and village chiefs. These structured interviews were conducted using questionnaires. All rice liquor farmers in the six communes were interviewed. They were identified based on the information provided by key informants, such as village and commune chiefs, since the accurate official information on the number and locations of rice liquor producers were not found in governmental institutes. In all of the 93 target villages, a non-rice liquor farmer was randomly selected in each village for comparison in this study.

One of the questionnaires required rice liquor farmers and non-rice liquor farmers to identify their socio-economic status. The questionnaire sought the following information: details about the head of the household and his/her spouse; businesses operated by the farmers; and income generated from the businesses, including other agricultural and non-agricultural economic activities to identify the main bearers and sources of a household’s income. The other questionnaire was devised exclusively for rice liquor farmers in the region, and it consisted of questions designed to elicit detailed information about the production and sale of rice liquor to identify the factors leading to its deficit and surplus. The questions were designed to elicit the following information: the experience of producing rice liquor; the production process and frequency; the costs of raw materials and equipment needed for rice liquor production; production failures; sales price and amount of the product; and existing issues and areas of improvement in rice liquor production. Closed-ended questions were used to elicit answers regarding these issues and areas of improvement. The frequencies of keyword appearances as used by the farmers during their responses were also factored into the analysis. The farmers’ awareness was also examined to ascertain whether there were issues that significantly affected the production and business of rice liquor farming.

The Statistical Package for Social Science Student Version 16.0 was used to conduct the Mann–Whitney test to compare the averages of the parameters between rice liquor farmers and non-rice liquor farmers. The deficit and surplus operation groups involved in the production of rice liquor were also compared in the same way.

RESULTS AND DISCUSSION

Interviewees and Features of the Households

Table 1 shows the numbers of farmers interviewed for this study and the numbers of their valid responses that were factored into the analysis. The 93 villages (in the six targeted communes) in the region consisted of 13,548 households (National Institute of Statistics 2009). A total of 166 rice liquor farmers, spread across 56 villages, were interviewed, and 117 valid responses were obtained. In each village in the target areas, a non-rice liquor farmer was randomly sampled for the interviews, and 87 valid responses were obtained from them. Table 1 shows that the average age of the husbands of rice liquor farmers was 39.9 years old and the average age of the wives was 38.5 years old. These averages are approximately six years younger than the average ages of the non-rice liquor farmers. There was, however, no difference in terms of the size of the household. Table 1 also shows the average sizes of the paddy fields and rice yields of the rice liquor farmers and non-rice liquor farmers. Most of both rice liquor and non-rice liquor farmers (96.6%) produced rice as the main staple food. Rice liquor farmers cultivated rice in 1.12 hectares of paddy field and harvested 1.78 tons of rice yield on average, which are larger by 31.8% and 27.1% than the corresponding values of non-rice liquor farmers (0.85 hectares and 1.40 tons), respectively.

Table 1 Interviewees

	Rice liquor farmers[2]		Non-rice liquor farmers[3]		Sig.[4]
Valid responses[1]	117		87		-
Average age (years old) of husbands (n)	39.9	(110)	46.5	(78)	0.00**
Average age (years old) of wives (n)	38.5	(116)	44.8	(85)	0.00**
Average number of household members (n)	6.0	(117)	6.2	(87)	0.63
Average size (ha) of the paddy fields in wet season (n)	1.12	(113)	0.85	(84)	0.02*
Average rice yield (t) in wet season (n)	1.78	(113)	1.4	(84)	0.02*

Note: [1]Overall, 166 rice liquor farmers were interviewed; 117 valid responses were obtained. Moreover, 93 non-rice liquor farmers were interviewed; 87 valid responses were obtained.
[2]Rice liquor farmers: 7 female household heads and 1 male household head did not have a souse.
[3]Non-rice liquor farmers: 9 female household heads and 2 male household heads did not have a spouse.
*[4]The Mann–Whitney test was used to compare the averages between the rice liquor farmers and the non-rice liquor farmers. The average difference is significant at * 5% and ** 1% levels.*

The Economic Status of Rice Liquor Farmers and Non-rice Liquor Farmers in Rural Areas

Figure 1 shows the average annual incomes derived from all economic activities by both groups: the rice liquor farmers and non-rice liquor farmers. The average income of rice liquor farmers was found to be 5,601,000 Riel (R) (4,000 R = 1 U.S. Dollar), which was lower than the average income of non-rice liquor farmers of 5,980,000 R by 379,000 R (6.3%). A large proportion (73.8%) of the income obtained by rice liquor farmers came from agricultural activities, of which 26.5% came from agro-processing including rice liquor, 38.7% from animal husbandry, 7.2% from rice milling, and 1.4% from crop/vegetable productions. On the other hand, non-rice liquor farmers obtained 73.8% of their income through non-agricultural activities, of which 43.9% came from off-farm business enterprises such as grocery shops, food stalls, and small restaurants; 17.4% came from the paid work (employment) such as agricultural work, construction, and public services; and 12.5% came from remittance provided by family members who lived away from home. The higher average income of non-rice liquor farmers was a direct result of the difference of average remittance that the two groups

received, which was 608,000 R. Rice was cultivated by both groups mainly for self-consumption, even though some of the rice was sold on the market. In addition, the rice liquor farmers fed rice to their pigs. As a result of this, the sales revenue could not cover the production costs. The rice production resulted in a negative income of minus 315,000 R for rice liquor farmers and minus 147,000 R for non-rice liquor farmers.

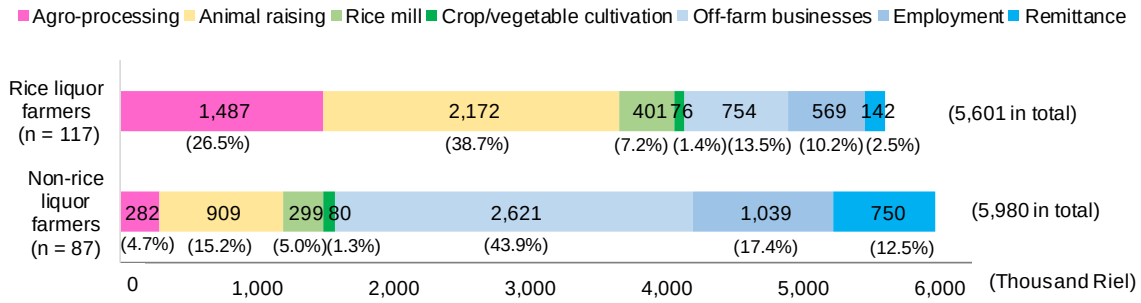

Fig. 1 Average annual incomes derived from economic activities

Table 2 shows the detailed figures of the average income structure from the related businesses practiced by rice liquor farmers and non-rice liquor farmers. The table shows details such as their annual revenue and income from each business, as well as the numbers of farmer who were engaged in. For the purpose of this study, the costs involved in family labor were not factored into the general costs. All 117 rice liquor farmers earned an average income of 1,364,000 R through the rice liquor production. Moreover, 31 out of the 117 households earned an additional 463,000 R by producing other agro-processed foods such as processed fish, palm juice and sugar, pickled vegetables, and traditional sweets. Of the 87 non-rice liquor farmers, 19 households earned an average income of 1,291,000 R through their involvement in agro-processing practices. The profitability of rice liquor, which was found to be 12.7%, was lower than the profitability of other agro-processing practices, which was found to be 39.8% for rice liquor famers and 46.5% for non-rice liquor farmers. All rice liquor farmers raised pigs, and the average income from pig rearing was found to be 2,012,000 R, and the profitability was found to be 55.6%. Most rice liquor farmers (107) also acquired an average income of 174,000 R through other animal husbandry involving cattle, chicken, duck, and fish, and the profitability was found to be 13.0%. A total of 26 non-rice liquor farmers obtained an average income of 649,000 R by raising pigs and 78 farmers obtained one of 798,000 R from other animal husbandry, the profitability of each of which was 54.1% and 33.6%, respectively. Forty rice liquor farmers obtained an average income of 1,172,000 R through rice milling; the profitability of this was found to be 38.3%. On the other hand, four non-rice liquor farmers obtained an average income of 6,495,000 R through rice milling, the profitability of which was 66.1%. For the latter, operating the rice mills was the main business, whereas for the former, rice milling was a secondary business.

Thirty-five rice liquor farmers and 31 non-rice liquor farmers sold surplus crops and vegetables such as maize, cucumber, pumpkin, watermelon, mung bean, sugarcane, cassava, and sweet potato, and their average incomes were 253,000 R and 225,000 R, respectively. Most rice liquor farmers and non-rice liquor farmers produced rice mainly for self-consumption, although 21 rice liquor farmers (18.6%) and 25 non-rice liquor farmers (29.8%) sold some of their rice. The incomes of rice production were minus 327,000 R by 113 out of 117 rice liquor farmers and minus 152,000 R by 84 out of 87 non-rice liquor farmers. The rice liquor farmers used some of their rice for rice liquor production and feeding their pigs. Since they spent most of their time on rice liquor production and rearing pigs within their daily activities, they tended to spend more on the hiring of extra labor during the transplantation and harvesting of rice than the non-rice liquor farmers did. As a result, the deficit for rice among the rice liquor farmers was greater than that by the non-rice liquor farmers, although the rice fields of the former were 31.8% larger than those of the latter group (Table 1).

In terms of non-agricultural activities, 69 (59.0%) rice liquor farmers were engaged in non-agricultural activities, while the number was 80 (92.0%) for non-rice liquor farmers. In detail, 28 (23.9%) rice liquor farmers managed off-farm businesses and gained an average income of 3,152,000

R through them. The profitability of these businesses was found to be 19.6%. On the other hand, 37 (42.5%) non-rice liquor farmers gained an average income of 6,163,000 R through off-farm businesses, the profitability of which was found to be 31.1%. In this context, the average income of the latter was 96% more than the former's income, and the latter's profitability through these businesses was 59% more than the former's profitability. It was found that 32 (27.4%) rice liquor farmers were employed as agricultural labor, construction labor, and government staff. Their average income through these sectors was 2,082,000 R. Twenty-three (19.7%) rice liquor farmers received an average remittance of 723,000 R from family members who lived away from home. On the other hand, 36 (41.4%) non-rice liquor farmers received an average income of 2,510,000 R through employment, and 33 (37.9%) received an average remittance of 1,977,000 R. The latter's income through employment was 21% more than the former's income. The average remittance received by the latter was 173% more than the remittance received by the former.

In summary, these results indicate that rice liquor farmers obtain a large part of their income through pig husbandry and rice liquor farming, although the profitability of rice liquor production is low compared with that of their other businesses. On the other hand, non-rice liquor farmers depend on non-agricultural businesses more than rice liquor farmers.

Table 2 Income structures of rice liquor farmers and non-rice liquor farmers

Economic activities	No. of operating farmers		Rice liquor farmers			Non-rice liquor farmers			Sig. [1]	Sig. [1]
Annual revenue and income	Rice liquor farmers	Non-rice liquor farmers	Average revenue	Average income[2]	Profit-ability[3]	Average revenue	Average income	Profit-ability[3]	*Revenue*	*Income*
	No. (% [4])	No. (% [4])	Thousand Riels	Thousand Riels	%	Thousand Riels	Thousand Riels	%		
Agriculture										
Agro-processing										
Rice liquor	117 (100.0)	-	10,728	1,364	12.7	-	-	-		
Others	31 (26.5)	19 (21.8)	1,164	463	39.8	2,775	1,291	46.5	0.00**	0.05*
Animal husbandry										
Pig rearing	117 (100.0)	26 (29.9)	3,622	2,012	55.6	1,199	649	54.1	0.00**	0.00**
Others	107 (91.5)	78 (89.7)	1,339	174	13.0	2,374	798	33.6	0.34	0.04*
Rice milling	40 (34.2)	4 (4.6)	3,059	1,172	38.3	9,819	6,495	66.1	0.03*	0.02*
Crop/vegetable	35 (29.9)	31 (35.6)	349	253	72.5	258	225	87.2	0.72	0.87
Rice[5]	113 (96.6)	84 (96.6)	305	-327	-107.2	286	-152	-53.1	0.89	0.09
Non-agriculture[6]	69 (59.0)	80 (92.0)								
Off-farm businesses	28 (23.9)	37 (42.5)	16,112	3,152	19.6	19,846	6,163	31.1	0.39	0.04*
Employment	32 (27.4)	36 (41.4)	-	2,082	-	-	2,510	-	0.36	0.36
Remittance	23 (19.7)	33 (37.9)	-	723	-	-	1,977	-	0.00**	0.00*

Note: The interviews asked the information on the previous year. Questionnaires on agricultural businesses included cost and revenue information such as the price and amount of the purchased materials and equipment for one operation cycle. On non-agricultural businesses, information on daily sales and cost of products were asked. On employment and remittance, amount of salaries and remittances in one month or one year were asked.

*[1]The Mann–Whitney test was used to compare the averages of the revenues and incomes between the rice liquor farmers and the non-rice liquor farmers. The average difference is significant at * 5% and ** 1% levels.*

[2]The farmer's labor costs were not included. [3]Profitability (%) = Average income ÷ average revenue × 100.

[4]Proportion for 117 rice liquor farmers and 87 non-rice liquor farmers.

[5]Numbers (proportions) of rice liquor farmers and non-rice liquor farmers who sold rice: 21 (18.6%) and 25 (29.8%).

[6]Numbers (proportions) of rice liquor farmers and non-rice liquor farmers who were not involved in non-agricultural activities: 48 (41.0%) and 7 (8.0%). Numbers (proportions) of rice liquor farmers and non-rice liquor farmers who depended on a single non-agricultural activity: off-farm businesses for 17 (14.5%) and 19 (21.8%), employment for 20 (17.1%) and 19 (21.8%), and remittances for 12 (10.3%) and 21 (24.1%). Numbers (proportions) of rice liquor farmers and non-rice liquor farmers.

Characteristics of Deficit and Surplus Operations of Rice Liquor Production

Table 3 describes in detail the economic status of rice liquor production. The average income obtained from rice liquor production was 5,210 R per production batch. The average sales revenue was found to be 51,548 R, and the total production costs were found to be 46,338 R. The average

production costs include the costs of raw materials, equipment, and the equivalent value of production failure. Rice, the main raw material in this process, accounted for 81.7% of the total costs, and the starter culture (*mee sraa*), fuel, and equipment accounted for 5.5%, 4.0%, and 2.6%, respectively. The production failure equivalent was found to be 6.2% of the total costs.

Table 3 Comparison of the economic status of surplus and deficit operations of rice liquor production

Rice liquor farmers	Total farmers		Deficit group	Surplus group	Sig. [1]
	n = 117 (100.0%)		n = 37 (31.6%)	n = 80 (68.4%)	
Average	Amount	%	Amount	Amount	
1) Income (Riel/time)	5,210		-8,065	11,349	0.00**
2) Sales revenue (Riel/time) [2]	51,548		45,359	54,411	0.00**
(1) Sales price of liquor (Riel/L)	1,561		1,435	1,619	0.00**
(2) Sales amount of liquor (L/time)	33.2		31.4	34.0	0.09
3) Total production costs (Riel/time)	46,338	100.0	53,423	43,062	0.00**
(1) Rice cost (Riel/time) [3]	37,869	81.7	42,660	35,653	0.00**
a. Rice unit price (Riel/kg)	1,890		1,994	1,842	0.00**
b. Rice amount (kg)/time	20.2		21.6	19.6	0.04*
(2) Starter cost (Riel/time)	2,550	5.5	2,895	2,391	0.94
(3) Fuel cost (Riel/time)	1,850	4.0	2,532	1,534	0.04*
(4) Equipment cost (Riel/time)	1,204	2.6	1,252	1,183	0.02*
(5) Failure cost (Riel/time) [4]	2,865	6.2	4,084	2,301	0.05*
a. Failure frequency (time/year)	9.7		12.7	8.4	0.02*
b. Production frequency (times/year)	211		186	223	0.07
4) Experience (years)	7.1		6.3	7.4	0.32
5) Age of husbands	39.9		41.3	39.2	0.23
Age of wives	38.5		39.5	38.0	0.34

Note: The interviews asked the questions on rice liquor production including production cost and revenue (sales) information such as the price and amount of the purchased raw materials, and sales amount and unit price for one time production, equipment cost, production frequency, and experiences.

*[1]The Mann–Whitney test was used to compare the averages between the surplus and deficit groups. The average difference is significant at * 5% and ** 1% levels.*

[2]The average sales revenue$= \frac{1}{N}\sum_{i=1}^{N} ab_i$. *[3] The average rice cost*$= \frac{1}{N}\sum_{i=1}^{N} ab_i$.

[4] Farmers recognized production failure when retailers and consumers refused to purchase the liquor due to its poor quality (Failure cost/time = Revenue/time × Failure frequency/year ÷ Production frequency/year).

Thirty-seven households (31.6%) of the rice liquor farmers in the region faced a deficit of an average of minus 8,065 R in their operation, whereas 80 households (68.4%) earned a profit, of 11,349 R on average. For the deficit group, the average revenue through sales was found to be 45,359 R, which is 83.4% of the revenue earned by the surplus group (54,411 R). The average total production costs for the deficit group were 53,423 R, which is 12.4% more than the surplus group (43,062 R). In terms of revenue, the average sales price for the deficit group liquor was 1,435 R/L, which is 11.4% less than the sales price of liquor produced by the surplus group (1,619 R/L). The deficit group produced rice liquor at 31.4 L/batch, which is 7.6% less than the liquor amount of the surplus group (34.0 L/batch). In terms of production costs, the cost of rice for the deficit group was 42,660 R (79.9% of the total product costs), which was 20% more than the amount paid by the surplus group (35,653 R, 82.8% of the total product costs). The deficit group used 21.6 kg of rice per batch and purchased rice at 1,994 R per kg; these amounts were 10% and 8% more than those by the surplus group, respectively. The deficit group experienced production failure at a rate of 12.7 times per year, which is 51% more than the failure rate by the surplus group. For the deficit group, the loss incurred from such failure was equivalent to 4,084 R, which is 77% more than the loss for the surplus group,

and constituted the second highest cost. On average, the deficit group produced rice liquor 186 times per year, which is 16.6% less than the value of the surplus group.

These results indicate that a low sales price, high cost of rice, and frequent production failure were the key factors that caused deficits for rice liquor farmers. Younger and more experienced rice liquor farmers produced rice liquor more frequently and also tended to earn a greater profit as a result.

Table 4 shows the conditions that characterize production failures. Keywords that were frequently encountered in responses pertained to "unsuccessful fermentation" characterized by acidic and spoiled smell/taste, bubble expansion of the fermented rice, and a "burnt smell". These results indicate that the failures typically occurred during the fermentation and distillation stages.

Table 4 Characteristics of production failure as identified by the farmers

Criteria	Frequency[1]	%
Unsuccessful fermentation[2]	59	46.8
Burnt smell	59	46.8
Low amount of liquor	6	4.8
Uncooked rice	2	1.6
Total	126	100.0

Note: [1]Frequent use of keywords in response to an open-ended question. Interviewees were asked to identify situations of "production failure"; 126 keyword appearances by 100 respondents were analyzed.
[2]Unsuccessful fermentation was characterized by "acidic" and "spoiled" smell/taste and bubble expansion of the fermented rice.

Issues and Areas of Improvement Identified by Rice Liquor Farmers

The issues identified by the rice liquor farmers who participated in this study are shown in Table 5. The areas in which they expected improvement are shown in Table 6. Closed-ended questions were used to elicit information about the two most important issues and expected improvement areas from the farmers. In terms of issues, the respondents most commonly mentioned expensive rice (55.5%), followed by the low quality of products (40.9%), low sales price (21.8%), scarcity and high cost of fuel (20.0%), and low volume of alcohol (18.2%). In terms of expected improvements, the respondents most commonly mentioned the production techniques (79.8%), followed by the quality of rice liquor (60.5%), sales price (23.7%), productivity (12.3%), and the cost of rice (4.4%). Among the 91 farmers who expected production techniques to be improved, 54 indicated that the quality of the rice liquor should also be improved simultaneously. These results indicate that rice liquor farmers place emphasis on improving production techniques, while also acknowledging the need to improve the quality of their product.

Table 5 Issues related to rice liquor production

Issues	Answers	% n = 110
Expensive rice	61	55.5
Low quality	45	40.9
Low sales price	24	21.8
Scarcity of fuel (expensive)	22	20.0
Low alcohol volume	20	18.2
Difficulties acquiring sanitary water	17	15.5
Late or incomplete payment by buyer	13	11.8
Production failure	10	9.1
Others	8	7.2
Total	220	

Note: A closed-ended question was used to ask interviewees to identify the two most important issues in rice liquor production. Total respondents: 110. Unavailable answers: 7

Table 6 Improvements farmers expected in rice liquor production processes

Improvements	Answers	% (n = 114)
Production techniques	91	79.8
Quality	69	60.5
Sales price	27	23.7
Productivity	14	12.3
Cost of rice	5	4.4
Marketing and sales	5	4.4
Packaging/bottling	4	3.5
Others	13	11.3
Total	228	

Note: A closed-ended question was used to ask interviewees to identify the two most expected areas of improvement. Total respondents: 114. No answers: 1. Unavailable answers: 2

Table 7 shows the keywords typically used by the farmers to characterize low-quality rice liquor. The most frequently used keyword was "acidic smell/taste" (37.9%), followed by "burnt smell/taste" (22.0%). Other frequently used words included "watery taste," "spoiled smell/taste," "stimulus smell/taste," "cloudy," and "addition of industrial alcohol."

Table 8 compares the sales prices and number of production failures of the 45 farmers who answered that "quality" was one of the most important issues with those of the 65 farmers who did not in Table 5. The sales price of rice liquor for the former was 1,495 R per liter, which is 6.7% lower than the sales price for the latter. The former tended to experience more production failures. On average, they experienced failures 12.2 times per year, whereas the latter experienced failures 8.6 times per year. These results show that the farmers who experienced more production failures tended to recognize the poor quality of their products and, as a result, sold their rice liquor at a lower price.

Table 7 Characteristics of low-quality rice liquor

Characteristics	Frequency[1]	%
cidic smell/taste	67	37.9
urnt smell/taste	39	22.0
Vatery taste (no smell/taste)	23	13.0
poiled/bad/strange smell/taste	13	7.3
timulus smell/taste	8	4.5
loudy	7	4.0
ddition of industrial alcohol	6	3.4
thers	14	7.9
Total	177	100.0

Note: The question aimed to identify the characteristics of low-quality rice liquor, as perceived by the farmers. Overall, 102 out of 117 respondents provided answers; the keywords were mentioned a total of 177 times. Fifteen respondents had no opinion. [1]Frequent use of keywords in response to an open-ended question.

Table 8 Comparison of the operational status between the farmers who answered that quality was an important issue and those who did not

Farmers' recognition of the poor quality as an important issue	Farmers who answered [1] (n = 45)	Farmers who did not answered [2] (n = 65)	Sig. [3]
Sales price (Riel)/L	1,495	1,592	0.15
Production failures (times)/year	12.2	8.6	0.26

Note: [1] Farmers who answered that "quality" was an important issue in Table 5.
[2] Farmers who did not answer that "quality" was an important issue in Table 5.
[3] The Mann–Whitney test was used to compare the averages between the two groups.

Comparisons of the income structures between the rice liquor farmers and non-rice liquor farmers revealed that the rice liquor farmers mainly depend for income on agricultural activities such as rice liquor production and pig rearing, whereas non-rice liquor farmers depend for income on non-agricultural activities such as off-farm business enterprises, labor work, and remittances from family members living elsewhere. However, producing rice liquor is not very profitable, and around 30% of rice liquor farmers faced deficits in their rice liquor business. Improving the economic benefits of producing rice liquor may help economically uplift rice liquor farmers.

Analysis of the economic status of the rice liquor farmers revealed the key factors that cause deficits in their rice liquor businesses. These factors included the low sales price of rice liquor, high cost of rice, and low productivity, such as more volume of raw rice, less volume of product, and higher rate of production failure.

Rice liquor farmers in rural areas expected improvements in the production techniques used and in the quality and productivity of liquor that they produce. Improving the quality of rice liquor may also enable the farmers to increase their sales price and reduce the frequency of production failure. Gaining more experience in terms of technique and management could improve the operational status of rice liquor farmers who are currently in a deficit in their business.

Thus, modifying production techniques to improve the quality and productivity of rice liquor and to reduce the rate of production failure are key strategies to improve the economic benefits of rice liquor production. Preventing production failures and improving productivity would directly decrease the costs and increase profitability. Solving the issues during fermentation and distillation that the farmers had noted could contribute to reducing production failures and improving the quality of their liquor by reducing low-quality characteristics such as an acidic or burnt smell/taste. If farmers had confidence in the quality of their product, they could increase its sales price, which would also increase their revenue.

CONCLUSION

This study has identified the factors that lead to deficits in the rice liquor business in rural areas of Cambodia. Technical modifications to improve the quality and productivity of rice liquor, and to reduce the likelihood of production failure, are key strategies to increase profitability.

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Research article

Evaluation of Bacterial Contamination level in Pickles Sold at Wet Market in Cambodia - Part 1- in case of the samples from Kampong Cham and Phnom Penh

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Abstract Agriculture is the main industry in Cambodia and home-made agricultural products for local Khmer people are commonly sold at wet markets. However, food poisoning and food-related diseases frequently occur due to these home-made products. The improper handling of food by vendors, inadequate storing conditions, and cross-contamination risk while on display, were observed when inspecting wet markets. Sanitary conditions in the wet markets were poor and the food handlers seemed to treat food based on their personal experience. In this study, we aimed to investigate the hygiene level of food products sold in wet markets in Cambodia. In Kampong Cham, a typical small town, processed foods are consumed in the local area and are also transported to large cities, like Phnom Penh. Pickled vegetables, which are a popular ready-to-eat food in Cambodia, were selected and assessed for microbial contamination. A total of 17 pickles were collected from the local market in Kampong Cham and we measured the Brix value, salt concentration, and pH in these samples. Adenosine triphosphate (ATP) concentration was also measured, because the amount of ATP

in a food sample indicates the approximate microbial contamination level. The five samples with the highest ATP values were used for a quantitative evaluation of microorganism contamination. In addition, five other samples with relatively low ATP concentrations were tested for comparison. An assessment of colony number and morphology indicated that nine of the samples showed initial putrefaction or putrefaction. There was one coliform-positive sample. Similarly, three pickles purchased in Phnom Penh showed putrefaction and two samples from these three pickles were coliform-positive. These results indicated that food sanitary conditions are unsafe and there is a critical need for improving food safety at wet markets in Cambodia.

Keywords food safety, contamination, wet market, pickles

INTRODUCTION

Agriculture is the main industry in Cambodia and home-made agricultural products for local Khmer people are commonly sold at wet markets. However, food poisoning and food-related diseases occur frequently due to these home-made products. Many consumers are not aware of the likelihood of spoilage of the purchased product when it is stored at an unsuitable temperature for a long period (Sanlier, 2009; Odeyami et al., 2019). Therefore, food handlers and service employees have a responsibility to provide safe food products. However, the lack of personal hygiene consciousness is a common cause of foodborne illness (Taulo et al., 2009). There are several reports describing a low level of knowledge regarding food hygiene among food handlers (Osaili et al., 2013; Baluka et al., 2014; Emmanuel et al., 2015). In Cambodia, the major reason for foodborne illness is that the vendors have little knowledge of food hygiene and safety. Large-scale foodborne outbreaks are monitored by event-based surveillance in Cambodia, but there are no formal statistics regarding individual food poisoning cases (Vandy et al., 2012). In addition, most foodborne diseases that occur at home are under-diagnosed and/or under-reported (Redmond et al., 2003; Keegan et al., 2009; Vrbova et al., 2012). Therefore, the current status of hygiene conditions in Cambodia requires clarification. Here, we aimed to evaluate the hygiene conditions of the food sales environment and food products used by the local Khmer people. These inspections will lead to practical ways of improving food safety.

Pickles are a very common ready-to-eat food in Cambodia. There are many types of vegetables used to make pickles. The basic procedure for making pickles is to wash the vegetables and then add sugar, salt, and other ingredients, such as fish sauce, soy sauce, garlic, chili, and rice. Most pickles stored in jars are placed in the sun or in a room at ambient temperature for 1 to 4 days. Some of these pickles are fermented spontaneously by lactic acid bacteria (Chrun et al., 2017). Although fermentation increases the shelf-life and the nutritional value of the product, the raw materials can be sources of microbial contamination. Therefore, these home-made fermented foods are often risky (Anal et al., 2019) and food poisoning incidents are often caused by these pickled products. Since these pickled products are consumed daily, they can be a critical hazard if not prepared hygienically. Investigating the quality of pickled products requires the local Khmer people to change their way of thinking about food safety.

Kampong Cham (KPC) is a typical small town and the food products produced there are consumed in the local area and also transported to large cities like Phnom Penh (PP). Pickled vegetables, which are a popular ready-to-eat food in Cambodia, were selected and examined for microbial contamination.

OBJECTIVE

The objectives of this study were: 1) to investigate the safety levels and simple chemical properties of pickles sold in the wet market in Cambodia, 2) to discuss the cause of the unsanitary conditions of these samples.

METHODOLOGY

In this study, we assessed the safety conditions of food and performed bacterial contamination inspections of pickles sold at wet markets in Cambodia.

Market Inspection

The market inspection was conducted through observation of equipment, facilities, and displaying and storage condition of products. The results of the evaluation of these conditions were ascertained by asking to seller.

Food Samples used in this Study

Popular pickled and fermented vegetables were collected from local wet markets in KPC in August, 2018. The products we selected by randomly but only the products from the vendors who are able to tell the detailed information such as raw materials, shelf life and the process from the production to selling. In total, 17 food samples were purchased from four vendors at three different wet markets. In PP, three food samples were purchased at a wholesale market. The food samples used in this study are shown in Table 1. The properties of all food samples were measured within 2 hours after purchasing. Ten KPC samples selected for bacterial inspection were placed in a sterilized storage bag and kept at 4 ℃ for 7 days until examination. PP samples were kept for 6 days under the same conditions as the KPC samples.

Measurement of Food Properties

The sugar and salt content and pH of foods affect microbial growth and these values can be indicators of the preservability of the food. We measured Brix sugar content (soluble solids content), salt content, and pH of food samples using a Brix refractometer (Atago, Tokyo, Japan), a salt meter (Horiba, Kyoto, Japan), and a pH meter (Horiba), respectively. ATP content is an approximate indication of the microbial contamination level of food samples. The standard ATP content value required to satisfy the sanitary conditions of food-handling rooms and equipment is 36 RLU. Therefore, samples showing greater than 100 RLU were selected as candidates for microbial investigation. Some samples with lower ATP content were also investigated for comparison. ATP content was measured using a luminometer and an ATP assay kit (SystemSURE Plus; Nitta, Osaka, Japan).

Sample Preparation and Bacterial Detection by Pour Plate Method

Ten grams of food sample was mixed with 90 mL of saline containing 0.1% peptone in a sterilized storage bag. To make a homogeneous suspension, the sample was homogenized using a stomacher. A series of sample dilutions was used for the detection of general viable bacteria, using standard agar medium and coliform bacteria, using desoxycholate agar medium. The solidified plates were incubated at 35 ℃ for 48 hours.

RESULTS AND DISCUSSION

Inspection of Wet Markets in Kampong Cham

To evaluate the hygiene level of food eaten on a daily basis in Cambodia, we inspected wet markets in KPC in August, 2018. Most food products were stored at room temperature and therefore, those products that do not have stable preservability at room temperature were susceptible to deterioration. In the wet markets, retailers displayed their products close together and nearly all pickled products were stored in a plastic bin at room temperature. The celling and the lights of the market were partly covered with dust and some unattended raw garbage was observed in the passage. Because pickles

were displayed without a lid, flies swarmed around them. From these inspection results, the wet market did not appear to have appropriate conditions for storing food products.

When most vendors served the pickles into a takeout bag, they did not usually use gloves, but served by bare hand. The risk of cross-contamination was also considered to be high for various reasons. For example, cross-contamination could occur between pickled products and other raw products and utensils, which can harbor microbes. The accumulation of waste and the manner in which it was disposed and stored may also result in the transport microbes and may lead to food product contamination. Although vendors decided on an approximate expiration date, unsold products were stored at room temperature. The hygiene conditions of the wet market meant that the food being sold was highly susceptible to microbial contamination.

From the inspection of the wet market, we concluded that the food products being sold were not handled in a hygienic manner. Therefore, we performed an assessment of food contamination levels in pickle products from the wet market.

Chemical Properties of Pickles from KPC and PP Markets

Popular pickle products were selected and examined for quality and safety. Seventeen pickle samples were purchased at the local wet markets in KPC and three pickle samples were purchased from a wet market in PP. These samples were measured for Brix value, salt concentration, pH, and ATP content immediately after purchase. The samples included several types of pickles. The Brix values ranged from 5.7 to 49.5 °Bx and salt concentration ranged from 1.4 to >25%. The pH values ranged from 3.6 to 5.2 (Table 1).

Table 1 Chemical properties of pickles from KPC and PP markets

Region	Vendor	Sample No.	Product name	ATP (RLU)	Brix	pH	Salt (%)
Kampong Cham	A	a-1	Young Pickled Onion	5	33.5	3.7	8.1
		a-2	Slice Fermented Cucumber	4	32.6	4.2	5.5
		a-3	Fermented Cucumber	5	30.8	4.6	12
		a-4	Young Pickled Cucumber	378	10.7	4.3	3.8
		a-5	Salty-sweet Raddish	94	16.0	5.2	5.6
	B	b-1	Young Pickled Onion	21	31.8	3.6	7.8
		b-2	Young Pickled Cucumber	542	40.9	4.3	1.4
		b-3	Salty-sweet radish	91	25.9	5.2	5.8
		b-4	Fermented Cucumber	2	43.0	4.0	13
		b-5	Fermented Green Mustard	184	16.9	3.6	3.0
		b-6	Fermented Ginger	4	31.4	4.0	8.3
		b-7	Fermented Papaya	400	49.5	4.9	9.1
		b-8	Fermented Mustard	64	5.90	3.9	-
	C	c-1	Fermented Papaya	148	48.3	4.3	9.6
		c-2	Fermented Small Mustard	212	9.80	4.2	3.2
	D	d-1	Fermented Sprout	5	14.3	3.9	4.4
		d-2	Fermented Cabbage	1	16.8	4.0	3.8
Phnom Penh	E	p-1	Fermented cucumber	1	40.5	4.1	7.2
	F	p-2	Fermented green mustard	1,882	5.70	4.0	>25
	G	p-3	Fermented green mustard	201	6.60	-	>25

Generally, most bacteria required a minimum water activity (a_w) of 0.88-0.91, most yeasts require a minimum a_w of 0.88 and regular molds need an $a_w < 0.88$ (Matthews, et al., 2017). The theoretical

amounts of salt and sugar required to achieve an a_w value of 0.88 (salt) and 0.92 (sugar) are 17.8% and 62.6%, respectively. The minimum and maximum ATP content values were 1 and 1,882 RLU, respectively, with 55% of food samples showing ATP content values greater than 36 RLU.

Microbial Contamination Level of Food Samples from KPC and PP Markets

Of the 17 food samples from the KPC market, 10 were examined for general viable bacterial counts and for coliform bacteria (Table 2). Four samples from the KPC markets and two samples from the PP market had bacterial counts greater than 7.00 $\log_{10}$ colony-forming units (CFU)/g. These samples showed initial putrefaction and they were not suitable for consumption. Moreover, after observing the colonies on the detection plates, 12 samples were found to contain various unwanted microbes. One sample from the KPC market and two samples from the PP markets were found to be coliform-positive. Generally, coliform bacteria are not able to grow at pH values less than 4.0 (Besser et al., 1993; Zhao et al., 1994), but some *E. coli* strains are reported to grow even at pH 3.8 (Presser et al., 1997; Zhao et al., 1993). The pH values of the coliform-positive samples were 4.1 and 4.0 for samples p-1 and p-2, respectively. It was not clear if *E. coli* could proliferate under these pH conditions, but the contamination with coliform bacteria was considered to have occurred during the preparation of these products. The pickle samples with lower salt concentration, such as a-4, b-2, and c-2, tended to show higher $\log_{10}$ CFU/g values. However, other samples with high salt and sugar concentrations also contained unwanted microbes. The result of Table 2 showed that 55% of the sample from the KPC market and all samples from the PP market were not enough microbial quality to eat. Taking into consideration our inspection results, it is assumed that some steps lead to the contamination. The causes of contamination are presumed by raw materials, the process of food processing, storage condition. These steps might have contained complicated factors and there may multiple routes of the contamination.

Table 2 Microbial contamination level of food samples from KPC and PP markets

	Sample No.	$\log_{10}$ CFU/g	Coliform
Kampong Cham	a-1	3.36	Negative
	a-4	7.77	Negative
	b-2	8.00<	Negative
	b-3	3.30	Negative
	b-4	3.68	Negative
	b-7	5.48	Positive
	b-8	6.88	Negative
	c-1	6.27	Negative
	c-2	8.00<	Negative
	d-1	7.00	Negative
Phnom Penh	p-1	4.06	Positive
	p-2	7.18	Positive
	p-3	7.14	Negative

CONCLUSION

In this study, we evaluated the hygiene conditions of local wet markets in KPC and investigated the safety level and chemical properties of pickled products sold at wet markets in KPC and PP. The pickle samples were found to be highly contaminated with unwanted microbes and these products were unsuitable for consumption. This result strongly suggested that the principle cause of food

contamination is improper food handling. In Cambodia, food handlers and vendors seem to lack sufficient knowledge of food safety and do not have the opportunity to practice safe food handling. Food safety education is considered to be one of the challenges for the future to reduce the incidence of food poisoning.

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Research article

Evaluation of Bacterial Contamination Levels in Pickles Sold at Wet Market in Cambodia -Part 2- Detection of Several Food-poisoning Bacteria of 48 samples from Phnom Penh

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Abstract Some pickles transported from the local province are sold in the wet markets of Phnom Penh, Cambodia. Therefore, products sold in Phnom Penh can be considered representative samples that reflect the approximate levels of bacterial contamination in the food supply chain of Cambodia. In this study, we conducted a microbiological inspection of the food samples from Phnom Penh to investigate the seriousness of the unsanitary conditions of food products. Eight kinds of pickles were purchased from three wholesale markets one week apart on two separate occasions. A total of 48 samples were used for microbial testing, and the values of Brix, pH, and salt content of these samples were measured. Although all food samples were purchased from the same markets and vendors, several pickles showed different results in the measured values between the first and second purchases. To determine the contamination level of the pickles, we targeted general viable bacteria, coliforms, fungi, *Salmonella*, *Staphylococcus aureus*, and *Bacillus cereus*. The total number of microorganisms detected by the aerobic plate count showed that 15 of 48 samples contained more than 7 $\log_{10}$ CFU/g of sample. Pickled onion and mustard showed relatively higher number of microorganisms compared to other products. Of the 48 pickles, 58.3% were

coliform positive, 41.7% of the samples were *Salmonella* positive, and 83.3% and 37.5% were *S. aureus* and *B. cereus* positive samples, respectively. These results indicate that the products from the wholesale market of Phnom Penh are significantly contaminated with bacteria. In general, food contamination result from raw materials, cross-contamination, and poor water quality. Thus, it is important to educate food handlers regarding the practical knowledge to ensure proper food sanitation practices. The results of this study will be useful to reveal the cause of food contamination and to develop appropriate countermeasures.

Keywords food contamination, food poisoning bacteria, wet market, pickles

INTRODUCTION

Pickles are ready-to-eat (RTE) products and are very popular to Khmer people in Cambodia. However, due to the absence of heat sterilization prior to consumption, the safety of the products is a major concern. Our previous study had found that several pickles sold at the wet markets of Kampong Cham and Phnom Penh (PP), Cambodia were unsanitary. In addition, the hygiene practices of the local wet market were very poor, which subsequently lead to food contamination. We speculate that these unsanitary conditions of food and food-processing and the selling environment were derived from the food handlers who had limited awareness and knowledge on food hygiene.

The vegetables that are often the raw material for pickled foods can harbor pathogens such as *Escherichia coli* and *Salmonella* (Francis, 1999; Matthews, 2017; Skočková, 2013). Oliveira et al. (2011) reported that there were *Salmonella* and thermotolerant coliforms in RTE vegetables. Further, there are several kinds of food spoilage microbes and foodborne pathogens that account for the majority of foodborne diseases. The World Health Organization reported that the leading causes of foodborne deaths included *Salmonella* and enteropathogenic *E. coli* (WHO, 2015). *B. cereus* is a well-known food poisoning bacteria. *B. cereus* has caused food-borne outbreaks via a large variety of foods in many countries (Tewari, 2015). *S. aureus* is a ubiquitous bacterium that causes potentially fatal infections (Kadariya, 2014). To assess the safety and quality of food products in Cambodia, the information on the actual hygiene practices for food products served to local Khmer people is very important. However, scientific reports on food safety in regards to the pickle products in Cambodia are nearly absent except for one report by Chrun et al. (2017). Therefore, it is necessary to accurately assess the microbiological safety of food products in Cambodia. In order to determine the food hygiene level in Cambodia, we investigated the major foodborne pathogens and food spoilage microbes in pickled products. The level of microbe contamination in samples we tested reflect the sanitary conditions of the wet market. In this study, we investigated the pickle products sold in PP. Because some products are transported from the local province to PP, the products sold in PP represent a model of the food supply chain in Cambodia. Due to the large population of PP, microbial food contamination leads to foodborne disease outbreaks.

OBJECTIVE

The objectives of this study were 1) to analyze the current status of food and microbiological quality of pickles sold in PP, 2) to assess the substantial food hygiene problem in Cambodia.

METHODOLOGY

Evaluation of the Quality of Pickle Products

Eight kinds of common pickle products were purchased from three major wholesale markets of PP. The popular pickle products were selected based on interviews with Khmer people. They were collected in March, 2019. In the following week, the same pickles were purchased from the same shops. In total, 48 samples were collected and used in this study (Table 1). The samples were stored at 4 °C for one day. The values of Brix, salt concentration, and pH of the samples were measured.

Table 1 Pickles sample used in this study

Market	Sample	Product name	Sample	Product name
A / B / C	A	Fermented papaya (sliced)	E	Pickled mustard (small)
	B	Fermented cucumber	F	Pickled cucumber
	C	Pickled young onion	G	Sweet salty radish
	D	Pickled mustard (big)	H	Kong chay

Microbiological Examination of Pickle Products

Ten grams of the food sample was mixed with 90 mL of Maximum Recovery Diluent (Merck KGaA, Darmstadt, Germany) solution in a sterilized storage bag. To make a homogeneous suspension, the sample was homogenized by a stomacher. After stomaching, 1 mL of the sample suspension was mixed with 9 mL of Maximum Recovery Diluent solution in a sterile tube. The serial dilution samples were prepared and used for testing. For the detection of *S. aureus* and *Salmonella*, Buffered Peptone Water (Merck KGaA, Darmstadt, Germany) solution was used for sample preparation. The standard agar medium (AS ONE, Osaka, Japan) was used for the general viable count. Desoxycholate agar medium (AS ONE, Osaka, Japan) was used for the detection of coliform. Potato Dextrose Agar medium (AS ONE, Osaka, Japan) was used for fungi. CHROMagar™ Salmonella medium (KANTO CHEMICAL, Tokyo, Japan) was used for *Salmonella*. Mannitol salt agar medium with egg yolk (KANTO CHEMICAL, Tokyo, Japan) was used for *S. aureus*. BACILLUS CEREUS AGAR BASE (KANTO CHEMICAL, Tokyo, Japan) with Oxoid Polymyxin B Supplement (KANTO CHEMICAL, Tokyo, Japan) and egg yolk was used for *B. cereus*. 10 μL of the dilution samples aliquoted onto plates. For general viable counts and the detection of coliform, *S. aureus*, plates were incubated at 35 ℃ for 48 hours. For the detection of *Salmonella* and *B. cereus*, plates were incubated at 35 ℃ for 24 hours. For the detection of fungi, plates were incubated at 30 ℃ for 5 days. All experiments were conducted three times independently.

RESULTS AND DISCUSSION

Evaluation of the Quality Variation of Pickle Products

Eight kinds of popular pickle products for local Khmer people were selected and purchased from three major wholesale markets. These 24 food samples were the first samples used in experiments. To examine the quality variation of the products, the same products from the same shop were purchased in the following week. In total, 48 samples were collected and used for the experiments.

To evaluate the quality of pickle products, Brix, salt concentration, and pH value were measured for the pickle products. Three samples were more than three times different in Brix values between the samples purchased on the first versus second weeks. Seven samples were more than 1% different in salt concentration values. Three samples varied in pH values greater than 1.0. The fact that the different values were obtained between the same pickle products showed the quality of pickle products were unstable and/or the way of food processing was varied (data not shown).

Contamination and Spoilage Level of Foodborne Pathogen and Microbe in Pickle Products

All samples were subjected to microbiological investigation. We investigated the generally viable microbes, coliform, fungi, *Salmonella*, *S. aureus,* and *B. cereus* to determine the food contamination and spoilage levels. The total number of generally viable microbes of 48 samples is shown in Table 2. Fifteen samples were over 7 $\log_{10}$ CFU/g, indicating initial putrefaction. The samples from market B and C had relatively higher total CFU than those from market A. The sample C, pickled young onion, sample D and E, and pickled mustard showed a higher number (6 $\log_{10}$ to 8 $\log_{10}$) of CFU (data are not shown).

Table 2 Total number of general viable microbes in pickle products

$\log_{10}$ CFU/g	Market					
	A		B		C	
	1st sample	2nd sample	1st sample	2nd sample	1st sample	2nd sample
< 3	1	1	1	2	0	1
4	2	1	1	0	0	1
5	3	3	2	1	1	1
6	0	2	3	1	3	2
7	1	1	1	3	2	2
8	1	0	0	1	2	1

Next, we investigated major food spoilage microbes and food pathogens. Results are shown in Table 3. Coliform is an indicator of whether or not the food was handled in a proper manner. Coliform inhabit the human intestinal tract, the presence of them means likely fecal contamination (Madigan, 2019). As a result, the total contamination rate of coliform was 58.3%. According to Ceuppens (2014), the existence of coliform was correlated to the presence of *E. coli* and a sufficient amount of *E. coli*. More than half of the pickles were coliform positive and had a significant risk of including pathogenic *E. coli* such as EHEC.

Microbial spoilage of fresh vegetables is often caused by fungi (Madigan, 2019) that are able to survive at lower a_w conditions. So, the contamination by fungi was examined. The total rate of contamination was 68.8%.

Salmonellosis is very common for bacterial food infection. This disease is typically caused by *Salmonella* and *Salmonella*-contaminated food and animals. Of the first 24 samples, two samples were *Salmonella* positive and in the second batch of samples, 18 samples were positive. In total, 41.7% of pickles were contaminated by *Salmonella*. Combined with the wet market conditions shown in our previous study, *Salmonella* contamination was most likely caused by cross-contamination of chicken and egg products and by *Salmonella*-carrying animals such as dogs that come into contact with the food.

S. aureus cause food poisoning and the produced toxins by *S. aureus* cause gastrointestinal symptoms. These toxins can be superantigens that lead to lethal toxic shock syndrome. The presence of *S. aureus* (83.3%) was surprisingly high in our tested samples. Chrun et al. (2017) reported that the contamination rate of fermented vegetables collected from the wet market in Phnom Penh was less than 10%, but the samples used in this study exceeded 80%. *S. aureus* can grow in both aerobic and anaerobic conditions and in many foods. *S. aureus* is often carried by humans. The interior of nostrils and skin are associated with *S. aureus* and a pus-forming wound becomes a frequent cause (Madigan, 2019; Matthews, 2017). In our previous study, we observed that the vendors handled their products with bare hands and utensils that were left out. Most staphylococcal contamination is caused by humans during food preparation (Matthews, 2017). It is assumed that the inappropriate manner of food handling increases the chance of food contamination.

B. cereus is widespread in nature and is frequently isolated from growing plants and soil. So, this organism is easily spread if there is no equipment to prevent dust and dirt from the outside. Foodborne illness by *B. cereus* is of two types—the emetic form results in vomiting and the diarrheal form results in diarrhea. Our results showed that 37.5% of the total samples were *B. cereus* positive. Upon microbiological examination, there were large variations in between different pickle products and even within the same pickle products. Some pickles were considered to contain enough sugar and salt to prevent spoilage; however, most products had some kind of microbiological hazard. Our previous study revealed that the wet market was in a condition where cross-contamination can easily occur. The cause of bacterial contamination could be from raw materials and cross-contamination. The water used for food processing and cleaning may also be a source of foodborne pathogens (Steel, 2004).

Table 3 The rate of microbiological contamination in pickle products

Microbial sp.	Number of positive / Number of total		
	First sample	Second sample	Total rate (%)
Coliform	14/ 24	14 /24	58.3
Fungi	13 / 24	20 / 24	68.8
Salmonella	2 / 24	18 / 24	41.7
S. aureus	19 / 24	21 / 24	83.3
B. cereus	12 / 24	6 / 24	37.5

CONCLUSION

In this study, we investigated the level of food spoilage and the rate of food contamination of pickle products. The results indicated that significantly poor sanitary conditions and unsafe food products were provided at the wholesale market in PP. It is necessary that food handlers as well as consumers receive practical knowledge on food hygiene to prevent the spread of bacterial food contamination. In the future, we will focus on the cause of food contamination and give countermeasures against it.

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Research article

Study of the Relationship between different Soil Properties in Agricultural Fields, Kyee Inn Village, Myanmar

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Abstract An understanding of the physical and chemical properties of soils is necessary due their relationship with productivity in agricultural fields. A study was conducted in 480 hectares of agricultural fields at Kyee Inn, Pyinmana Township, Naypyitaw, Myanmar to determine the relationship between different soil properties (bulk density, soil moisture, soil pH, cation exchange capacity, organic matter, total nitrogen, total phosphorus, and total potassium) using Geographic Information Systems (GIS). Soil samples were collected on a grid method (300 m × 300 m) from three places in each grid at a depth of 0-15 cm. Global Positioning System (GPS) was used to determine the coordinates of sampling points. The collected samples were composited to 80 soil samples and analyzed. To compute the relationship between soil properties, simple linear correlation was performed using statistix 8th version. Finally, the relationship among the soil properties was shown by overlay mapping in Arc Map 10.5 with the spatial analytical function of ArcGIS software. The results revealed soil pH was significantly and negatively correlated with total nitrogen (r=-0.412), and significantly and positively correlated with total phosphorus (r= 0.248). Total potassium content was highly significant and positively correlated with soil moisture (r=0.782). The relationships that are commonly found among soil properties are evident in this study with a positive correlation of soil organic matter and total nitrogen (r=0.058), a negative correlation of bulk density with soil organic matter(r=-0.191) and soil moisture (r=-0.066), a positive correlation of cation exchange capacity with total potassium (r=0.204), and a negative correlation of cation exchange capacity with bulk density (r=0.018), but these were not statistically significant. The observed information from this study can provide a clear understanding of the relationship among soil properties, which positively or negatively affect nutrient availability.

Keywords GIS, GPS, relationship among soil properties

INTRODUCTION

The overall productivity and sustainability of a given agricultural sector are functions of fertile soils and productive lands (Buol et al. 2003). Food productivity and environmental quality is dependent on the physical and chemical properties of soil, so it is very important to have a detailed knowledge of properties of soil (Tale and Ingole, 2015).

The productive capacity of Myanmar soils is an increasing concern. Many years of poor agriculture and land management practices has led to serious land degradation. As elsewhere, the agricultural sector's performance in Myanmar is highly dependent upon soil quality (IFDC, 2018). Soil quality is controlled by the physical, chemical and biological properties of soil and their interaction (Papendick and Parr, 1992). Therefore, it is important to maintain soil health for food security and to allow for increasing agricultural production. An understanding of physical and

chemical conditions of any soil is essential for the proper implementation of other management practices (Tale and Ingole, 2015). Most physical and some chemical characteristics of soils allow a ranking, indicating whether an area has a high potential for agricultural production (Lelago and Buraka, 2019).Therefore a physico-chemical study of soil is very important because both these properties affect soil productivity (Tale and Ingole, 2015).

OBJECTIVE

The main objective of this research is to determine the relationship between different soil properties in the agricultural fields of the study area.

METHODOLOGY

Site Description and Soil Sampling

The study was conducted in agricultural fields of Kyee Inn Village, Pyinmana Township, situated in mid-Myanmar. The study covers a total area of 480 hectares, situated between 19°42'30"-19°43'40" N and 96°13'30"-19°15'30" E (Fig 1.). This area receives a mean annual rainfall of about 1420 mm and an average temperature of 26.8°C and monsoon rice and pulses are the main crops. Soil sampling was on a grid method (300 m × 300 m). There was a total 80 grid plots, and soil samples were collected from three places for each grid at 0-15cm depth using GPS to determine the coordinates of the sampling points. All samples were taken after the harvest of the previous crops and before the land preparation for the next season to ensure base line conditions for the analysis.

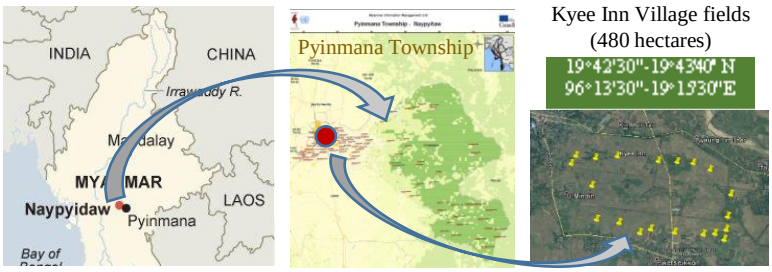

Fig. 1 Location of the study site

Laboratory Analysis

Table 1 Soil parameters and analytical methods adopted for laboratory analysis

	Soil Parameters	Unit	Analytical Methods
Physical	Bulk Density	g cm^{-3}	Core sampler method (Black, 1965)
	Soil Moisture	%	Gravimetric method (Black, 1965)
Chemical	Soil pH	-log[H^+]	1:5 (soil: water) pH meter (Hesse, 1971)
	Cation Exchange Capacity	meq100 g^{-1} soil	Bascomb's method (Bascomb, 1964)
	Organic Matter	%	Walkley and Black method (Walkley and Black, 1934)
	Total Nitrogen	%	Modified Kjeldahl Digestion method(Ohyma et al., 1991)
	Total Phosphorus	%	Molybdivanado phosphoric acid method (Spectrophotometer)
	Total Potassium	mg kg^{-1}	Atomic Absorption Spectrophotometer (AAS) (Flame)

The collected soil samples were composited for each grid. The samples were air-dried, ground, and sieved. The soils' pH levels, organic matter content, cation exchange capacity, bulk density, soil moisture, total content of nitrogen, phosphorus, and potassium were measured. Analysis was done at the laboratory of the Department of Soil and Water Science, Yezin Agricultural University. The analytical methods used for conducting this analysis are described in Table (1).

Statistical Analysis and Overlay Mapping

The laboratory results of all soil properties were subjected to correlation analyses to detect functional relationship among soil parameters using statistix (8^{th} version). Firstly, the interpolation maps were generated using an inverse distance weighting (IDW) method in ArcGIS software version 10.5 and then some of the more significant relationships among soil properties were able to be shown by overlay mapping.

RESULTS AND DISCUSSION

Correlation Matrix of Soil Properties

The correlation coefficient values of soil parameters viz; soil pH, cation exchange capacity, bulk density, soil moisture, soil organic matter, total content of nitrogen, phosphorus and potassium were determined for the surface soils (0-15 cm) and are presented in Table (2).

Table 2 Correlation between the different soil parameters under study

	pH	CEC	OM	TN	TP	TK	BD	SM
pH	1							
CEC	0.014	1						
OM	-0.025	0.035	1					
TN	-0.416**	0.145	0.058	1				
TP	0.242*	-0.036	-0.107	0.216	1			
TK	0.047	0.204	0.238*	0.045	-0.217	1		
BD	0.052	-0.018	-0.191	0.092	0.096	-0.161	1	
SM	-0.047	0.352**	0.162	0.182	-0.117	0.782**	-0.066	1

**Correlation is significant at the 0.05 level; **Correlation is significant at the 0.01 level*
CEC: cation exchange capacity, OM: organic matter, TN: total nitrogen, TP: total phosphorus, TK: total potassium, BD: bulk density, SM: soil moisture

Relationships between Soil Parameters

In Figure 2 (a), the correlation coefficient reveals soil pH shows a highly significant but negative correlation with total nitrogen content (r=-0.416). This suggests that pH accounts for about 16.96% of the total variability in total nitrogen. Similarly, with an increase in pH, total nitrogen decreases progressively and vice-versa. In addition to this, with an increase on soil pH by one unit, total nitrogen decreases by 0.098 unit and vice-versa. According to major crops growing in this area, pulses may take much cations and thus may cause lowering soil pH, but growing of pulses on every year may also lead to encourage total nitrogen content by fixing nitrogen of pulses.

Similar results were obtained by Singh and Mishra (2012). Similarly, Khadka et al. (2016) stated that total nitrogen content was significantly and negatively correlated with soil pH. Xue et al. (2013) also reported that the correlation between the soil nitrogen forms and soil pH was negative. However, a significant and positive correlation between soil pH and total nitrogen was obtained by Athokpam et al. (2013), and a non-significant relationship was obtained by Dhamak et al. (2014).

Figure 2 (b) illustrated that soil pH is significantly and positively correlated with total phosphorus (r=0.242). For these parameters, the results are in harmony with the findings of Athokpam et al. (2013). But non-significant correlation between them was observed by Ogaard (1994).

According to the literature, soils with inherent pH values between 6 and 7.5 provide ideal conditions for phosphorus availability, while pH values below 5.5 and between 7.5 and 8.5 may limit phosphorus availability to plants due to fixation by aluminum, iron, or calcium. The observed pH values of this study ranged from 5.48 to 7.58, and therefore, the soil test phosphorus content would be expected to be significantly and positively correlated with this observed pH range.

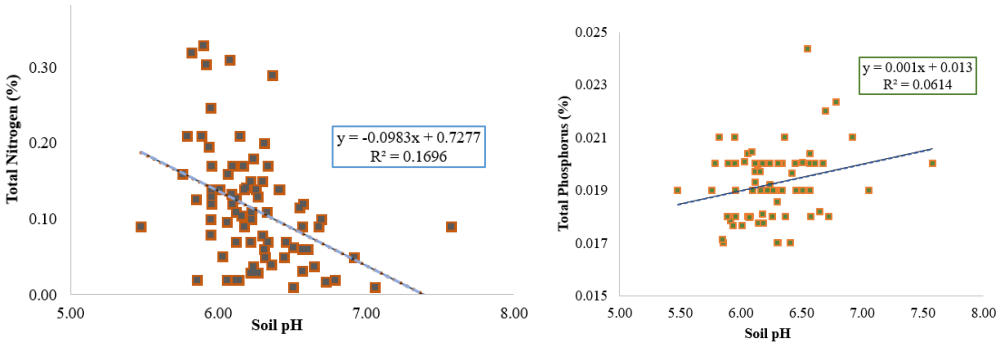

Fig. 2 Relationship between soil pH with (a) total nitrogen and (b) total phosphorus

The total potassium content is positively correlated with soil moisture, to a highly significant level, expressed in the correlation matrix of r=0.782 (Figure 3 a). The results were in conformity with those of Singh and Singh (2004), and Zeng and Brown (2000) who found a positive correlation between moisture content and potassium content in soils. Total potassium also shows a significant positive correlation with soil organic matter and a significant negative correlation with total phosphorus. In addition, it shows a non-significant positive correlation with soil pH, total nitrogen, cation exchange capacity, and a negative correlation with soil bulk density. This means that the total potassium content may increase with increases in pH, cation exchange capacity, soil organic matter, total nitrogen, and may decrease with increases in bulk density and total phosphorus and vice versa.

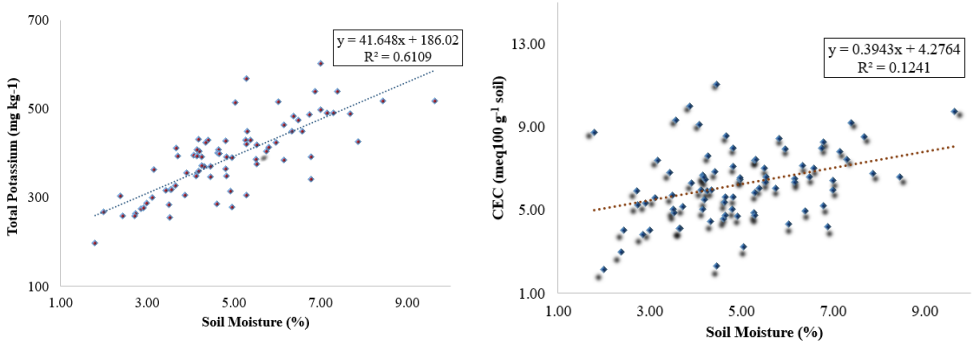

Fig. 3 Relationship between soil moisture with (a) total K and (b) CEC

The commonly found relationships between soil properties is also observed in non-significant correlations, such as the positive correlation of soil organic matter and total nitrogen (r=0.058), the negative correlation of soil bulk density with soil organic matter(r=-0.191) and soil moisture (r=-0.066), and the positive correlation of the soil's cation exchange capacity with total potassium (r=0.204) and the negative correlation of cation exchange capacity with bulk density (r=-0.018). A significant and positive correlation between cation exchange capacity and soil moisture content (r=0.352) is also observed (Table 2 and Figure 3 b). According to topographic position of this area, relatively higher soil moisture content was found on slightly lower elevation of southwest and also northeast portion as located nearby a small stream on this side. The cation exchange capacity and total potassium were obviously increased with high moisture content portions of this area.

The negative correlation between bulk density and soil moisture content suggests two possibilities: that soil moisture content declines as bulk density increases due to less storage space or that soil moisture content is sufficient for the soil to resist compaction (Carter and Shaw, 2002). This

is consistent with studies that have examined bulk density and soil moisture content (Hill and Sumner, 1967). Many researchers (Askin and Ozdemir 2003; Morisada et al, 2004) obtained the relationship between organic matter and bulk density of soils all indicating a strong correlation between them. Bulk density tends to decrease as a soil's organic matter concentration increases (Curtis and Post, 1964).

Overlay Mapping of Significant Relationships of Soil Parameters

Figure 4 (a) and (b) display an overlay map showing significant relationships of soil pH with the total contents of nitrogen and phosphorus in the study area. It can be seen clearly that the areas with higher total nitrogen content correspond to areas largely occupied 'Moderately acidic' soil pHs in the study area and vice versa. The total phosphorus content, however, is positively distributed in all classes of soil pH of the study area. The overlay map of the significant positive relationships of soil moisture content with CEC and total potassium are shown in Figure 5 (a) and (b). It is obvious that the variation of CEC and total potassium is positively coincidental with areas with a higher amount of soil moisture content.

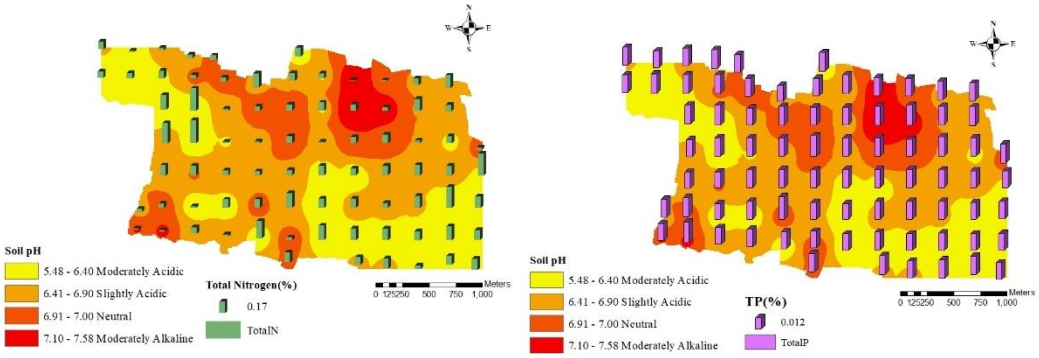

Fig. 4 Overlay Maps of soil pH with (a) total N and (b) total P

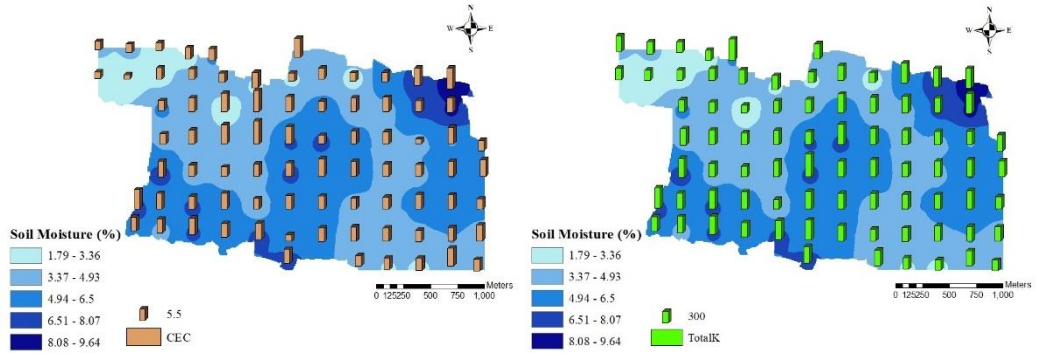

Fig. 5 Overlay Maps of soil moisture with (a) CEC and (b) total K

CONCLUSION

Results from correlation analysis show that many of the soil parameters are interrelated with each other but often these relationships are non-significant. Since this study area occupies agricultural fields and thus some soil properties can be reflected by many practices of crops growing such as tillage systems, application of inputs, cropping patterns and so on. The results of this study have discussed and suggested with farmers as field day for proper implementation of their soil management practices. Finally, this study clearly illustrates that an understanding of soil properties and their inter-relationship, would prove to be useful for the development of an effective soil management plan allowing for efficient utilization of limited agricultural land resources.

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Research article

Monitoring of Crop Plant Height Based on DSM Data Obtained by Small Unmanned Vehicle Considering the Difference of Plant Shapes

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Abstract Unmanned Aerial Vehicle (UAV) has been recognized as a potential tool to obtain spatial information of crop state in small-scale farming fields. The objectives of this study are to assess the availability of UAV photographs to determine the plant height (PH) for three crop varieties (barley, oat, and perilla); and to evaluate the effect on the accuracy of the estimated PH caused by different plant shapes. The UAV photography and ground surveys were conducted weekly from May 31 to September 3, 2019, at the examination field of Obihiro University of Agriculture and Veterinary Medicine. The estimated PH was obtained from the differential value (D_value) of Digital Surface Models (DSMs) generated from UAV photographs through the Structure from Motion (SfM) process. The results demonstrate that the D_value of DSMs produced the highest estimation accuracy (R^2=0.97, *RMSE*=9 cm) for perilla, which is a herb crop with luxuriant spade-shaped leaves, and a moderate estimation accuracy (R^2=0.87, *RMSE*=23 cm) for oat, which is a grain crop making small spikes during the heading time with lanceolate leaves. The estimated PH produced the lowest accuracy (R^2=0.34, *RMSE*=28 cm) for barley, which makes outward spikes with long prickly awns above the ear of grain. However, a higher accuracy (R^2=0.67, *RMSE*=17 cm) for barley was obtained after a lodging of the spikes caused by rain on July 2. Furthermore, the accuracy of the estimated PH increased in both barley and perilla fields after corrected by plant coverage of the field. These findings suggest the D_value of DSMs obtained from UAV photographs can provide an accurate PH estimation for crops with luxuriant leaves like dicotyledons, but comparably less accurate estimation for crops with long and sharp leaves like monocots. Additionally, the elimination of the effect of unrecognizable factors such as long awns and non-plant factors such as the ground can also increase the accuracy of the estimated PH.

Keywords unmanned aerial vehicle, digital surface model, plant height estimation, plant shape

INTRODUCTION

Plant height (PH) is an important indicator for farmland management as it directly relates to crop growth status. However, traditional methods of PH measurement are time- and labor-consuming because of its requirement for mass sampling. In the past decade, the rapid development of

Unmanned Aerial Vehicle (UAV) has provided an efficient, labor-saving, and precise approach to monitor crop biophysical parameters such as Normalized Difference Vegetation Index (NDVI) and Photochemical Reflectance Index (PRI) (Berni et al., 2009). Due to its ability of frequent aero photography, UAV has been also considered a suitable tool for crop PH monitoring. The method to detect crop PH using multi-temporal crop surface models (CSMs) generated with UAV-based imaging has been proved available by Bendig et al. (2013). This method has later been applied in several studies using different crops such as paddy rice (Tilly et al., 2014), summer barley (Bendig et al., 2014), and winter wheat (Lu et al., 2019).

However, no study has yet evaluated the estimated PH for crops with significant differences in plant shapes using UAV photographs taken under same flight conditions, and no study has discussed the effect on estimation accuracy of PH caused by different crop plant shapes. Thus, the objectives of this study are: (1) to determine the PH estimation accuracy for three subjects with different plant shapes; and (2) to evaluate the effect on PH estimation accuracy caused by plant shapes.

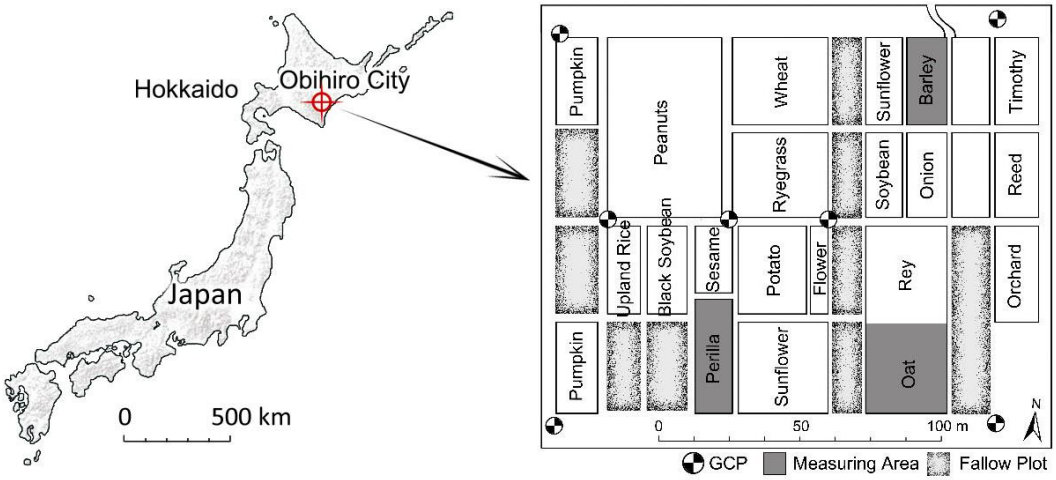

Fig. 1 Position and detail of the study site

METHODOLOGY

Surveys were carried out at the experimental field of Obihiro University of Agriculture and Veterinary Medicine in the city of Obihiro in Hokkaido, the largest and northmost prefecture of Japan (Fig. 1). The experimental field with a spatial extent of 180 m×160 m was divided into 22 small fields (average area: 700 m^2) and was cultivated with 19 different crop varieties. Barley field, oat field, and perilla field were used as the measuring areas to measure PH in this study. To provide accurate position information for the UAV photographs, ground control points (GCPs) were evenly settled at seven positions across the experimental field. Geographic coordinates of the GCPs were taken using a HiPer V RTK-GNSS receiver (TOPCON, Japan).

Photo. 1 Self-made PH measure

The UAV used in this study was a Phantom 4 Pro (DJI). The flights were carried out weekly from May 31 until September 3 (15 times) using an autopilot application known as Pix4D Capture

(Pix4D). The UAV photographs were taken at 50 m above ground level on a flight path of double grid, with both forward and side overlap of 80%. The camera angle was adjusted to 70° from the horizon. Ground surveys to obtain the measured PH were conducted after each flight. Approximately 4-10 measuring points were settled and marked with pink marking tapes at each measuring area. A self-made PH measure was used to obtain the optimal value of PH under natural state (Photo. 1).

The UAV photographs were processed using a structure-from-motion (SfM) software, known as Agisoft Metashape 1.5.1 (Agisoft), to generate GCP-georeferenced DSMs (ground resolution: 5.6 cm) and orthomosaic photos (ground resolution: 1.6 cm). According to the method provided by Bendig et al. (2014), the differential value of DSMs (D_DSM) used for PH generation was calculated by subtracting the bare ground model from the DSM for each survey. The calculation of DSMs and extraction of PH value were conducted using ArcGIS Pro 2.3.1 (Esri). The measuring points marked with marking tapes were determined on the orthomosaic photos, and a circular polygon with a diameter of 20 cm was created at each measuring point. The maximum D_DSM value for each polygon was extracted and used as the estimated PH, which was compared to the measured PH. The coefficient of determination (R^2) and root mean square error (*RMSE*) were used to evaluate the PH estimation accuracy. In addition, within the UAV photographs of a field where the stems of crop were not fully extended, there was a considerable area of ground surface exposed through the leaves that may affect the value of the estimated PH. To find out the effect caused by the exposed ground area, the vegetation cover (VC) of barley field, where the VC increased significantly during the survey period, and perilla field, where the VC changed slightly, were calculated and used for the correction of estimated PH. A raster graphic editor software, Adobe Photoshop Creative Cloud 14.0 (Adobe Inc., USA), was used to extract and tally up the pixels of vegetation within a field plot to calculate the VC.

RESULTS

Figure 2 shows the comparisons of the time series between the measured and estimated PH for the three crop varieties. The measuring surveys were carried out weekly from June 19 until August 15 for barley, June 13 until September 3 for oat, and July 31 until September 3 for perilla. In the barley field, a lodging of spikes caused by rain happened on July 2 and continued until harvest. In the oat field, a soiling, which refers to the cutting of the leaves of crops for green feed in the middle of the growth stage, was carried out on July 24. In the perilla field, a thinning, which refers to the removal some plants of crop to make room for the others, was carried out on July 26. These natural or man-made phenomena were also reflected in the time-series of both estimated and measured PH.

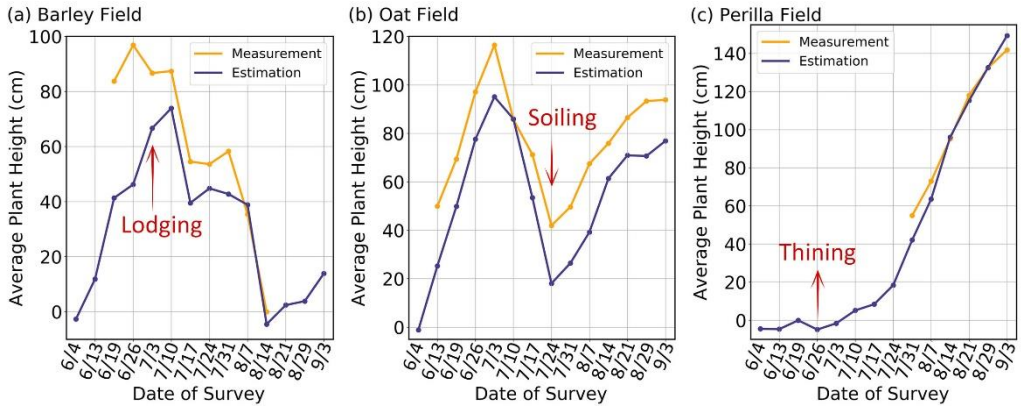

Fig. 2 Comparison of time series between measured and estimated PH

The relationship between the measured and estimated PH for each crop are shown in Fig. 3. A low correlation (R^2=0.43) and an *RMSE* of 27.9 cm were observed in the barley field. A high correlation (R^2=0.87) and an *RMSE* of 23.1cm were found in the oat field. An extremely high correlation (R^2=0.97) and a much lower *RMSE* of 9.2 cm were perceived in the perilla field. In view

of the above, the estimated PH based on DSMs performed most satisfactorily for perilla, which is a dicotyledon crop. Between the other two varieties which are both monocotyledon crops, the estimated PH performed better for oat than for barley.

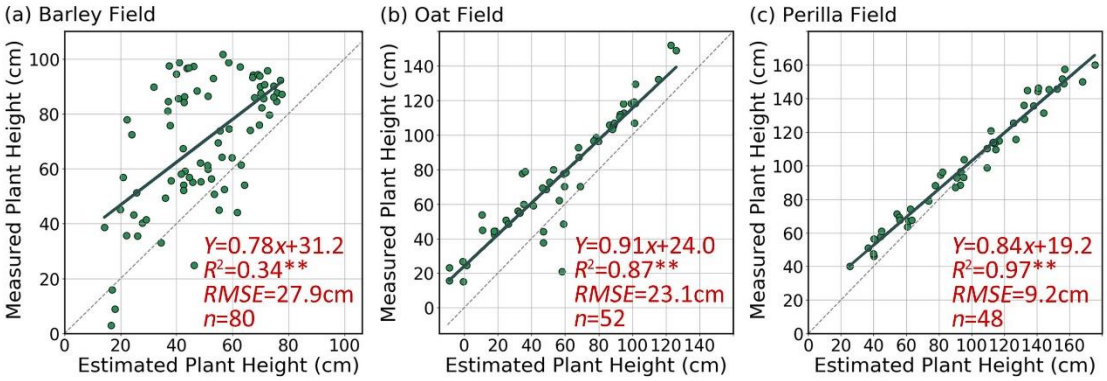

Fig. 3 Relationship between measured and estimated PH

The VC value and the dates of the UAV photographs by which the VC was calculated are shown in Table 1. In the barley field, the VC increased pronouncedly after the lodging from 88.9% (June 26) to 97.1% (July 3), while in the perilla field, the VC increased gradually from 90.4% (July 31) to 100.0% (September 3). The relationship between the measured PH and the estimated PH corrected by VC is shown in Fig. 4. In the barley field, the performance of the estimated PH after correction by VC (R^2=0.57, *RMSE*=20.9 cm) was shown to be more accurate than before correction. In the perilla field, the estimation accuracy was slightly increased (R^2=0.97, *RMSE*=7.9 cm) after it was corrected by VC.

Table 1 Vegetation Cover (VC) during survey period

(a) Barley Field

Date	June 19	June 26	July 3	July 10	July 17	July 24	July 31
VC	87.3%	88.9%	97.1%	98.8%	98.8%	99.2%	95.5%

(b) Perilla Field

Date	July 31	August 7	August 14	August 21	August 29	September 3
VC	87.3%	88.9%	97.1%	98.8%	98.8%	99.2%

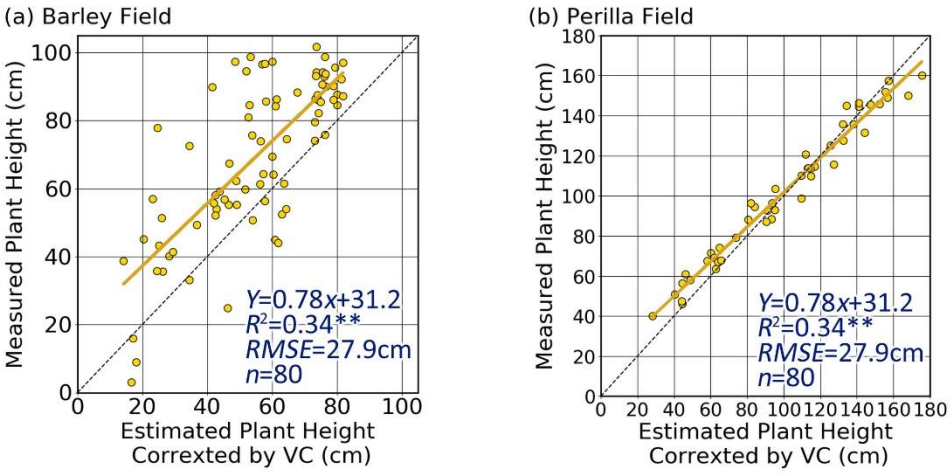

Fig. 4 Relationship between measured and estimated PH corrected by VC

DISCUSSION

The method to manually obtain the optimal measurement of PH under natural state has been a difficult issue due to the variety of PH in real farmland, and the individual difference between measurers (Bendig et al., 2014; Tilly et al., 2014). The problem of determining the representative mean of PH of a field plot was also discussed in an earlier study (Bendig et al., 2014). In addition, it is time- and labor-consuming even for skilled surveyors to set GCPs and obtain their precise coordinates every time before the UAV is flown over the field.

To solve these problems, a self-made PH measure was used in this study to obtain the measurement of PH properly and efficiently. A sliceable plastic plate with an area of 10 cm×20 cm was installed on a 150 cm-long pole, on which a tape measure was stuck (Pic. 1). When measuring the height, the plate was slid down slowly until there were most leaves reached it with the slightest shape changing. Each measurement was carried out at a certain measuring point, which was marked by a 100 cm-long pole (diameter: 0.5 cm) with a pink marking tape bound to it. These marking tapes could be found on the orthomosaic photos and used for the determination of the measuring points. Although there might still be a slight influence caused by a subjective judgement when adjusting the plate, it was expected to improve the accuracy of the measured PH through this method. Furthermore, in order to mitigate the cost of time and workforce caused by GCP settling and measuring, fixed points of GCPs were used in this study. Seven wooden posts (length: 20 cm), each with a nail at the top, were inserted into the ground at different positions in the experimental field. The geographic coordinates were taken once by RTK-GNSS on May 28 and were used for the generation of DSMs and orthomosaic photos ever since.

The comparison between the measured and estimated PH shows that the DSM-derived PH was generally lower than the measured value for barley and oat, which are both monocotyledons. In this study, each pixel of DSM represented the ground surface with an area of approximately 31.4cm^2 . Although the maximum value of D_DSM of the polygon area of a measuring point was extracted, it still represented the average height of several leaves including those in the lower position. Therefore, for crops which has detectable distance among leaves such as monocotyledons, the problem of underestimation should be considered when estimating the PH using DSM data.

Between the two monocotyledons used in this study, the estimated PH of oat performed better than barley. The reason for the low estimation accuracy of barley is considered to be the shape of the spikes. Barley produces peculiar, outward spikes with long, prickly awn (10 cm-15 cm) above the ear of grain. The height of the spikes was included in the measured PH. However, it is considered to be ignored during the DSM generation because it was too small to be recognized. To verify this possibility, the relationship between the measured and estimated PH before and after the lodging of spikes were calculated which are shown in Fig. 5. A low correlation (R^2=0.39, *RMSE*=47.1 cm) was observed before the lodging, while a medium correlation (R^2=0.67, *RMSE*=17.2 cm) was observed after the lodging. The lodging, which is the elimination of the effect of spikes, was helpful in increasing the PH estimation accuracy of the barley plant. Like barley, oat is also a poaceous crop. However, oat produces scattered spikes which have little effect on both measured and estimated PH. This is considered the reason why the DSM data showed a better performance in the PH estimation for the oat plant.

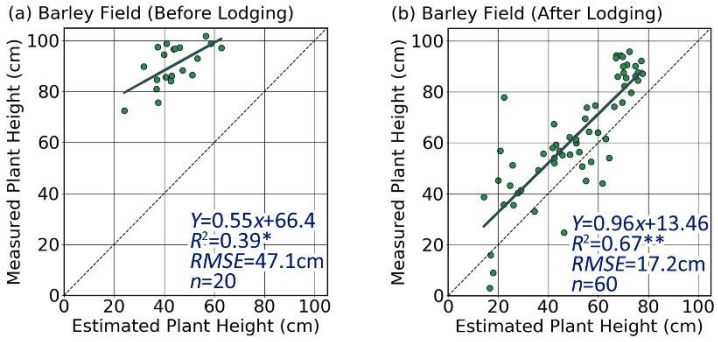

Fig. 5 Relationship between measured and estimated PH before and after lodging

The extremely high accuracy of the estimated PH for the perilla plant is considered to be due to the luxuriant plant shape. Perilla is an erect, frontend crop that can grow to 0.6 m-2.0 m. The leaves are broad shaped with a length of approximately 10 cm-15 cm and grow densely on the stem. There was barely detectable distance among the canopy leaves in the perilla field during the survey period. This characteristic of the plant shape is considered as the reason why the estimated PH for perilla was much closer to the measured PH than the other two subjects, and even became higher than the measured PH at the late stage of the surveys. Although the underestimation problem of PH estimation using DSM has been suggested by many studies (Bendig et al., 2014; Lu et al., 2019), overestimation of the estimated PH caused by the growth of crop has not been observed and discussed yet. Considering this is probably a unique phenomenon of dicotyledon, future studies using other dicotyledon crops such as potatoes, peanuts, and soybean are expected to verify this assumption.

Furthermore, correcting the estimated PH using VC was considered as a feasible method in this study to improve the estimation accuracy. The results showed in Fig. 5 indicate that the accuracy of the estimated PH for both barley and perilla plants increased after they were corrected with VC. VC is, thus, considered a potential indicator for PH estimation using UAV photographs.

CONCLUSION

In this study, the accuracy of estimating PH based on DSM data generated from UAV photographs for three crops with different plant shapes were compared. Although the estimation accuracy for barley was low during the whole survey period, it increased after the elimination of the effect of the spikes. For both barley and oat plants, the estimated PH were lower than the measured PH, because the DSM provided the average height of all factors within one pixel. However, the estimated PH for perilla was more accurate than the other subjects and surpassed the measured PH late in the growth stage due to its luxuriant plant shape. Future study is expected to discuss and verify this difference of estimation characteristic between monocotyledons and dicotyledons. Furthermore, VC was proved to be helpful to increase the estimation accuracy of PH for both barley and perilla plant.

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Research article

Evaluation of Soil Ecosystem Health in Different Farming Systems by Observing Diversity of Soil Arthropods

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Abstract Organic or natural farming practices are known to promote soil fertility as well as biological diversity. Organic matter recycling, multiple cropping and ecological corridors are available as reservoirs for biological control agents such as predators or parasitic insects. These practices allow ecosystem services to reduce the presence of phytophagous insects and microorganisms. The objective of this study is to analyze the effect of the different farming systems on the diversity of arthropods. The sampling of arthropods was performed by pitfall trap method. The traps buried at surface level of the ground were set at 3.5 m intervals for 24 hours in the line of the cultivated crops. In addition to this method, Tullgren funnel method is applied in this study. In the experimental results, there were no significant differences in richness and abundance of observed arthropods. In the natural farming system, taxonomic group of Araneae, Acari and Coleoptera was observed. In the conventional farming system, the group of Formicidae was dominant. Using the Simpson's (inverse) index and Shannon-Weaver's index, the diversity was calculated. The results indicated there was more diversity of arthropods in the natural farming compared to conventional farming system. It is evident that agricultural practices (natural or conventional) may affect the diversity of arthropods within an agroecosystem.

Keywords beneficial arthropods, pitfall traps, pest management

INTRODUCTION

Soil health is associated with biological diversity and stability. Plant and animal diseases outbreaks can be considered as indicators of instability and poor ecosystem health. Therefore, there is likely also to be a link between soil health, the ability of the biological community to suppress plant pathogens, the population density of plant pathogens in soil, and ultimately disease incidence and severity (van Bruggen and Grunwald, 1996). The organic and natural farming is a production system that promotes processes which improve soil fertility and biological activity. Pest population density is related to factors such as climate and population of predators. The climate generates immediate and drastic changes in the population of the pests, but the control through natural enemies is more complex. In a successful biological control of pest, the natural enemy reduces the pest to a level that does not cause harm, but does not eliminate it completely, since the natural enemy requires a minimum population of pest for its survival (Nicholls, 2008). The idea of biological control is to keep the natural community in balance, and unlike chemical control it is safe, selective, efficient and works for long term. Those practices such as buffer zones, rotation and intercropping system, promote biodiversity and it would provide more shelter, food and reproductive possibilities, allowing the natural enemies to establish themselves as a tool for biological control of pests. And these practices also will make the production system more stable and productive in the medium and long term. Therefore, this study focuses on analyzing the richness and abundance of arthropods in two different production systems. By measuring the diversity of arthropods, it could indicate the stability and health of the soil ecosystem of the farms.

MATERIALS AND METHODS

The study was conducted at a natural farm in Saitama prefecture and a conventional farm in Tokyo City, both located in Kanto region of Japan. The difference between them is that the natural farm does not use chemical products and uses a system of rotation and intercropping. Which means that to control pests and diseases they have a complex vegetation structure in the farm to distract insects and prevent them from attacking their production. The macro or meso arthropods were collected using pitfall traps and microarthropods were extracted using Tullgren funnel method. The samples were preserved in 70% ethyl alcohol and were identified at taxonomic order.

Data Analysis

For all the statistical analyses EstimateS 9.1.0 (Colwell, 2013) was used. For estimates of species richness, Abundance based Coverage Estimator of species richness (ACE) was used (Chao and Lee, 1992; Chao et al., 1993). ACE is based on relative abundance data, those species with ≤ 10 individuals in the sample (Chao et al., 1993; Chazdon et al. 1998). Ace takes the form

$$S_{ace}=S_{common}+\frac{S_{rare}}{C_{ace}}+\frac{F_1}{C_{ace}}\gamma^2_{ace} \quad (1)$$

Where S_{common} is number of common species, S_{rare} is number of rare species, C_{ace} is the sample abundance coverage estimator and Υ_{ace} is the estimated coefficient of variation of F_1 for rare species. This estimator has been found to give good results and is highly recommended (Chazdon et al. 1998; Hortal et al. 2006).

And for indices of species diversity, Shannon – Weaver's diversity index (H´) and Simpson´s (inverse) diversity (D) index were used.

$$H' = -\sum_{i=1}^{s}(pi)(\ln pi) \quad (2)$$

Where H' is species diversity index, s is number of species and pi is proportion of the total sample belonging to i th species. Shannon-Weaver's index (H´) considers the relative abundance and number of species and expresses the uniformity of the values of importance across all the species in the sample. In addition, it assumes that individuals are randomly selected, and that all species are represented in the sample (Magurran, 2004).

$$D = \sum\left(\frac{ni(ni-1)}{N(N-1)}\right) \quad (3)$$

Where *ni* is the number of individuals in the *i* th species and *N* is the total number of individuals. As *D* increases, diversity decreases. Simpson's index is therefore usually expressed as 1-D or $1/D$ (Magurran, 2004). This index is heavily weighted towards the most abundant species in the sample, while being less sensitive to species richness. For comparing both diversity indices, *t*-test was used (Hutcheson, 1970). This test was developed to compare the diversity of two communities samples for Shannon-Weaver's index and Simpson's index.

RESULTS AND DISCUSSION

Richness and Abundance of Species between Natural and Conventional Farming System

The arthropods collected in conventional system are represented by 7 taxa of arthropods. They were: Acari, Araneae, Collembola, Coleoptera, Hymenoptera, Orthoptera and Thysanoptera. In natural agroecosystem in addition to those named, 6 taxa more were recorded: Dermaptera, Diptera, Chilopoda, Hemiptera, Homoptera and Lepidoptera. In the conventional agroecosystem, 21 species and an abundance of 174 individuals were found, whereas in the natural agroecosystem 47 species and 270 individuals were registered. Figure 1 shows the distribution of total abundance among the different taxonomic groups registered in both farming systems. The most abundant taxonomic group in natural farming were Formicidae (33%), Orthoptera (14%) and Acari (12%). In the conventional

one the Collembola (45%), Orthoptera (16.7 %), Formicidae (18.4 %) and Other Hymenoptera (11.5 %) were the taxa with greater abundance of individuals.

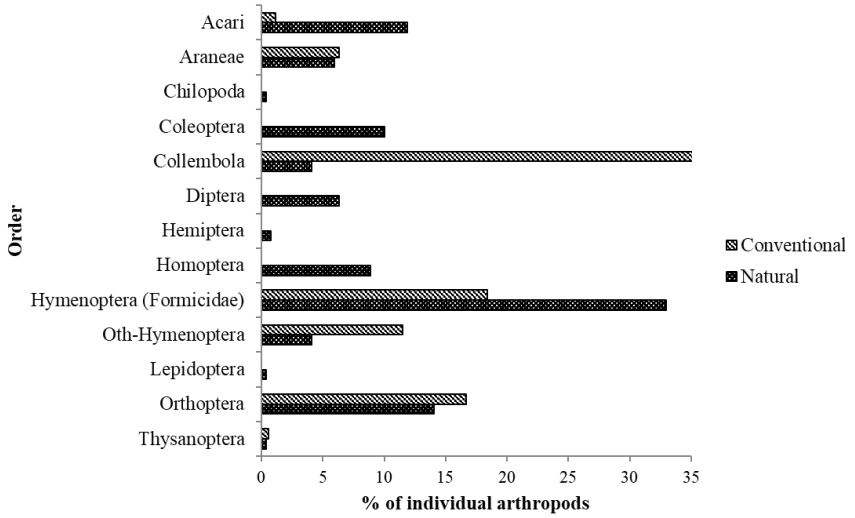


Fig. 1 Percentage of abundance of individuals per taxonomic group for both systems

With these results, we could discuss the significance of the different taxonomic groups in agroecosystems. Ground beetles predators (Carabidae and Staphylinidae) were found because they are usually found in arable lands. These species as well as spiders (Araneae) are non-specific predators, unlike parasitic wasps that are specific predators. Mites (Acari) are important in the soil as fungivores, bacterivores and nematode predators (Largerlof and Andren, 1988). In addition, they are related with the decomposition of organic residue in the soil.

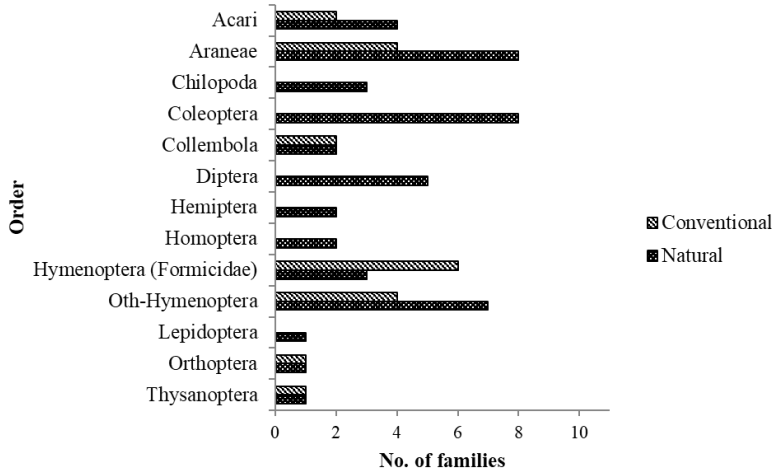


Fig. 2 Number of families per order for both systems

Figure 2 shows the distribution of the total richness among the taxonomic groups recorded in both evaluated sites. In natural agroecosystem the taxa with the highest number of families were: Coleoptera (17 %), Araneae (17 %) and Other Hymenoptera (15 %). In contrast, in the conventional agroecosystem the taxa with the highest percentage of species were: Formicidae (29 %), Araneae (19 %), Other Hymenoptera (19%) and Collembola (14%). An advantage of species richness is that it provides a broad measure of the complexity of communities and perhaps their resilience to change. Its disadvantage lies in the practical difficulty of distinguishing invertebrate species and how little it reveals about species interactions. However, species richness has the potential to tell us more about invertebrate communities and soil quality than straight biomass, density or abundance (Stork and Eggleton, 1992).

Diversity Functional Group between Natural and Conventional Farming System

Although there was no significant difference in richness and abundance in both cropping systems, in an agroecosystem, we can discuss the function that has each arthropod. From an ecological system it is important to know this since not all invertebrates that we find in the system could have different functions. That is, although there is more diversity, it could not mean that there are more functional groups. In Fig. 3, we can see that in the two systems, we could find a higher percentage of predators abundance in the natural system than in the conventional one.

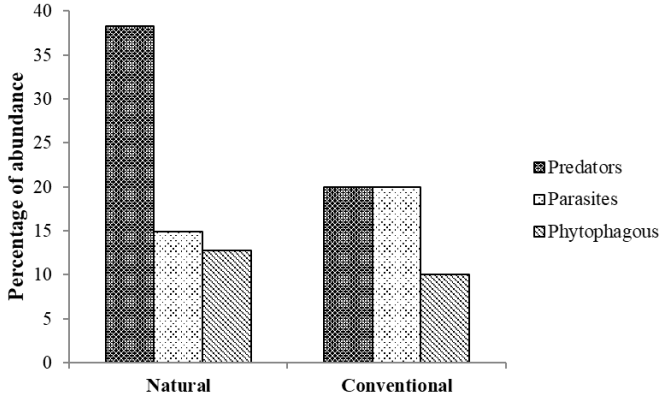
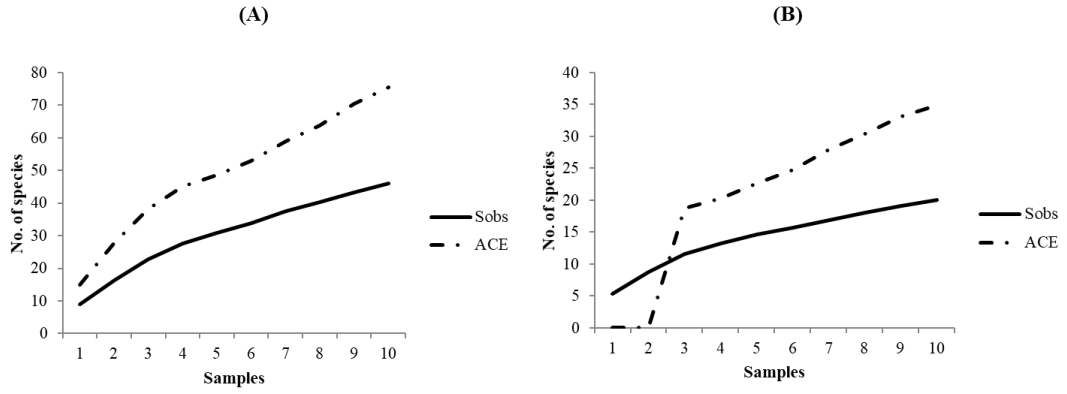


Fig. 3 Percentage of the abundance for functional group in both systems

Species Accumulation Curves (ACE) between Natural and Conventional Farming System

In order to understand the correlation between the observed and the estimated, Fig. 4 could be used to analyze the scenarios. In this figure we can see that the effort of the samples was insufficient in both systems. But we could conclude that despite that, in both systems the natural one is more diverse than the conventional one, since it is estimated that in the natural system, there are more than twice as many species as in the conventional one.



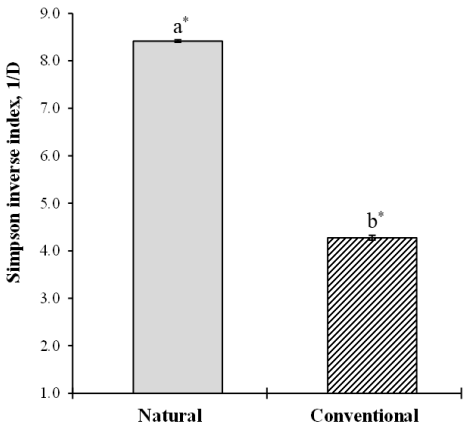
Sobs: observed species, ACE: estimated

Fig. 4 Species accumulation curves in natural system (A) and conventional system (B)

Diversity Indices between Natural and Conventional Farming System

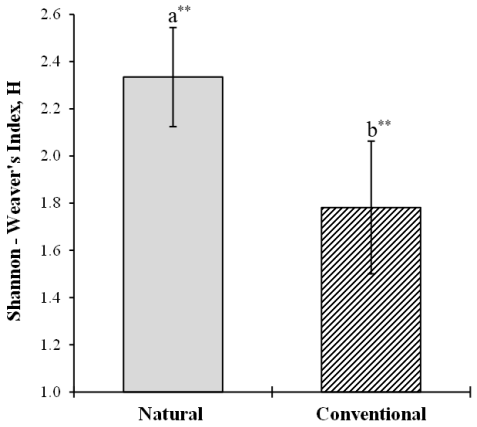
Both diversity indices indicate a higher value in natural system than conventional system. Diversity in agroecosystem, or agro biodiversity, promotes the presence of beneficial fauna, optimizing the ecological processes that favor stability, and consequently favoring their sustainability (Altieri and Nicholls, 2000). But it should be clarified that it could not be quantified how an agroecosystem is only considering the relation that exists in the same space and time by a determined number of species. This is because the interaction between the same amounts of species in different conditions

can vary (Ewel, 1986, 1999). The diversity indices give us an indication of the stability of the system, indicating that the farm of natural agriculture is more stable. And this indices at the same time coincides with the abundance and richness of the arthropods found in the two systems. A strong point of Simpson's index is that it considers rare species. These arthropods could indicate that they are specific to the system. In other words, rare arthropods include predators with general habits and parasitoids that are more specific, such as the parasitoid wasps which in total collected 11 species, 7 of which were in natural farm and 4 in conventional farm. Predators such as spiders and beetles recorded 18 species in natural agriculture and 4 species in the conventional.



(*) denotes significant difference at P<0.05

Fig. 5 Simpson Inverse Index in both farming system



(**) denotes significant difference at P<0.01

Fig. 6 Shannon – Weaver Index in both farming system

These results would support the hypotheses of Altieri and Letourneau (1984) and Altieri and Nicholls (2000) that diverse systems stimulate a greater diversity of arthropods. The first hypothesis is that more complex systems mean more diversity of species. And the diversity of species and structural plants would be associated with the diversity and abundance of insects because it would generate more food resources and temporary shelters. Increased abundance of predators and parasitoids in diverse plant associations reduces prey / host density (Root, 1973), so competition between herbivores is reduced, which in turn allows for the addition of new species of herbivores that support more species of natural enemies. And finally, they assume that the productivity of polycultures is greater, stable and predictable than in monocultures. Increased productivity and heterogeneity of the agroecosystem would mean that in a temporal and spatial environment, more species of arthropods could coexist.

CONCLUSION

There was no significant difference in richness and abundance, but more predators were observed in the natural system. Among the predators, the spiders and beetles population were dominant. The diversity indices were higher in the natural system, which means the distribution and abundance in the community is more equitable.

The farming system influences the diversity of arthropods in an agricultural environment. Therefore, if a system cannot conserve or increase the biodiversity of the farmland, it will be more unstable and with poor soil ecosystem health. However, more research is needed to better understand the interaction and roles of arthropods in a soil ecosystem.

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Research article

Risk Assessment of African Swine Fever Virus in Pork in Phnom Penh, Cambodia

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Abstract African swine fever (ASF) is an acute infectious and deadly viral disease that affects domestic and wild pigs of all breeds and ages. ASF virus (ASFV) can spread vastly to non-infected pig population, but it cannot be transmitted from pigs to humans. In Cambodia, first ASF outbreak was transmitted from bordering countries and reported in five provinces. While estimated 70% of ASF widespread all over the country, local farmers experienced a greater economic loss. Among the four components of risk analysis, the study determines the risk assessment, and hazard identification plays a crucial step in risk assessment. The objectives of this study aimed to detect the presence of ASFV in pork on local markets through qualitative risk assessment approach and propose possible measurable recommendations to prevent ASF outbreak. The study was conducted during the period of ASF outbreak in August 2019, and the qualitative detection of ASFV was conducted on pork tissue samples selected from wet markets and supermarkets in Phnom Penh. Sample extractions were isolated from 30 pork tissue samples and detected virus by iiPCR. The qualitative result on detection of ASF virus is confirmed by PCR technique. The ASFV is found in pork tissue samples in wet markets and supermarkets. Of the 30 samples, 21 (70%) were found positive with ASFV, 6 in 9 (20%) tissue samples from supermarkets and 15 in 21 tissue samples from wet markets (50%) confirmed the presence of ASFV. With this result, it indicates that likelihood of the ASF virus transmission would be very likely to occur and the spread of ASF virus in pork tissue samples in wet markets and supermarkets is significantly prevalent, and the virus is likely to spread quickly. Scientifically, there is no vaccine to prevent ASF, and as recommended by FAO, the influenced policy-based implementation is required in place to minimize further production losses. The implementations must be strengthened through strict farm biosecurity guideline and slaughter of infected pigs, strict import regulation (border and movement control of live pigs) and heavy penalty to illegal import of live pigs. Based on this result, it may contribute to bring consumers' and stakeholders' awareness to reduce high risk though early detection of ASFV at the

slaughterhouses and markets by risk assessment approach. Further studies on risk management and risk communication to complete the risk analysis of ASFV in pork are highly recommended.

Keywords African swine fever virus, risk assessment, pork, markets, Cambodia

INTRODUCTION

African swine fever (ASF) is an acute infectious and deadly viral disease that affects domestic and wild pigs of all breeds and ages, and caused by a DNA virus belonging to *Asfarviridae* family (Guberti et al., 2018). ASF virus (ASFV) can spread vastly to non-infected pig population, but it cannot be transmitted from pigs to humans (FAO, 2008). Although humans are not susceptible to ASF, its outbreak causes noticeable socio-economic consequences to infected countries (Bellini, Rutili and Guberti, 2016). In Cambodia, first ASF outbreak transmitted from bordering countries, was reported in Ratanakiri province by the Ministry of Agriculture, Forestry and Fisheries, MAFF (FAO, 2019). ASFV has continued its transmission and spread quickly to Tboung Khmum, Svay Rieng, Takeo and Kandal provinces. While estimated 70% of ASF widespread all over the country, local farmers in these five areas experienced a greater economic loss. Majority of small- and medium-scale pig farms stop to operate temporarily, and a small number of commercial farms are being operated (Siem Reap PDAFF, 2019).

In such cases, risk analysis, the process composed of hazard identification, risk assessment, risk management and risk communication, is required. FAO/WHO (2006) defined risk assessment as the term that is generally used to describe the entire process of making a public health decision regarding a specific drug or agent and it is the scientific evaluation of known or potential adverse effects resulting from human exposure to food borne hazards. According to Venn et al. (2014) as cited in the Codex Alimentarius Commission (1999), risk assessment is defined as integrated elements of the structure of risk analysis and to be based on the following steps as shown in Fig. 1 and Fig. 2.

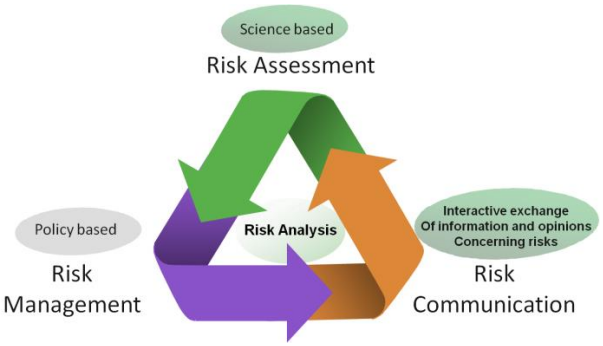

Fig. 1 Structure of risk analysis (Venn et al. 2014 cited in CAC, 1999)

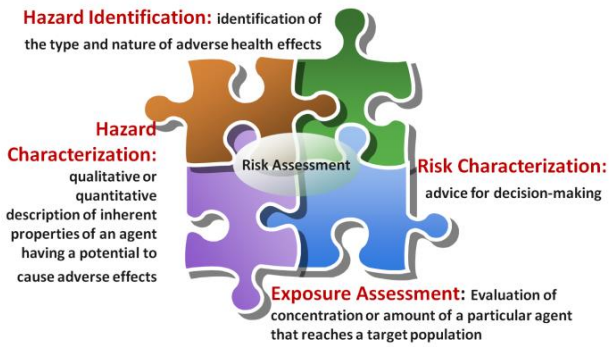

Fig. 2 Risk assessment (Venn et al. 2014 cited in CAC, 1999)

ASFV can be transmitted and spread from infected pigs directly to uninfected populations. The cause of transmission is associated with virus-containing matter (blood, faeces, urine or saliva from infected pigs) that contact directly with brought-to-farm infected pork, farm inputs and in-farm used materials (bedding, pig cage, feed, equipment, clothing and footwear, means of transportation (vehicles), studied by Thomson (1985). In the research of Mellor et al. (1987), it has shown that ASFV can be airborne within a short distance, approximately less than 2 kilo meters.

ASFV has a remarkable ability to survive for long periods in a protein environment, and therefore meat from pigs slaughtered in the infective stages of ASF or die naturally of the disease, provides a good source of virus. Pork slaughtered from infected pigs with ASF provides a favorable protein environment for the virus to survive in the tissues for a long period of time. The virus is strongly resistant to high temperatures. The studies of McKercher et al. (1978) and Plowright et al. (1994) confirmed that fresh, frozen, processed, or preserved (salted and dried) pork may contain the infective virus. As ASFV is transmitted in a closer distance, it may be possible to prevent the occurrences by applying strict biosecurity rules and observation. While taking precautionary measures in use, to limit accesses for people/ farm workers/ visitors and vehicles to enter the areas or farms where pigs are kept. This is also ensuring the farm managers/ owners and veterinarians are disinfected before entering the critical areas/ farms with protective clothing and footwear, and free from inadvertent feeding of leftovers and pork (Penrith and Vosloo, 2009).

OBJECTIVE

This study aims to detect the presence of ASF virus in pork in Cambodian markets through risk assessment approach, and propose possible measurable recommendations to prevent ASF outbreak.

METHODOLOGY

The study was conducted during the period of ASF outbreak, and the qualitative detection of ASF virus was conducted on pork tissue samples using PCR technique certified by OIE approval number 20130108 for registration of diagnostic kits (GeneReach Biotechnology Corp., 2019). The samples were selected from 7 wet markets and 3 supermarkets in Phnom Penh in August 2019. Primary information was gathered by interviewing the key informants of the city slaughterhouses and sellers in both markets. The distribution of live pig movement and slaughtered pork was from smallholder famers, middlemen and traders who source for pigs from the small-scale farms and neighboring countries.

Sample extractions were isolated from 30 pork tissue samples and detected virus. The results were evaluated based on the insulated isothermal PCR technique that automates sample lysis, nucleic acid extraction and amplification and detection of the target sequences. Pork tissue samples were pretreated by weighting 40 mg of each pork tissue sample and placing them into a clean 1.5 ml microcentrifuge tube with 0.5 ml of Sample Storage Solution atc-lysis. The pork tissues were homogenized in the grinder and spined the tube for 1 minute in mini-centrifuge before transferring 200 µl of supernatant to an Extraction Cartridge. Then, Transfer Cartridge was prepared by placing one Premix and one Transfer Cartridge for each sample; labeling the sample ID and Premix ID on the side of Transfer Cartridge; removing Transfer Cartridge Cap; turning the notched side of the cartridge away, and snapping the Premix vial into well #3 of the Transfer Cartridge. The Extraction Cartridge was prepared by placing one Extraction Cartridge (B) for each sample; removing the Extraction Cartridge from the aluminum pack, labeling the sample ID on the side of Extraction Cartridge; slowly peeling off the aluminum film; turn notched side, and loading 200 µl of homogenized sample to the sample well of the Extraction Cartridge. After the preparations of Transfer Cartridge and Extraction Cartridge were completed, the Extraction lot number of the Extraction Cartridge was entered into the PCR; then the loaded Extraction Cartridge was place into the selected slot before the Reagent lot number of the Premix Reagent was entered. The Transfer Cartridge to the selected was loaded into the slot and the analysis were ready to run in the PCR.

RESULTS AND DISCUSSION

The qualitative result on detection of ASF virus is confirmed by PCR technique. The ASFV is found in pork tissue samples in wet markets and supermarkets. Of the 30 samples, 21 (70%) were found positive with ASFV, 6 in 9 (20%) tissue samples from supermarkets and 15 in 21 tissue samples from wet markets (50%) confirmed the presence of ASFV (Table 1). With this result, it indicates that likelihood of the ASF virus transmission would be very likely to occur (OIE, 2010) and the spread of ASF virus in pork tissue samples in wet markets and supermarkets is significantly prevalent. Guberti et al. (2018 and 2019) confirmed that the virus is present in the meat of sick animals and can survive for more than 3 months in the meat and offal, about one year in dry meat and fat, and more than one year in the frozen meat.

Table 1 Percentage of sample detection

Sample detection	Positive number (ratio%)	Negative number (ratio%)
Supermarkets (9 tissue samples)	20% (6/9)	10% (3/9)
Wet markets (21 tissue samples)	50% (15/21)	20% (6/21)

Source: Results from pork tissue samples detection of ASFV conformed by PCR technique

Based on this early detection of ASFV, risk assessment as scientific-based approach identifies four components including hazard identification, hazard characterization, exposure assessment, and risk characterization are described in Table 2.

Table 2 Risk Assessment of ASF virus

Components of Risk Assessment	Identifications
Component 1. Hazard Identification	African Swine Fever Virus (ASFV), a DNA virus in the *Asfarviridae* Family. The causative agent of the disease, the ASF virus (ASFV), is the only member of the *Asfaviridae* family, genus *Asfivirus.*
Component 2. Hazard Characterization	- Human consequence: ASF virus cannot be transmitted from pigs to humans. - Economic consequence: In Cambodia, first ASF outbreak was transmitted from bordering countries and reported in April 2019 in five provinces, while estimated 70% of ASF widespread all over the country, local farmers estimated in greater losses. The pig price is increasing. Infected pigs' weight 50kg loss approximately 90% of selling price, while pigs' weight 80kg loss about 45%. Majority of small- and medium-scale pig farms stop to operate temporarily, and a small number of commercial farms are being operated.
Component 3. Exposure Assessment	Spread of the disease related vehicles and staff movements at the farms and operation of kitchens inside the farms (bring-in infected pork/contaminated foodstuffs with ASF virus), and contamination of vehicles and staff movements and carcass at the slaughterhouse.
Component 4. Risk Characterization	Combining the results of the preceding three steps and advice for decision making (to continue conducting the study on risk management).

Source: Results from pork tissue samples detection of ASFV conformed by PCR technique

As shown in Fig. 3, a timely detection and identification of an incursion of initial event (Event is NOT likely to occur) of infected pig in the farms can remove/ cull the sources of ASFV and break the routes of risk outcomes in slaughterhouses and markets (NO RISK). However, the result indicates that 70% of samples were found positive with ASFV and the contaminated pork are distributed in the markets that would be very likely to occur (RISK outcome of interest DOES Occur).

Economically, the sources of infected pigs may not be removed/ culled even though early detection is positive in farms which are still slaughtered and distributed in the markets. It seems the supply chain of pigs is less identical. There are a number of actors in the pig supply chain; in which, mostly buyers, middlemen and traders are those who source for pigs in the local villages. Sometimes

farmers may contact buyers, middlemen and traders directly to sell their pigs. The purchases are operated daily, and pigs are transported by motorcycles or trucks from farms directly to the slaughterhouses. The research studies conducted by Thomson (1985) and Thomson and Tustin (1994) confirmed that ASFV can be transmitted and spread from infected pigs directly to uninfected populations. The transmission is associated with virus-containing matter (blood, faeces, urine or saliva from infected pigs). The infected pigs may be in contact directly with brought-to-farm infected meat, farm inputs and in-farm used materials such as bedding, pig cage, feed, equipment, clothing and footwear, and other means of transportation (motorcycles and vehicles). Mellor et al. (1987) noticed that ASFV can be airborne over in a short distance approximately less than 2 kilometers that may give a higher chance for the virus to spread in the affected populations/areas.

The pork is sold raw and distributed to local markets. Some semi-commercial farms have arranged the contracts with village famers and the farms will purchase the pigs when they reach a certain market weight (Mutua et al., 2011 and Levy et al, 2013). A main cause of concern linked to the spread of AFS is a typical practice of buyers, middlemen and traders visit villages and households regularly. Farmers may sell their infected pigs to the buyers and the spread of ASFV virus may get in contact with other pigs. After slaughter those infected pigs, ASFV can survive for long periods in a protein environment, and meat from pigs slaughtered in the infective stages of ASF or that die naturally of the disease provides a good source of virus and a favorable protein environment for the virus to survive in the tissues for a long period of time (FAO, 2010; Plowright et al. 1994 and McKercher et al. 1978). Bellini et al. (2016) emphasized on the improvement of efficiency of the disease control measures by early detection of ASF that the infected pigs may be identified at the farms/slaughterhouses/markets.

CONCLUSION

The results show that the spread of ASF virus in pork tissue samples in wet markets and supermarkets in Phnom Penh is significantly prevalent, and the virus is more likely to spread quickly in Cambodia. Scientifically, there is no vaccine to prevent ASF. Technically, influenced policy-based implementation is necessary to address to minimize further production losses. The implementations must be strengthened through strict farm biosecurity guideline and slaughter of infected pigs, strict import regulation (border and movement control of live pigs) and heavy penalty to illegal import of live pigs. Based on this result, it may contribute to bring consumers' and stakeholders' awareness to reduce high risk though early detection of ASFV at the slaughterhouses and markets by risk assessment approach. Further studies on risk management and risk communication to complete the risk analysis of ASFV in pork are highly recommended.

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Research article

Ant Biodiversity under Different Fruit Agro-ecosystem in Nam Phong Watershed, Thailand

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Abstract Ants are one of significant components of ecosystems. They play important roles in agro-ecosystem functioning and provide ecological services as bioindicator, pollinator and biological control. Ants are diverse taxonomic groups. The study of ant diversity in economic crop areas including guava, mango, custard apple and banana gardens in Nam Phong Watershed, Khon Kaen province was conducted during November 2017 to August 2018. Ants were collected using three random sampling methods: manual catching, plant litter sifting and syrup trapping. The result revealed that 5 subfamilies, 13 genera of ants were found in this study. Five subfamilies found in the studied sites comprised of Dolichoderinae, Formicinae, Myrmicinae, Ponerinae and Pseudomyrmecinae. The most common species of ant with wide distribution in the study area were Anoplolepis and Diacamma. The Shannon-Wiener's species diversity index revealed that the diversity was highest in guava (0.36) followed by mango (0.35), custard apple (0.34) and lastly the banana garden (0.26). There was no dominant species of ant in the study areas. The β-diversity score, using Sorensen's similarity coefficient to determine the similarity in community composition, was found highest between guava and custard apple garden at 62%, follow by between mango and guava garden at 46 %, and between mango and the banana garden at 38 %, the results indicated that ant species diversity was varied in the four studied sites. Therefore, the results from this study suggests that ant species diversity can be used to support agro- ecosystems management.

Keywords ant diversity, ecosystem service, economic crops, Nam Phong Watershed

INTRODUCTION

Ants may function as bio-indicators, due to their complex ecological interaction within their, and to their sensitivity to disturbances (Read and Andersen, 2000). It is possible to analyze variations in the community of ants under the concept of functional groups, defined in accordance with their tolerance to disturbance and environmental stress, as well as with their ability for competitive interactions (Andersen, 1995). Ants play diverse and important ecological roles. Because of their ecological significance in ecosystems, ants are considered to be the suitable bio-indicator species for biodiversity studies (Alonso, 2000). Moreover, ants have been used as biological agents of insect pests in agriculture in several countries include Malaysia (Khoo and Chung, 1989) and Thailand (Kritsaneeapiboon and Saiboon, 2000). Although ants have relatively low species diversity, they are the single most important arthropod group by their dominance in animal biomass (Alonso and Agosti, 2000). Environmental changes have an impact on macro-arthropod abundance (Pearson and Derr, 1986; Adis and Latif, 1996). Overall, common species, most habitats are likely to have specialized species, which occur in sufficient species diversity and abundance as to be able to serve as suitable terrestrial indicator species of habitat quality and changes.

OBJECTIVE

The objective of this research was to investigate biodiversity of ants in four different agro-ecosystems; guava, custard apple, mango and banana gardens in Nam Phong Watershed, Khon Kaen Province, Thailand.

METHODOLOGY

Study sites were located at Namphong Watershed, Khon Kaen, Thailand. Four different fruit agroecosystem included guava, custard apple, mango and banana gardens were chosen to investigate ant diversity. Guava garden with the area of 6 Rai (0.96 ha) was located at Kok Tah Village, Mueang District, (16.5° 38' 81.3" N, 102.90° 12' 75" E). There was not any management system in this garden. Custard apple garden in area of 2 Rai (0.32) was located at Tha Kra Some Village, Nam Phong District, (16.62° 22' 47" N, 102.87° 73' 75" E. Mango garden in area of 2.5 Rai (0.4 ha) was located at the same village of the custard apple garden (16.60° 59' 83" N, 102.87° 61' 40" E), both gardens had no management system. Banana garden in area of 3.7 Rai was located at Nong Ngu Luam Village, Mueang District, (16.5° 149' 74" N, 102.93° 11' 17" E), herbicide and chemical fertilizer (N-P-K-15-15-15) were applied in banana garden. All four studied sites were in Khon Kaen Province.

Fig. 1 Study sites

Ant samples were collected from November 2017 to August 2018. The seasons of collecting data were divided into wet season and dry season. Ant specimens were collected by using three random sampling methods: manual catching, plant litter sifting and syrup trapping. The ecological factors were measured at the same time. Identification of ants to family, genus and species was based on the keys by Bolton (1994), Hölldobler and Wilson (1990), and Wiwatwitaya and Jaitrong (2001). The Shannon-Wiener's diversity index (Krebs, 1999), was used to calculate ants diversity collected. The formula of the Shannon-Wiener's diversity index used is presented below

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

Where, H' = Species diversity index

s = Number of species

pi = Proportion of the total sample belonging to ith species

The Sorensen's similarity coefficient (Krebs, 1999) was used to measure the beta diversity or the similarity between two study sites as follows:

$$S = \frac{2a}{2a + b + c}$$

Where, S = Sorensen's similarity coefficient
a = Number of species in site A and site B
b = Number of species in site B but not in site A
c = Number of species in site A but not in site B

The evenness index (Krebs, 1999) was calculated to determine the equal abundance of ants in each study site as follows:

$$\text{Evenness} = \frac{H'}{H'\text{MAX}}$$

Where, H' = Observed index of species diversity
H'MAX = Maximum possible index of diversity

RESULTS AND DISCUSSION

Table 1 Number of genera and family of ants in all sites at Nam Phong Watershed

Subfamily	Genus	Study area				Total
		Guava	Custard apple	Mango	Banana	
Amblyoponinae	*Amblyopone*	7	0	2	0	9
Dolichoderinae	*Ochetellus*	1	0	1	0	2
	Iridomyrmex	0	0	0	1	1
Formicinae	*Anoplolepis*	329	112	8	11	460
	Camponotus	3	16	0	0	19
	Nylanderia	7	5	1	10	23
	Oecophylla	76	43	195	4	318
Ponerinae	*Diacamma*	10	26	0	1	37
	Odontoponera	3	33	0	0	36
Myrmicinae	*Pheidole*	9	11	0	0	20
	Cardiocondyla	0	0	0	1	1
	Monomorium	23	42	136	130	331
	Crematogaster	25	0	0	0	25
Number of genus		10	8	6	7	13
Number of specimens		503	296	349	165	1295

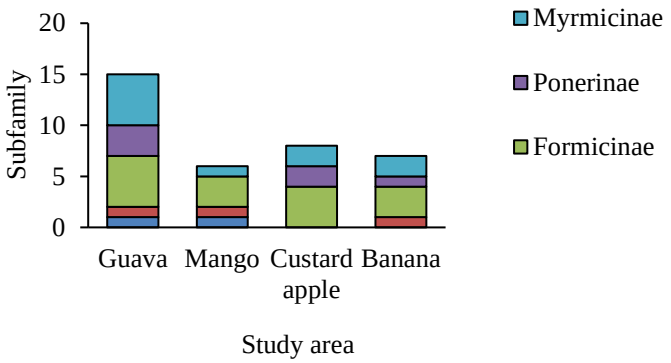

Fig. 2 Comparison of ant diversity in each crop areas

Total of 23 ant genera distributed among five subfamilies were identified from four difference agro-ecosystems (Table 1, Fig.2). With the comparative ant communities between the four agro-ecosystems, the highest number of specimens was recorded in guava garden followed by custard apple, banana and the lowest in mango garden. Ten genera and five subfamilies were found in guava garden follow by eight general and four subfamilies from custard apple, seven genera and four subfamilies from banana garden. Meanwhile there are only six genera and four subfamilies from mango garden. Four species of ants included *Anoplolepis, Nylanderia, Oecophylla, Monomorium* were found in all four agro-ecosystems, whilst other species, *Iridomyrmex* and *Cardiocondyla* were found only in banana garden and one species of *Crematogaster* was found only in guava garden. At the subfamily level of all sites, Formicinae and Mymicinae had the highest number of four genera. The richness of genera found in the study is lower compared to the richness recorded in other studies carried out in crop area in central Thailand (Weerapadtra et al., 2018).

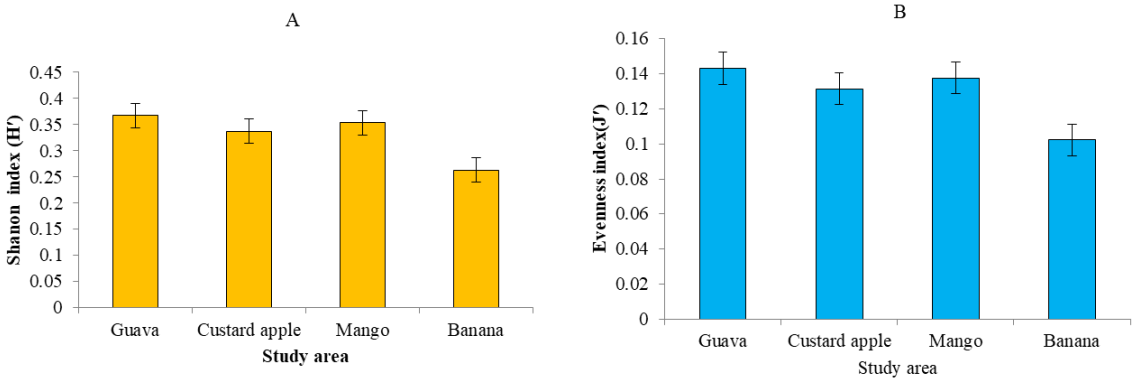

Fig.3 Comparison between Shannon index (A) and Evenness (B) of ant diversity in each plantation

The Shannon-Wiener's species diversity index (Fig. 3A) indicated that the year-round diversity was the highest in guava garden, followed by mango, custard apple and lastly in banana garden. Moreover, the highest value of the evenness index was found in guava garden followed closely by mango and custard apple gardens, whereas those for banana garden was markedly lower (Fig. 3B). This result indicates that a relatively equal abundance of each ant species was present in guava and mango gardens whereas banana garden had an unequal abundance of some ant species.

The species similarity between guava and custard apple gardens, as evaluated by Sorensen's similarity coefficient was the highest, whilst that of between guava and mango gardens was intermediate and the lowest similarity was found between in custard apple and banana garden (Table 2). The relatively high ant species diversity in guava garden may be caused by the correspondingly high diversity in the plant community and as such would potentially reflect the differences in the canopy cover and leaf shedding. Hasin (2008) reported that the leaf litter, soil moisture content, and

leaf litter biomass in each study site would likely be affected by differences in each plant community. The leaf litter provides both food and nest sites to many ant species, so it might be expected that an addition of both resources will produce a stronger response from litter-nesting ants (Armbrecht et al., 2006).

Table 2 The Sorensen's similarity coefficient ants from the four sites

Study area	Sorensen's similarity			
	Guava	Mango	Custard apple	Banana
Guava	1	-	-	-
Mango	0.46	1	-	-
Custard apple	0.62	0.31	1	-
Banana	0.38	0.38	0.31	1

CONCLUSION

In conclusion, diversity of ants was different in four crop gardens, which may reflect the different ecological service they provide in different land uses of the studied sites. However, more detailed study needs to be done to confirm include potentially factors influenced ant community species, diversity, and composition, as somewhat intuitively expected but not to date ascertained for these habitats. Some species were found in all four crop areas, whilst other species were more specifically being found only in specific microhabitats in the studied areas. If the understanding of microhabitats used by specific ant species can be developed along with the key trophic interactions, then the potential of using ants as terrestrial indicator species for detecting environmental changes can potentially be reliably and easily (low cost and time) performed compared to some other indicator species. Future research on the roles of ants in an ecosystem and their contribution to ecosystem service need to be investigated.

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Research article

Temporal and Spatial Distributions of Soil Apparent Electrical Conductivity in Paddy Rice Fields, Khon Kaen, Thailand

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Abstract The temporal and spatial distribution of soil apparent electrical conductivity (ECa) was measured to elucidate the process of soil salinization in rainfed paddy rice fields in Khon Kaen, Thailand. Soil ECa was measured in 2.3 ha of paddy fields using a ground conductivity meter, utilizing the principle of electromagnetic induction. The average soil ECa was measured at 150 cm and 75 cm depth at 10 m intervals. Observations were conducted every two weeks for two months, from mid-May 2018 to mid-July 2018. The collected data were interpolated using an inverse distance weighted method with 1 m intervals and then analyzed in terms of temporal and spatial distributions. The results showed that (1) higher soil ECa was observed in the northern part of the study area near a swamp throughout the monitoring period; (2) the average soil ECa at a depth of 0–75 cm ranged from 233 to 282 mS/m, while it ranged from 236 to 268 mS/m at a depth of 0–150 cm; (3) the average soil ECa in the upper layer was slightly higher than that of the lower layer in May, but this difference became smaller over time and the situation reversed in mid-July; and (4) a larger spatial distribution was observed in the upper layer compared with the lower layer based on the difference of a coefficient of variation of soil ECa. A soil salinization process was clearly observed.

Keywords electric conductivity, soil salinization, rainfed paddy fields, wet season, resilience

INTRODUCTION

In Thailand, saline soil covers an area of about 2.3 million ha, especially in inland areas (Pongwichian et al., 2013), and the accumulation of salt occurs in rainfed paddy fields. A major source of the salt is the Rock Salt Member of the Maha Sarakham Formation, which consists mainly of rock salts, wherever it is exposed or lies close to the surface. However, other potential sources of salt were formerly classified as salt-free strata (Wongsomsak, 1986). The management of these soils is very problematic and strictly depends upon the degree of salinization and the mode of the salt-forming processes. As general countermeasures, the management of these soils involves leaching, proper drainage control, land leveling, surface mulching, organic amendments, deep plowing, and the use of salt-tolerant plant varieties (Land Development Department). However, before taking any countermeasures, it is important to understand to what extent fields are affected by salt. Topark-Ngarm et al. (1990) conducted physical and chemical analyses of soil samples collected from a depth

of 30 cm at 5 cm intervals in Ban Thum, Khon Kaen. Hanchai et al. (2010) monitored changes in biotic activity in relation to the chemical and physical properties of salt-affected soil before and after tree planting. However, the high-resolution temporal and spatial distributions of salt accumulation have not been well studied in the Khon Kaen Province.

OBJECTIVE

This study aimed to elucidate the high-resolution temporal and spatial distribution of soil apparent electrical conductivity (ECa) in paddy fields and areas adjacent to them in Khon Kaen, Thailand. When combined with groundwater level fluctuation, rainfall, and microtopography data, the monitoring results should contribute to the understanding of the soil salinization mechanism.

METHODOLOGY

Measurement and analysis of soil ECa

Although there are many saline-damaged farmlands in northeastern Thailand, a rain-fed paddy rice block of Ban Pasan village in Khon Kaen was selected as a study site because of its clear spatial distribution of the degree of salinity. The study area, in Ban Pasan, Khon Kaen, encompassed paddy fields and an adjacent forest and swamp (N16.296° W102.612°; elevation 243 m). The difference in elevation between the south and north ends of the monitoring area is 28 cm and the area is quite flat (< 1/1,000). The groundwater level in the study area ranged from 140 cm below the ground surface in April to 0 cm in September. Soil ECa was measured using a ground conductivity meter (EM38-MK2; Geonics Limited), which simultaneously measured both quad-phase (conductivity) and in-phase (magnetic susceptibility) components within two distinct depth ranges, without any requirement for soil-to-instrument contact (GEONICS). With a maximum effective exploration depth of 150 cm, this meter is used for agricultural, archaeological, and general soil science purposes e.g. Kume et al. (2003), Zukemura et al. (2016), and Rafael et al. (2011).

The study area is shown in Fig. 1. The yellow dotted line indicates the domain of the ECa survey. Rice had been planted in a rainfed paddy in the southern part of the domain, with a fallow area in the center. A swamp was located to the northeast, and a tree plantation was located to the west. Soil ECa measurements were conducted at ~ 10 m horizontal intervals, with about 150–160 points, at two different depths, 75 cm and 150 cm vertically. Measurements were collected five times between 16 May 2018 and 11 July 2018, every two weeks. The collected soil ECa data were interpolated using an inverse distance weighted method with a 1 m mesh.

Fig. 1 Study area

RESULTS AND DISCUSSION

Temporal Distribution of Soil ECa

The average soil ECa in the upper soil layer (0–75 cm) and the deeper layer (0–150 cm) are summarized in Tables 1 and 2, respectively. The average soil ECa between 0 and 75 cm ranged from 233–282 mS/m, while it ranged from 236–268 mS/m between 0 and 150 cm. The average soil ECa in the upper layer was slightly higher than that of the lower layer in May, but this difference reduced over time, with the situation being reversed in mid-July. The average ECa peaked in late May, with an average ECa of 282.3 mS/m at 0–75 cm and 268.0 mS/m at 0–150 cm. The highest median ECa and the highest coefficient of variation (CV) occurred in late May at both depths.

Table 1 Summary of soil ECa in the shallow layer (0–75 cm)

mS/m

Date	Average	Max	Min	Median	STD	CV
2018/5/16	247.8	928.6	32.6	214.5	141.9	0.57
2018/5/30	282.3	989.1	35.2	217.2	198.0	0.70
2018/6/14	243.0	982.9	26.1	203.8	149.7	0.62
2018/6/27	242.0	971.4	24.1	217.4	150.5	0.62
2018/7/11	233.1	895.9	27.2	214.5	133.0	0.57

Table 2 Summary of soil ECa in the deeper layer (0–150 cm)

mS/m

Date	Average	Max	Min	Median	STD	CV
2018/5/16	243.3	769.7	52.7	214.0	103.3	0.42
2018/5/30	268.0	987.3	39.2	225.2	155.7	0.58
2018/6/14	236.1	928.4	35.1	211.0	120.8	0.51
2018/6/27	241.2	773.0	38.2	223.4	120.2	0.50
2018/7/11	237.6	802.2	41.2	216.5	112.2	0.47

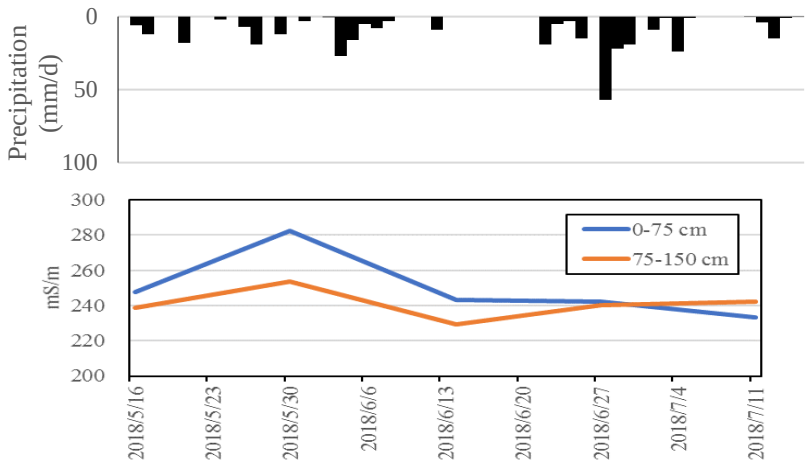

Fig. 2 Average soil apparent electrical conductivity (ECa) in the upper (0–75 cm) and lowest layers (75–150 cm) and daily rainfall

The average soil ECa in the lowest layer (75–150 cm) was then calculated, as shown in Fig. 2. The difference between the ECa in the upper soil layer (0–75 cm) and the lowest soil layer (75–150 cm) was greatest during May, but the difference reduced, and the ECa of the lowest layer was higher than that of the upper layer from late June. It is generally understood that saline water moves upwards by capillary action, and the increasing difference in ECa in the upper and lowest soil layers can be explained by capillary action. The reversal of the difference between the upper and the lowest layers might have been due to rainfall during late June and there was actually about 100 mm of rainfall (at the Khon Kaen airpoirt which is the nearest whether station from the study site) during the three days from June 25-27, 2018.

Spatial Distribution of Soil ECa

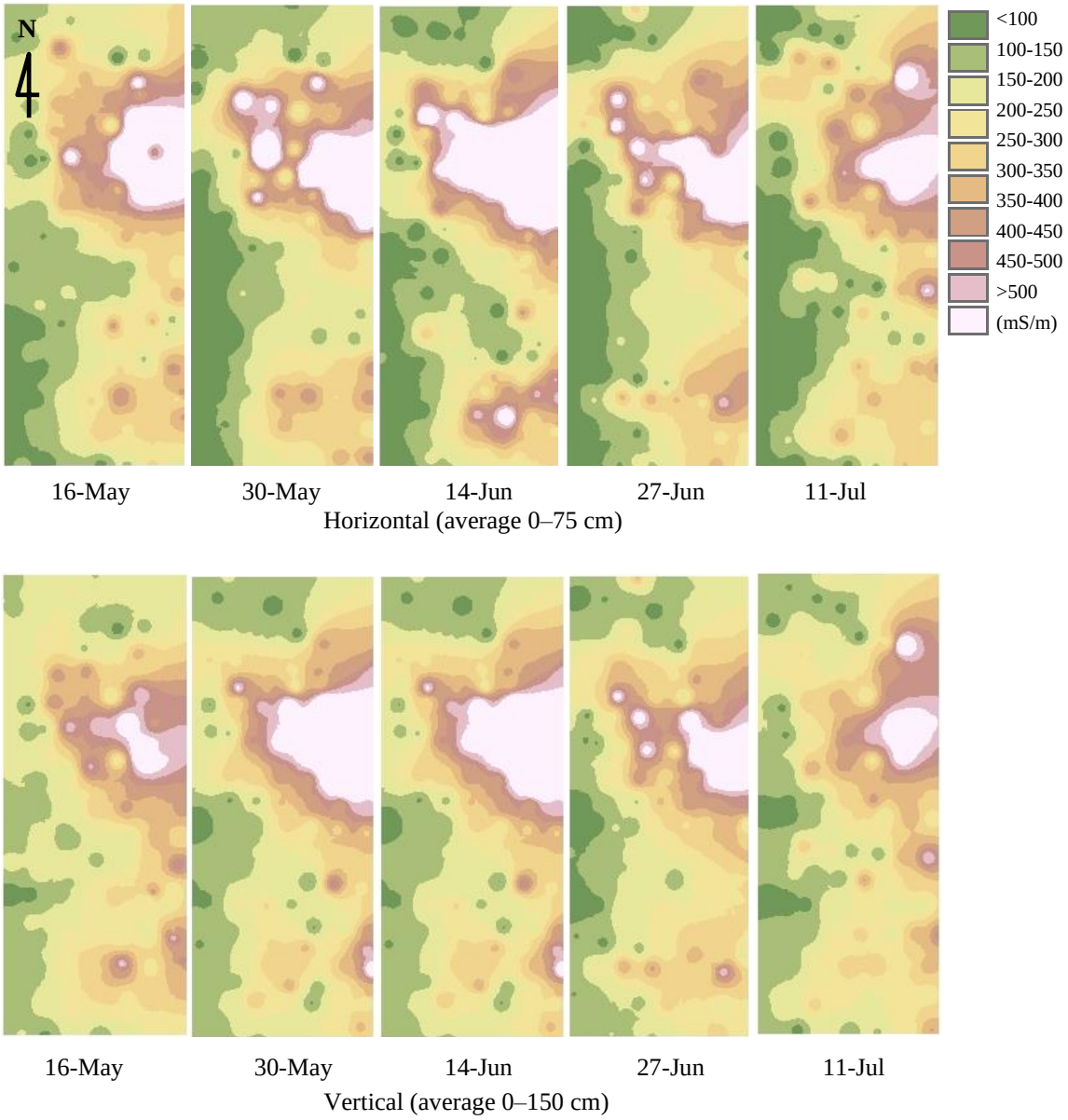

Fig. 3 Temporal and spatial distributions of soil apparent electrical conductivity (ECa)

Figure 3 shows the spatial distribution of soil ECa at different depths. Higher soil ECa at both depths was observed in the northern part of the study area near the swamp throughout the monitoring period.

There were some spot high ECa values in the southern paddy fields in May; however, these were lower in June and July. At a glance, the ECa values were highest during May, then decreased in June and July. The ECa in and around the rainfed paddy field was about 200 mS/m. The FAO states that rice is a salt-sensitive crop, with an ECa threshold of 300 mS/m (FAO, 2002). As shown in Figure 3, the ECa in the central and northern areas exceeded this threshold; therefore, these areas were left fallow due to the high salinity. The reason of high salinity of the central and northern part of the study area is to be discussed by considering spatial and temporal distribution of groundwater level fluctuation, soil type, and inundation of ground surface.

CONCLUSION

A high-resolution investigation of soil ECa over a large area was conducted using the electromagnetic induction method. The ECa of two soil layers (0–75 cm and 0–150 cm depth) was measured and a soil salinization mechanism discussed. The results can be summarized as follows: (1) higher soil ECa was observed in the northern part of the study area near the swamp throughout the monitoring period, (2) the average soil ECa at a depth of 0–75 cm ranged from 233 to 282 mS/m, while it ranged from 236 to 268 mS/m between 0 and 150 cm, (3) the average soil ECa in upper layer was slightly higher than that of the lower layer in May, but the difference between them was reduced over time and the situation reversed in mid-July, and (4) a larger spatial distribution was observed for the upper layer compared with the lower layer, judged by the difference of the CV of the soil ECa. Soil salinization during the wet season was clearly observed. A comprehensive analysis of the soil salinization process, considering the fluctuation of the groundwater level, rainfall, and microtopography is planned for the future.

ACKNOWLEDGEMENTS

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Research article

Reducing Nitrogen Emission during Cow Manure Composting with Adding of Rice Husk Biochar

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Abstract Nitrogen losses in the forms of ammonia and nitrous oxide emission are major causes for low nitrogen content in cow manure compost. In addition, nitrogen losses decrease the agronomic value of compost. In this study, rice husk biochar was added in cow manure to assess its effects on reducing nitrogen losses. Rice husk biochar is a product of thermochemical reaction in limited oxygen supply resulting in a product with micro-pores and large surface area with negative charge. A small scale composting experiment was designed and conducted using cow manure for a period of 60 days. Gases released were measured periodically with static gas chamber method. In addition, total nitrogen content and C/N ratio were analyzed. The experiment results showed that the loss of ammonia which is in peak during initial stages were lower in the treatments added with biochar. The cumulative ammonia emission was lowered by 12.6%, 14.5% and 23.2% in 5%, 10% and 15% biochar added treatments respectively, as compared to control. The cumulative gas flux result of N_2O showed similar trend to that of NH_3. N_2O emission was lowered by 40.0%, 46.4% and 60.4% in 5%, 10% and 15% biochar added treatments respectively, as compared to control. Furthermore, total nitrogen content and C/N ratio had better results in biochar added treatments. The obtained results may be attributed to the fact that micro-pores and negative charge in rice husk biochar adsorbed the nitrogenous compounds. Additionally, biochar increased retention of moisture and nutrients enhancing microbial activity for better degradation and humification of organic matter. The results indicated that biochar could be a good medium in reducing the nitrogen loss and increasing agronomic value during composting of cow manure.

Keywords cow manure composting, nitrogen emission, rice husk biochar, agronomic value

INTRODUCTION

Composting is a sustainable method for waste management of cow manure. It is a naturally occurring process where various distinctive microorganisms break down organic matter to produce humus like substance, which has high agronomic value. On the other hand, composting produces harmful gases like ammonia (NH_3) and nitrous oxide (N_2O), which causes environmental problems. High nitrogen content of cow manure causes the release of NH_3, which is one of the principal malodorous compounds produced during composting. Aerobic degradation of organic material in cow manure causes intensive NH_3 generation and emission. Ammonia volatilization leads to the loss of nitrogen and effects compost nutrition content (Pagans et al., 2006). N_2O is released from nitrification or denitrification (Fig.1) of nitrogenous compounds and has a high global warming potential (Houghton et al., 1992). Nitrous oxide is considered 265 times more potential GHG than carbon dioxide (IPCC, 2013). Emission of these gases causes loss of nitrogen, which decreases the agronomic value of compost. Loss of nitrogen through ammonia volatilization can be as high as 70% (Martin and Dewaes, 1992; Eghball et al., 1997; Beck-Friss et al., 2001) and 0.62 to 1.07% in the form of N_2O in manure (Hao et al., 2001). Nitrogen transformation during of manure composting is a complex mechanism

and is shown in fig. 1 (Wu et al., 2012). It is of great concern on developing measures for reducing nitrogen losses during composting process to minimize the emission of hazardous gases and increase the agronomic value of compost.

Recently, biochar amendment has been used in limiting N_2O emission in manure composting and soil (Kamman et al. 2015; Wang et al. 2013). Biochar is a carbon rich material derived from pyrolysis of biomass characterized by high number of micro pores and large surface area with negative charge. In this study, it is speculated that these properties of biochar can reduce the emission of NH_3 and N_2O when composted with animal manure as biochar can effectively retain NH_3, NH_4^+ and NO_3^- in animal manure (Steiner et al., 2010).

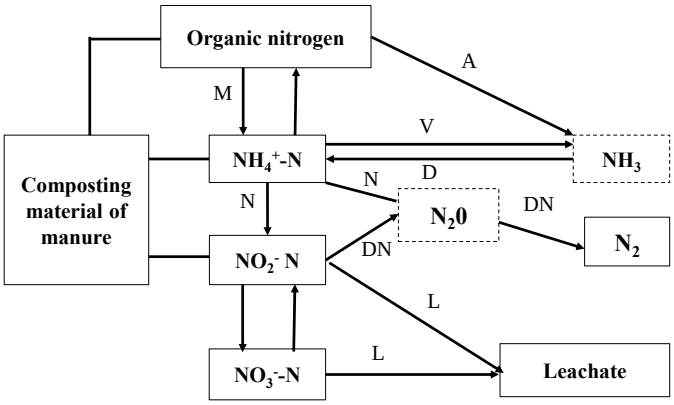

Fig. 1 Nitrogen transformation during manure composting (adopted from Wu et al., 2012)
A: Ammonification; I: Immobilization; M: Mineralization; V: Volatilization;
D: Dissolution; Nf: N-fixation; N: Nitrification; DN: Denitrification; L: Leaching loss

Therefore, this study concentrates to evaluate the effects of composting cow manure with rice husk biochar amendment to reduce the emission of NH_3 and N_2O and increase the agronomic value of compost.

METHODOLOGY

Designing of Compost Box and Gas Chamber

A compost box was designed using glass container of dimension 30 cm^3. The glass box was covered with styro-foam sheets of thickness 2 cm on five sides for minimizing the heat loss (Fig. 1). A static gas chamber was designed to measure the gas flux. A digital thermometer and a fan were attached inside the chamber for measuring temperature and uniform circulation of air during measurement of gas respectively (Fig. 2 and 3). The volume of air inside the chamber was calculated as 0.017705 m^3.

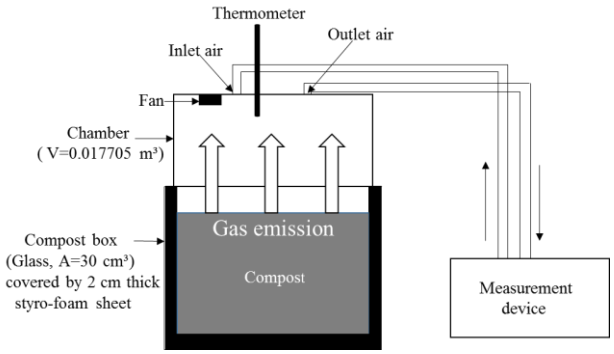

Fig. 2 Schematic diagram of composting box and gas flux analysis

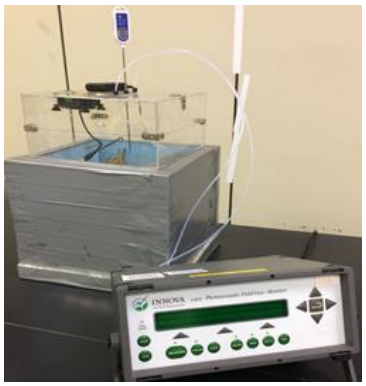

Fig. 3 Apparatus used during gas flux measurement

Conditions of the Experiment

The composting experiment was conducted from 8 August 2019 to 7 October 2019 in Laboratory of Land and Water Use Engineering, Tokyo University of Agriculture. The average temperature was 23.0℃ during the experiment. Cow manure, rice straw and litter was used as main components for composting. The nitrogen content in cow manure and rice husk biochar was 23695 mg/kg and 1241 mg/kg respectively at the start of the experiment. Rice husk biochar was added in three different variations (Table 1). The initial water content of the composting material was set at 70±2% for all the treatments.

Table 1 Composition of treatments

Composition	Control	Treatment with 5% added biochar	Treatment with 10% added biochar	Treatment with 15% added biochar
Cow manure (g)	3200	3200	3200	3200
Litter + rice straw (g)	1800*	1800*	1800*	1800*
Rice husk bio-char (g)		250*	500*	750*

*Note: * represents air-dry weight basis*

Measurement of Gas Emission

Gas flux was measured using static gas chamber method with photoacoustic spectrometer. The spectrometer used in this study was INNOVA 1412 Photoacoustic Field Gas Monitor (Fig.3). Gas flux was calculated using linear aggression method showed in Equation 1 (Minamikawa et al., 2015).

$$F = \rho \times \frac{V}{A} \times \frac{\triangle c}{\triangle t} \times \frac{273}{T} \quad (1)$$

Where, F is gas flux (mg m^{-2} hr^{-1}), ρ is density of gas (kg m^{-3}) where density of NH_3 is 0.772 kg m^{-3} and of N_2O is 1.96 kg m^{-3}, A is bottom surface area of chamber (m^2), V is volume of air inside the chamber (m^3), △c/△t is average increase rate of gas density inside the chamber (10^{-6} m^3 m^{-3} hr^{-1}), T is average temperature inside the chamber (K)

Compost Sampling and Analysis

Compost was sampled at 5, 10, 20, 30, 40 and 60 days to analyze its agronomic value. Temperature of the compost pile was measured using Custom CT-0580 data logger and digital thermometer on daily basis. Water content of the sample was analyzed using gravimetric method, where samples were kept at 105°C for 24 hours. Carbon content was determined by using the formula C=0.580* IL. Total nitrogen was analyzed by absorption spectroscopy using HC-1000 (Central Science Corp.) as measurement device (Mihara and Ueno, 2000).

RESULTS AND DISCUSSION

Biochar Effects on Composting Temperature

Temperature of composting process is widely considered as significant factor in gas emission during cow manure composting as microbial metabolism and activities are all temperature sensitive and dependent. NH_3 is released when the temperature is high and are carried by thermophiles. Whereas, N_2O is released after temperature declines and mesophiles are responsible for it. In this study, all the treatments showed a similar pattern of temperature evolution with a rapid activation of composting process carried by intensive microbiological degradation of organic matter. Biochar added treatments had increased temperature profile during the thermophilic phase compared to control (Fig. 3). The

result coincides with previous studies using biochar as a co-substrate for manure composting (Jindo et al., 2012, Wang et al., 2013, Wei et al., 2014). It is speculated that higher temperatures in biochar added treatments were attributed to the structure of biochar, which provided suitable habitat conditions with positive effects on substrate properties such as porosity, surface area and moisture content. These factors promoted microbial activity, explaining higher temperatures.

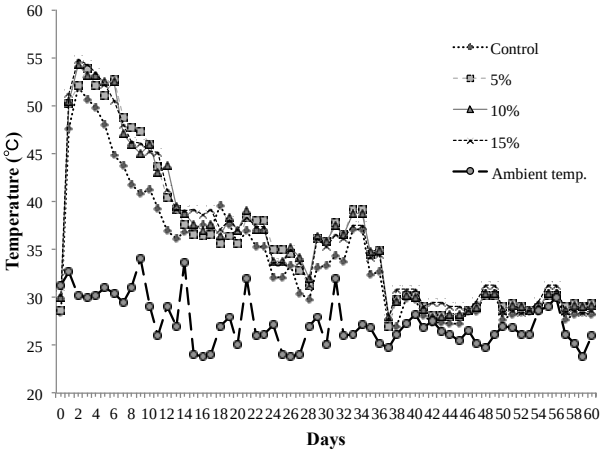

Fig. 4 Periodic changes in temperature with time

Biochar Effect on Ammonia Emission

Ammonia emission is inevitable during cow manure composting which has high content of nitrogen. Generally, emission is high during early stage of composting where temperature and pH are high. In this study, emission was high during the first week of composting which lowered gradually as the temperature decreased for all the treatments (Fig. 5) with negligible emission after 20 days of composting. The emission pattern of the results of this study coincides to that of Osada et al. (2000) and Kuroda et al. (1996). The total ammonia emissions were significantly lower in biochar amended treatments with 15% added treatment having the lowest emission. The cumulative gas emission was lowered by 12.6% , 14.5% and 23.2% in 5%, 10% and 15% biochar added treatments respectively, as compared to control (Fig. 6). The reduced emission can be attributed to the microscopic porous structure having negative charge adsorbing ammonium ions by electrostatic attraction (Montes-Moran et al., 2004; Nguyen et al., 2017).

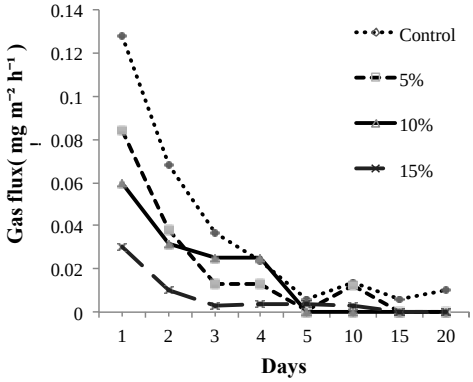

Fig. 5 Periodic changes in ammonia flux

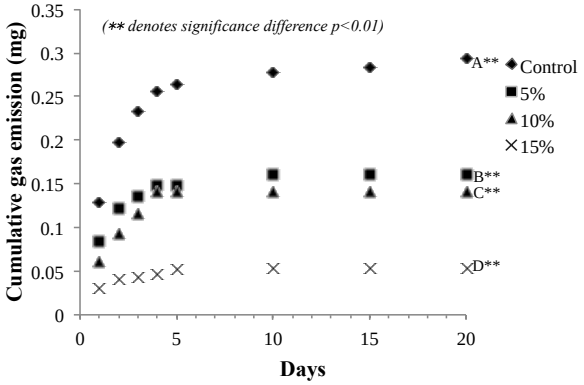

Fig. 6 Cumulative ammonia emission

Biochar Effect on Nitrous oxide Emission

Composting of high organic content materials has been shown to produce N_2O by nitrification and denitrification under aerobic and low oxygen conditions respectively. Fig. 7 shows the periodic change in emission between the treatments. The cumulative gas flux resulted in least emission in 15%, 10% and 5% biochar added treatments followed by control (Fig. 8). The cumulative gas emission was lowered by 40.0%, 46.4% and 60.4% in 5%, 10% and 15% biochar added treatments respectively, as compared to control. The result observed is supported by that of Jeffery et al., 2015, which states that addition of biochar can decrease the emission of nitrous oxide.

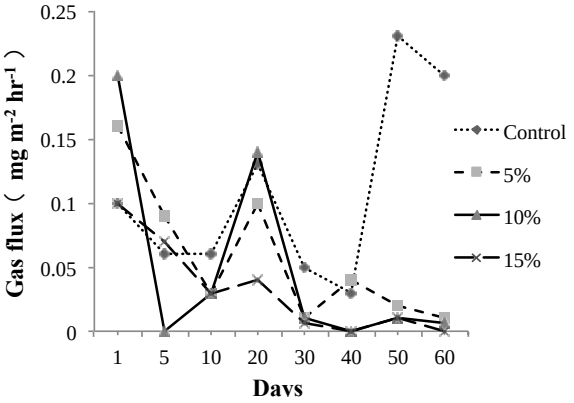

Fig. 7 Periodic changes in nitrous oxide flux

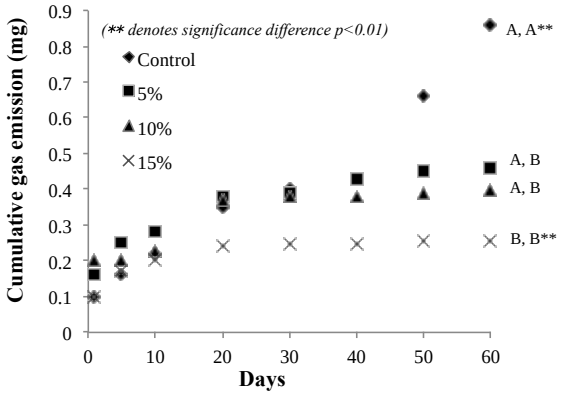

Fig. 8 Cumulative nitrous oxide emission

Biochar Effects on Agronomic Value of Compost

Nitrogen content and C/N ratio are oftenly used as a criteria for determining the agronomic value of compost. Nitrogen is the most esential plant nutrient for growth and development of plants. Compost which has high nitrogen content is considered having high agronomic value. The experimental results showed that total nitrogen content of biochar added treatments were higher than control (Fig. 9) at 60 days of composting with 99% significant difference. The high nitrogen content in biochar added treatments can be due to the result of reduced emission of NH_3 and N_2O. In addition, biochar may have enhanced aeration, water holding capacity and microbial activity increasing humification of organic material. This resulted in high nitrogen content and concurrs to that of Akdeniz, 2019; El-Naggar et al., 2019; Godlewska et al., 2017. C/N ratio is used as an indicator of compost stability and nitrogen availability. The periodic change of C/N ratio showed better values in biochar added treatments compared to control (Fig. 10). The C/N value of biochar added treatments at 60 days of composting had siginificant difference at 99%, compared to control. This can be explained as increased surface area and moisture content favoured compost microorganisms for degradation and humification of organic material. Also, biochar addition increased sorption of nitrogen compounds in the microspores providing microorganism with sufficient nitrogen for their metabolism.

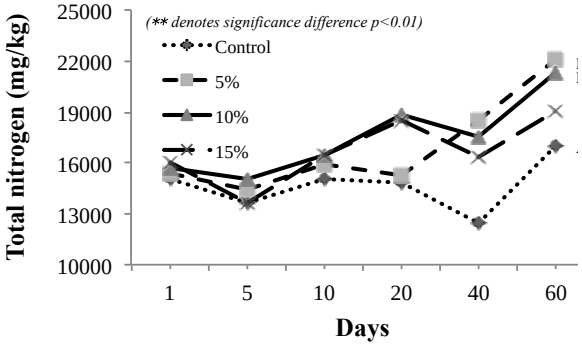

Fig. 9 Periodic changes in nitrogen content

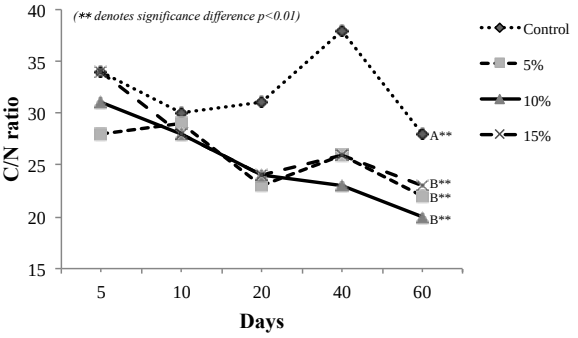

Fig. 10 Periodic changes in C/N ratio

CONCLUSION

This study discusses the effects of composting cow manure with rice husk biochar in reducing the emission of NH_3 and N_2O and increasing the agronomic value of compost. A small scale laboratory experiment was conducted where rice husk biochar were composted with cow manure The results showed that addition of biochar is effective in reducing emission of NH_3 and N_2O with 15% treatment being the most efficient. This can be attributed to the structure of biochar with high number of micropores and surface area that enables absorption / adsorption of NH_3, N_2O, water soluble NH_4^+ as well as NO_3^-. The result also showed better nitrogen content and C/N ratio in biochar-amended treatments. The author speculates that adding of biochar helped in increasing oxygen content and retention of water enhancing better microbial metabolism and mineralization. The author believes that composting biochar with cow manure is encouraging method for reducing emission and increasing better quality compost. However, further researches are needed to understand the role of biochar and interaction of manure, biochar and microbes during composting process.

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Research article

Socioeconomic Conditions and Perception of Climate Change in Rice Varietal Selection by Smallholder Farmers in Myanmar

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Abstract Rice is an economically, socially, politically, and culturally important crop grown in diverse agro-ecological conditions all over Myanmar. Climate change impacts affect rice production directly and link in farming decisions for cropping systems. As the population keeps growing and climatic variabilities and extreme weather events keep increasing the marginal productivity of land would not be negligible for the food security and sustainable agriculture. This study was conducted to meet the objectives of to overview the socioeconomic characteristics of farmers, find out the serious problems faced by the farmers in rice production, know the most practicing coping strategy to adopt the weather variability and determine farmers' preferred characteristics of rice and perception on climate change in rice variety selection. A sample of 203 rice farmers from Thazi Township were randomly selected and conducted interview. Descriptive analysis and weighted average method were employed. Rice varieties were very diverse and Manawthukha was the most favorite variety. The newly released salt tolerant variety, Pyi Myanmar Sein was adopted by only one percent of respondents. The farmers are quite aware of climate change and they claimed the extreme weather conditions are the most stressful to rice production and they want shorter duration variety in order to make sure the enough soil moisture because majority of them do not have access to irrigation water. Changing rice variety was the most cited coping strategy to climate change adaptation followed by changing crop, changing sowing time, practicing crop rotation, changing cultivation methods and managing fertilizer application. The most preferred trait was high yielding variety followed by high quality, resistance to disease, pests and drought.

Keywords climate change, strategy, adaptation, stress, traits, coping strategy

INTRODUCTION

Myanmar has been experiencing various features of climate change conditions such as frequent and strong storms, floods, late onset of monsoon, early departure of monsoon, lower minimum temperature and higher maximum temperature, erratic rainfall patterns, frequent falls of hales and thunder storms, and sea level rise, etc. According to the long-term climate risk index (CRI) published by Germanwatch, Myanmar stood as the third most affected country in the world on annual average from 1998-2017**.** Increased intensity of storms has taken a toll on small island states and poor countries since 1997, and over 520,000 people have been killed by more than 11,000 extreme weather events (Burck et al., 2017). Myanmar is the second most vulnerable country revealed by global climate risk index. Extreme weather events have a strong negative impact on economic development of a developing country. Besides, their main economic sector is still agriculture and it is extremely vulnerable to weather variabilities. Furthermore, more than two third of farming society are smallholders and they grow rice in rain fed and/or irrigated lowland area in Myanmar. Therefore,

this study was conducted to learn more about how socioeconomic background of farmers and their perceptions on climate change affect their choice of rice varieties.

OBJECTIVE

The study was conducted to meet the objectives for to overview the socioeconomic characteristics of farmers, find out the serious problems faced by the farmers in rice production, know the most practicing coping strategy to adopt the weather variability and determine farmers' preferred characteristics of rice and perception on climate change in rice variety selection.

METHODOLOGY

Description of Study Area

This study was conducted in Thazi Township located in Meiktila District of Mandalay Division, Myanmar. Thazi Township is situated in North Latitudes 20˚ 50' and East Longitude 95˚ 59', and its area is 2,039 km². It is located in Central Dry Zone of Myanmar and has a tropical climate. According to the Department of Population (2014 Census, 2015), its total population was 202,680 - males were 95,463 and females were 107,217. In Thazi Township, about 182,119 (89.9 %) of its population live in rural area and about 20,561 (10.1 %) live in urban area.

Data Collection

For this study, both quantitative and qualitative data were used. Pilot survey was done in November and main survey was conducted in December 2016. Simple random sampling method was used to collect primary data and 203 sample farmers from 19 villages in Thazi Township were interviewed by using structured interview schedule. Secondary data were collected from the Township Department of Agriculture Office.

Methods of Analysis: Descriptive Analysis

Descriptive analysis was used to describe demographic characteristics of the household such as age, education, family size, farming experience, farm size and agricultural land utilization and to observe the problems faced by the rice farmers.

Weighted Average

Weighted average method was used to investigate farmers' preferences on rice varietal characteristics. Farmers' preferences were categorized into three groups: production characteristics, stress tolerant characteristics and grain quality characteristics. Farmers were requested to score on the given rice varietal traits. If they assumed that the given trait was extremely important or important, the trait was scored as 3 or 2, respectively. If the trait was assumed as not important, it was scored as 1.

$$\text{Weighted Average} = \frac{\text{Sum of Weighted Terms}}{\text{Total Number of Terms}}$$

The score values were calculated by using weighted average method to rank farmers' preferences on rice varietal trait.

RESULTS AND DISCUSSION

Socioeconomic Conditions of Farmers

The demographic characteristics such as age, farming experience, family size, education and farm size the sample farmers are presented in Table 1. In Thazi Township, the average farmer age was 55.6 years, and ranging from 28 to 86 and most farmers are quite old. Agriculture is mainly threatened by climate change and becoming less profitability. Therefore, young people from rural area are not interested in agriculture and moving out of rural areas. That is becoming an important issue for Myanmar Agriculture. The average farming experience was 29.6 years with the range of 2-70 years. Although farmers have many years of farming experience with a lot of knowledge and experience in agriculture, they may rarely adopt new agricultural technologies. The average family size was 5.5, ranging from 1 to 14 family members. In case of education, the average schooling years was 7.3, and ranging from 3 to 16 years. Some farmers were graduated, and thus they can adopt new technologies and can manage their farm very well. The average farm size was 4.1 hectares with a range between 0.4 and 14.9 hectares, respectively.

Table 1 Demographic characteristic of the respondents in Thazi Township

Items	Unit	Average	Minimum	Maximum
Age of household's head	Year	55.6	28	86
Farming experience of household's head	Year	29.6	2	70
Family size	No.	5.5	1	14
Education of household's head	Year	7.3	3	16
Farm size	ha	4.1	0.4	14.9
Low land (70.2 %)	ha	3.0	0.4	13.0
Upland (29.2 %)	ha	1.7	0.2	8.1
Orchard (0.6 %)	ha	2.8	2.4	3.1

In Thazi Township, the average farm size of lowland, upland and orchard were 3.0, 1.7 and 2.8 hectares, respectively. Lowland area ranged from 0.4 to 13.0 hectares while upland area ranged from 0.2 to 8.1 hectares. Orchard was the smallest agricultural land area, ranging from 2.4 to 3.1 hectares. Among the agricultural land areas, lowland occupied 70.2%, and rice was the major crop in Thazi Township. Upland growing area was the second largest, and it occupied 29.2%. Orchard was the smallest area and it was only 0.6% of total agricultural land of the respondents.

Table 2 Annual household incomes in Thazi Township (MMK in million)

Types of Income	N	Average	Minimum	Maximum
Crop Income	203	3.51	0.08	33.70
Livestock income	61	1.68	0.18	6.40
Off-farm income	16	0.84	0.03	4.73
Non-farm income	106	2.36	0.02	8.64
Total annual household income	203	5.32	0.38	38.70

Annual household incomes earned by respondents in Thazi Township are shown in Table 2. Crop income was the main income source for sample farmers. Average crop income was 3.51 million MMK per year for farmers, ranging from 80,000 MMK to 33.7 million MMK per year. Livestock income was earned by 61 respondents, and it amounted to 1.68 million MMK in average per year while maximum and minimum livestock incomes were 0.18 million MMK to 6.4 million MMK per year, respectively. Only 16 respondents had off-farm income, and the average off-farm income was 0.84 million MMK per year. The maximum off-farm income was 4.73 million MMK per year, but the minimum income was only 30,000 MMK per year. Non-farm income was earned by 106 sample households, and the average non-farm income was 2.36 million MMK per year ranging from 20,000 MMK to 8.64 million MMK per year. As a total annual household income, the average annual household income was 5.32 million MMK per year. The minimum and maximum total annual household incomes were 0.38 million MMK and 38.7 million MMK per year.

Problems Faced by Rice Farmers

As lowland was the largest area, rice was the major crop in Thazi Township. Therefore, stress or problems in rice production faced by the respondents were collected. It was found that six main stresses for rice farmers were climate change, insects, disease, salinity, rats and weeds. According to the opinions of farmers, the largest group of respondents (48.3%) assumed that climate change is one of the biggest stresses for rice production. The second (31%) and third (15.3%) biggest group of farmers said that insects and diseases were major serious problems for rice production. In addition, 4.4% of respondents thought that soil salinity was one of the problems for rice production. Incidence of rats and weed problems were faced by 3.4% of respondents. Moreover, 6.9% of respondents faced other stresses such as scarcity of labor and high price of inputs, especially fertilizer in their rice production. (Figure 1)

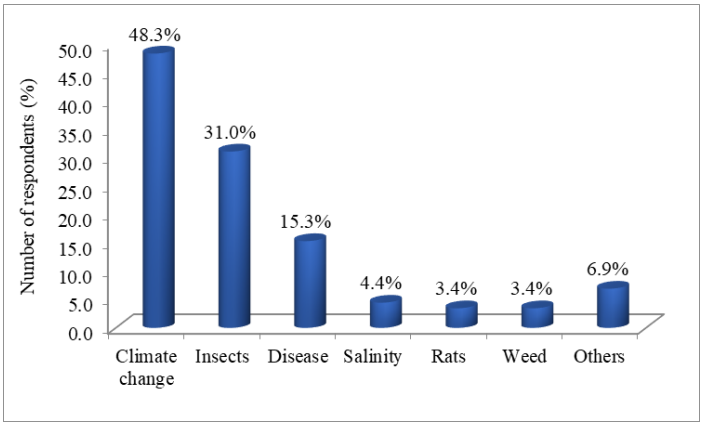

Figure 1 The stresses in rice crop production in Thazi Township

Climate Change Coping Strategies

Table 3 Adaptation strategies to climate change in Thazi Township

Response to climate change	Frequency	Percent (%)	Rank
Change varieties	88	41.7	1st
Change crop	57	27.0	2nd
Change sowing time	18	8.5	3rd
Crop rotation	15	7.1	4th
Change cultivation methods	10	4.7	5th
Use fertilizer	10	4.7	5th
Use underground water	4	1.9	6th
Put F.Y.M	4	1.9	6th
Use traditional varieties	3	1.4	7th
Use quality seeds	2	0.9	8th

Since climate change was the major stress according to farmers' opinion, adaptation strategies of local farmers to climate change were observed. According to the results, changing crop varieties was the strategy used by most of the respondents (41.7%) to combat climate change. It was followed by changing crop as the second rank and used by 27% of respondents. Changing sowing time, practicing crop rotation, changing cultivation methods and using fertilizer were the strategies used by 8.5%, 7.1%, 4.7% and 4.7% of respondents, respectively. Using underground water, putting F.Y.M and using traditional varieties were used by 1.9%, 1.9% and 1.4% of respondents. Using quality seeds was the least strategy used by respondents (0.9%) to adapt to climate change (Table 3).

Farmers' preferences on production characteristics of rice are shown in Table 4. Majority of farmers preferred the trait of high yielding most. It is clear that a variety to be yielding high is the most important factor for rice growing farmers. Moreover, farmers preferred rice variety trait of high yield with less inputs, and it was ranked as the second. However, few of them think rice variety with that trait is not that important. Rice variety producing high number of tiller ranked as third factor

according to farmers' preferences. Most of farmers assumed that the more the tiller numbers, the higher the rice yields. Resistance to lodging and shorter growing duration were ranked as fourth and fifth factors, respectively. Heavy rains and floods caused lodging of rice plants causing the yield loss. If the farmers were able to grow lodging resistant variety, they could reduce yield loss. Short duration variety can avoid extreme climatic conditions relative to traditional long duration variety. In addition, farmers preferred shattering resistant variety as the sixth rank. It is clear that shattering leads to both pre-harvest and post-harvest yield losses. Therefore, shattering resistant variety is also important for farmers. High rice straw production was ranked as the last according to farmers' preferences. Farmers mostly used rice straw for cattle feeding. During recent years, cattle have been scarce in the study area, and some of farmers did not prefer to get high rice straw.

Table 4 Farmers' Preferences on Production Characteristics of Rice

Production characteristics	Extremely important	Important	Not important	Weighted average	Rank
	3	2	1		
High yield	198	4	1	2.97	1st
high yield with less inputs costs	191	7	5	2.92	2nd
High tillering	181	17	5	2.87	3rd
Resistant to lodging	164	29	10	2.76	4th
Shorter growing duration	130	48	25	2.52	5th
Resistant to shattering	115	38	50	2.32	6th
High straw production	82	47	74	2.04	7th

Farmers' preferences on stress tolerant characteristics of rice are presented in Table 5. Majority of farmers preferred pests and diseases resistant varieties, and ranked them as first and second, respectively. Actually, pests and diseases are the main important stresses or problems for farmers, thus farmers preferred pest and disease resistant varieties most. Since the study area is in the dry zone, farmers preferred drought and salinity tolerant varieties as third and fourth ranks, respectively. In addition, some farmers preferred rice variety tolerant to cold injury, and it ranked fifth. Flood or submergence was also one of the stresses for some farmers, and it ranked sixth.

Table 5 Farmers' Preferences on Stress Tolerant Characteristics of Rice

Stress tolerant characteristics	Extremely important	Important	Not important	Weighted average	Rank
	3	2	1		
Resistant to pests	184	15	4	2.89	1st
Resistant to diseases	183	14	6	2.87	2nd
Tolerant to drought	173	15	15	2.78	3rd
Tolerant to salinity	76	43	84	1.96	4th
Tolerant to cold injury	81	30	92	1.95	5th
Tolerant to flood/submergence	66	24	113	1.77	6th

Rice varieties Grown in the Study Area

There were about twenty varieties of rice grown in Thazi Township. The farmers are still growing the local varieties which still suit the weather and soil type. During the survey period, there was no summer paddy cultivation because of no supply of irrigation water from the dams. Therefore, the study included the only monsoon season rain-fed rice. Local cultivars are the primary source for farmers to cope with changing environments. Genetic diversity gives a species or a population that can have the ability to adapt to changing environments (Sthapit. et.al., 2007). Manaw Thukha was the most popular rice variety among others and mainly grown by nearly half of the respondents (49.8%). (Table 6)

Table 6 Rice varieties grown in Thazi Township

No.	Rice Varieties	F	%	No.	Rice Varieties	F	%
1.	Manaw Thukha	101	49.8	12.	Shwe Manaw	2	1.0
2.	90 Days	29	14.3	13.	Thee Htet Yin	2	1.0
3.	Sat Thukha	17	8.4	14.	Byawt Tun	2	1.0
4.	Thukha Tun	16	7.9	15.	Mann Nga Sein	1	0.5
5.	Khun War	6	3.0	16.	Shine Nat	1	0.5
6.	Yezin Thukha	4	2.0	17.	Tun Thiri	1	0.5
7.	Pale Thwe	4	2.0	18.	Taung Htate Pan	1	0.5
8.	Shwe Pyi Htae	4	2.0	19.	Shwe Manaw	1	0.5
9.	100 Days	3	1.5	20.	Yadana Thukha	1	0.5
10.	Shwe Poe	3	1.5	21.	Byawt Thukha	1	0.5
11.	Pyi Myanmar sein	2	1.0	22.	Shwe Thwe Yin	1	0.5

CONCLUSION

Poverty prone rural dry zone still depends on rice cultivation and it is at the high risk under climate change. Farmers change the rice varieties with shorter days to secure the moisture to get filled grains in rain fed low land area. Nevertheless, they still prefer the high yielding variety most to reap high profit. On the contrary, they are facing problems with so much weather variability resulted in poor yield and profit. That is why more suitable variety for climate change resilient one, 90 Days variety was gradually accepted by many farmers. It is recommended that income diversification is one of the good strategies to combat the climate change impacts that more than half of farmers have non-farm incomes and many of them have income from livestock raising.

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Research article

Estimation of Flooded Areas and Water Levels after the Heavy Rain in July 2018 in Okayama

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Abstract Paddy fields in the Osaka Prefecture were heavily flooded by heavy rain in July 2018 due to levee breaches. To estimate the flooded area and water level, it was necessary to combine aerial- and ground-based surveying. Accordingly, aerial photographs of the flooded area were taken on the day after the heavy rain. In this study, we developed a digital surface model (DSM) of the flooded area using the structure-from-motion (SfM) software, which can produce three-dimensional (3D) models based on multiple aerial photographs and multiple ground control points (GCPs). Using the global navigation satellite system (GNSS), we surveyed the target area to observe the 3D coordinate values of the GCPs. The DSM of the flooded area could be made by the SfM with the aerial photographs and GCPs. The DSM was input into the geographic information system to analyze the flooded area and water level. The water levels were calculated from the differences between the DSM and the digital elevation model (DEM). We used airborne laser surveying to build the DEM because it provides higher accuracy than the SfM software. To check the accuracy of the DSM, we compared the elevations of the DSM on the ground points of non-flooded areas with those of the DEM, and the differences were found to be less than 0.2 m. Then, the water levels on the actual water level observation points were compared to verify their accuracy, and the differences were found to be less than 0.4 m. The flooded area was found by overlaying the water level on the existing map.

Keywords structure-from-motion, digital surface model, digital elevation model, geographic information system, paddy field

INTRODUCTION

Heavy rain in July 2018 seriously affected the Okayama Prefecture in the west of Japan (particularly the paddy fields) due to levee breaches. As a result, nearly half of harvest of the paddy fields was lost.

A combination of aerial- and ground-based surveys was necessary for a prompt understanding of the complete picture of the damaged area (Kubodera et al., 2017). Therefore, we conducted an aerial photogrammetry and a global navigation satellite system (GNSS) survey. Aerial photogrammetry is a surveying technology that utilizes three-dimensional (3D) ground-based models, which are constructed from aerial photographs, camera coordinate values, and coordinate values of ground control points (GCPs). Based on the aerial photogrammetry, we also built orthophoto mosaics and a digital surface model (DSM), which captures the land surface elevations, including the heights of buildings and vegetation. An orthophoto mosaic is a single aerial photograph on which several orthographically projected aerial photographs are assembled. To obtain the coordinate values of the GCPs in the devastated areas, we conducted a GNSS survey (Yamazaki et al., 2019), which is a method to determine the positions using signals from positioning satellites, such as the global positioning system (GPS), global navigation satellite system (GLONASS), and Galileo. The accuracy of these satellites ranges from several meters to several millimeters. In this research, we conducted a network-based real-time kinematic (RTK) GNSS survey to determine the

coordinate values of the GCPs with an accuracy of several millimeters. We used the geographic information system (GIS) to determine the difference between the DSM and digital elevation model (DEM), which captures the ground elevations (excluding the heights of buildings and vegetation), to analyze the flooded area and water level in the paddy fields quantitatively.

We considered that aerial photogrammetry by airplane would be preferable than by satellite or drone for the analysis of the flooded area and water level. The aerial photographs used were captured from an airplane immediately after the heavy rain. The Geospatial Information Authority of Japan (GSI) has built a detailed database of Japan's land surface from photographs taken from airplanes and has released the DEM (5 m mesh) from airborne laser surveying throughout Japan. Furthermore, the GSI has released aerial photographs of Okayama taken immediately after the heavy rain in July 2018.

METHODOLOGY

Figure 1 shows the target area of the survey and analysis. The Okayama Prefecture is located to the west of Osaka and Kyoto. Of the large area damaged by the heavy rain, we selected Mabi City to focus on the damage to paddy fields. Figure 2 shows the levee breach at the Oda river in Mabi City that caused the flooding of the paddy fields. The first author took the picture on November 10, 2018.

We used the photogrammetry structure-from-motion (SfM) software PhotoScan Professional, which allows the aerial triangulation based on multiple aerial photographs and multiple GCPs. It is used to build DSMs through image matching and create orthophoto mosaics automatically. Figure 3 shows the 3D model built in this study. The Oda river and paddy fields are in the center of Fig. 3; the point of water level observation, which was performed every hour, is in the right of Fig. 3. The twelve blue rectangles in the sky show the 3D positions from which the aerial photographs were taken. The 15 circles on the ground surface indicate the 3D positions of the GCPs where we conducted the GNSS survey. AS coordinate system, we used the Japanese geodetic datum (JGD) 2011 plane-rectangular coordinate system Area 5 (Matsumura et al., 2004; Tsuji and Matsuzaka, 2004; Imakiire and Hakoiwa, 2004; Geospatial Information Authority of Japan, 2011). We successfully set a group of 3D points on the ground surface through aerial photogrammetry. The aerial photographs were taken at 12:00 on July 9, 2018, immediately after the heavy rain with a well-calibrated digital aerial camera. Using the RTK GNSS surveying and inertial measurement unit (IMU) technology, we set the coordinate axes and altitudes of the digital aerial camera with an accuracy of several tens of millimeters.

As shown in Fig. 4, we conducted a network-based RTK GNSS surveying at GCPs in Okayama on November 10, 2018. We used the Trimble R10 for the GNSS surveying, and three types of satellites: GPS, GLONASS, and the quasi-zenith satellite system (QZSS). In addition, we used two frequency bands: L1 (1575.42 MHz) and L2 (1227.60 MHz). We used the geoid model GSIGEO2011 (Miyahara et al., 2014; Kubodera et al., 2016). For the GNSS survey at the GCPs, we selected the fifteen points enclosing the flooded area and the point of observation of the water level, sites accessible by car, and pavements to obtain clear photographs.

We conducted aerial triangulation based on the 3D coordinate values of the camera and the GCPs. Table 1 shows the standard deviation (SD) values of the residual errors of the most probable values of fifteen GCPs. The SD values for the X and Y coordinates and elevation H were lower than 0.10 m, indicating high accuracy.

We created a DSM with 0.4 m mesh to determine the differences between the DSM and DEM. Furthermore, we created orthophoto mosaics to obtain more information on the flooded area.

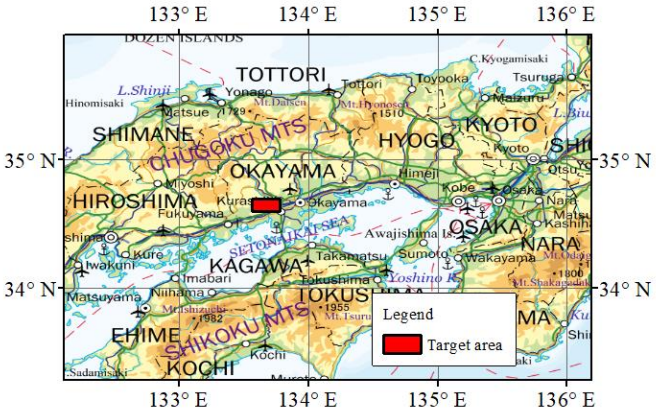

Fig. 1 Target area in Okayama

Fig. 2 Levee breach at Oda river in Mabi City (The first author took the picture on November 10, 2018)

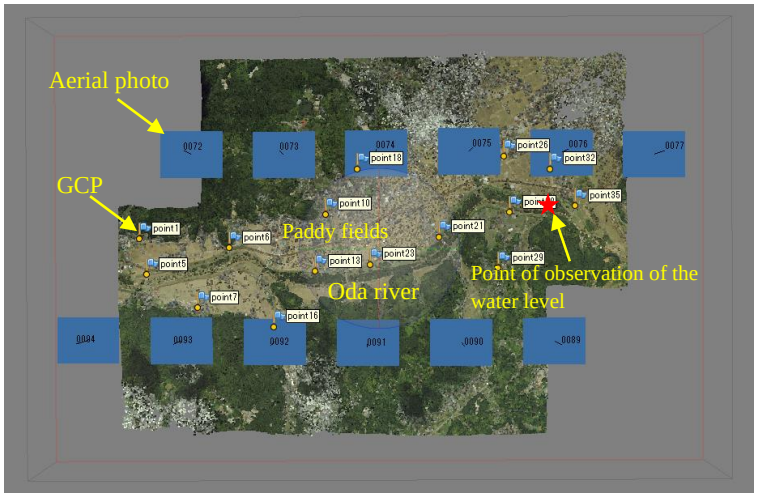

Fig. 3 3D model by aerial photogrammetry

Fig. 4 GNSS surveying

Table 1 SD values of the residual errors of the most probable values of fifteen GCPs

	X [m]	*Y* [m]	*H* [m]
SD	0.097	0.061	0.078

RESULTS AND DISCUSSION

Specifying the Position of Levee Breaches with Orthophoto Mosaics

Figure 5 shows the orthophoto mosaic developed from the GIS. For the aerial photogrammetry, we used the coordinate axis JGD2011 Plane-rectangular Coordinate System Area 5. The GIS software used was ArcGIS 10.7. By comparison with an existing map, we confirmed that the mosaic was developed on the designated positions correctly. The black areas in Fig. 5 were either not in the aerial photograph field of view or covered by cloud or water, because SfM could not create the clouds and water. As shown in Fig. 6, we successfully specified the exact positions of the levee breaches, and the orthophoto mosaic indicates that the paddy fields were flooded.

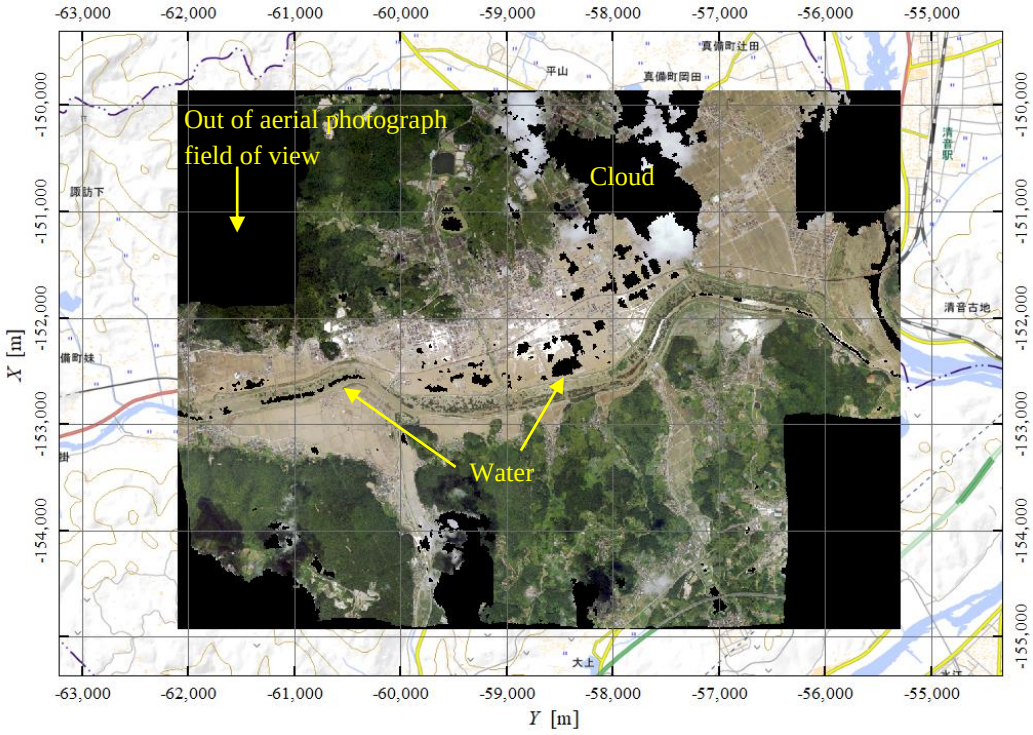

Fig. 5 Orthophoto mosaic developed from the GIS

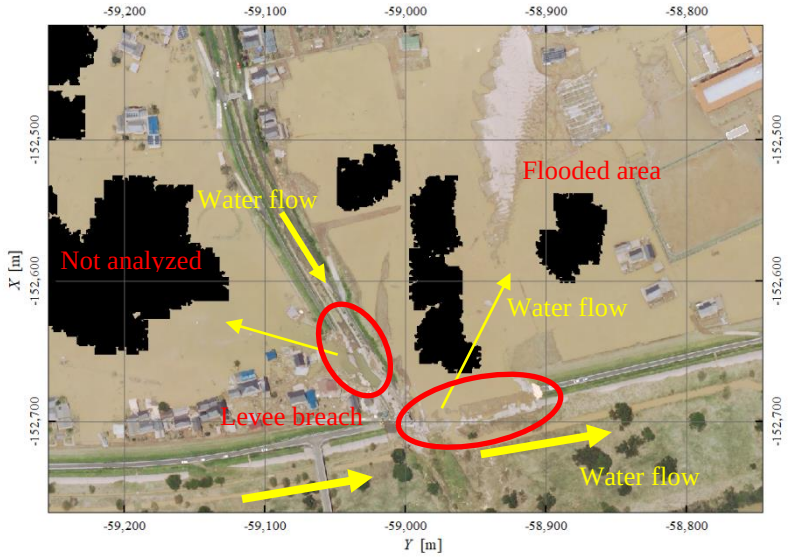

Fig. 6 Levee breaches and flooded paddy fields based on the GIS

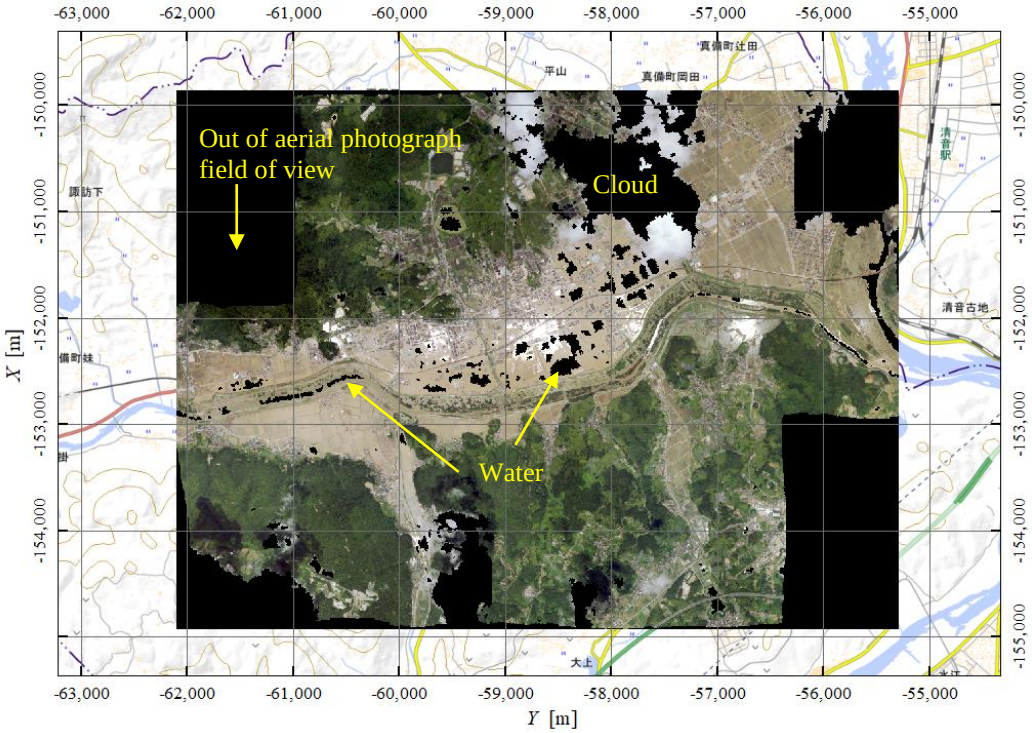

Fig. 5 Orthophoto mosaic developed from the GIS

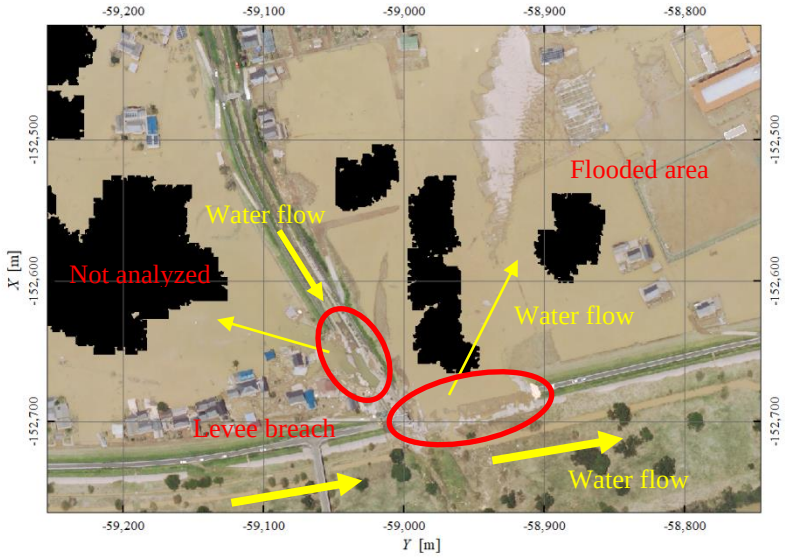

Fig. 6 Levee breaches and flooded paddy fields based on the GIS

DSM accuracy verification

We compared the elevation values of the DSM to those of the actual water surface at the point of water level to verify the accuracy of the constructed DSM. Figure 7 shows a photograph of the instrument used to observe the water level in Yakatabashi, which observed the actual water level every hour during the heavy rain in July 2018. The first author took the picture on October 29, 2018. Figure 8 shows the DSM of the area around Yakatabashi. The areas of not-heat-map were those that PhotoScan Professional could not create the DSM. Table 2 shows the elevation values in the DSM around Yakatabashi at 12:00 on July 9, 2018. The aerial photographs were taken at 12:00 on July 9,

2018. So, this DSM was at 12:00 on July 9, 2018. The elevation values of DSM were measured at 10 points in the water surface of the verification area of Fig. 8. The average and SD of the ten elevation values were 8.208 and 0.096 m, respectively. Table 3 shows the elevation values of the actual water surface at Yakatabashi on July 9, 2018. As shown in the table, the elevation values of the actual water surface at 12:00 was 8.167 m. Therefore, the difference between the elevation values of the DSM and those of the actual water surface was +0.041 ± 0.096 m.

Fig. 7 Photograph of the location of the water level observation in Yakatabashi (The first author took the picture on October 29, 2018)

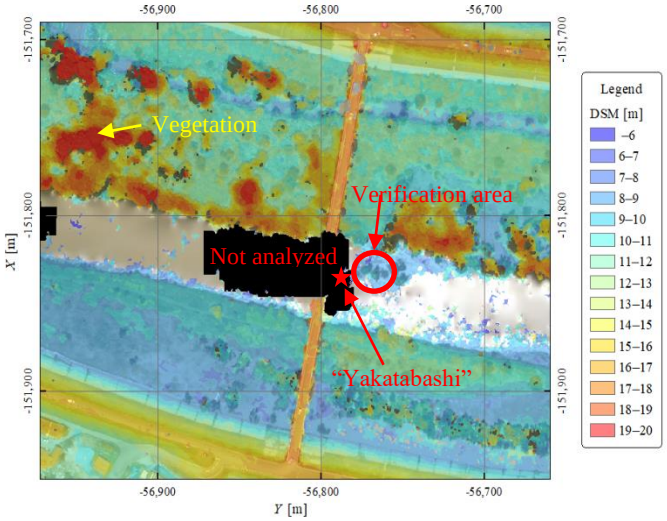

Fig. 8 DSM around Yakatabashi

Table 2 Elevation values in the DSM around Yakatabashi at 12:00 on July 9, 2018

No.	1	2	3	4	5	6	7	8	9	10	Ave.	SD
Elevation [m]	8.122	7.923	8.514	8.220	8.125	7.731	8.024	8.318	8.799	8.302	8.208	0.096

Table 3 Elevation values of the actual water surface at Yakatabashi on July 9, 2018

Time	09:00	10:00	11:00	12:00	13:00	14:00	15:00
Elevation of water surface [m]	8.507	8.357	8.247	8.167	8.107	8.047	7.987

Differences between DSM and DEM

To build the DEM before the heavy rain, we used the results (5 m mesh, elevation value in units of 0.01 m) obtained from the GSI. We deducted the elevation values of the DEM before the heavy rain from those of the DSM after the heavy rain to obtain the differences. Figure 9 shows the results of the analysis in the same area as that shown in Fig. 6. The black areas indicate areas for which the PhotoScan Professional software could not create the DSM. We whited out the objects with a height difference greater than 3 m because these were assumed to be buildings or vegetation. The analysis results indicate that the vertical water level was 0−2 m and vertical levee breaches levels were between -5 and -6 m. Based on the analysis of the differences between the DSM and DEM, we successfully clarified the vertical water level both dimensionally and quantitatively.

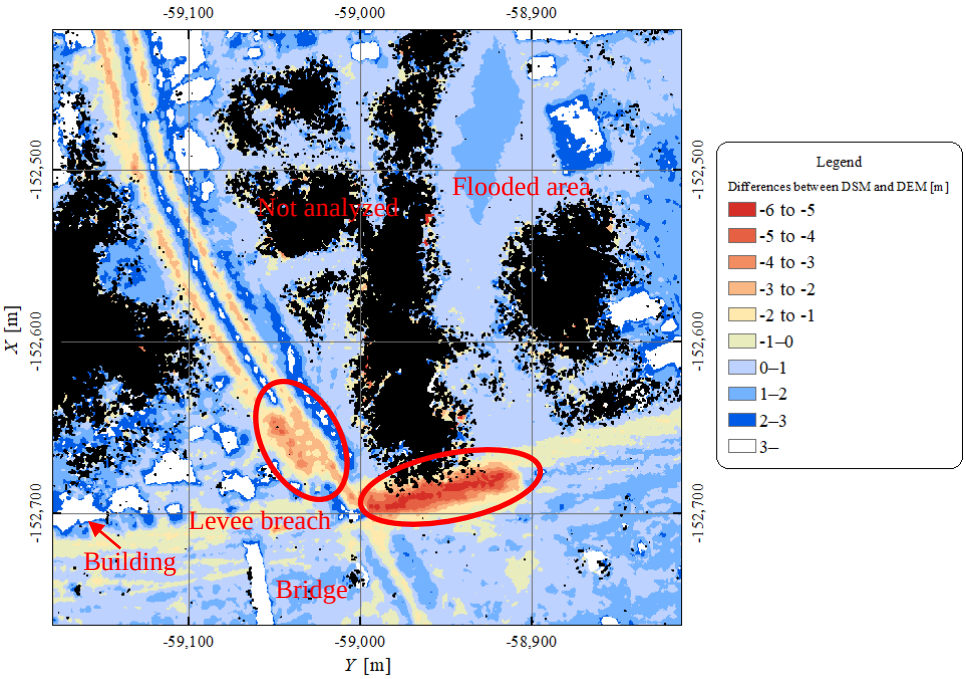

Fig. 9 Differences between DSM and DEM

CONCLUSION

The contributions of this study are as follows:
(1) The exact levee breach in flooded paddy fields was specified based on the orthophoto mosaic.
(2) We compared the elevation values of the DSM and those of the actual water surface at the point of water level observation to verify the accuracy of the constructed DSM. We determined that the difference between the elevation values of the DSM and those of the actual water surface was +0.041 ±0.096 m.
(3) The analysis of the differences between the DSM and DEM indicated that the vertical water level was 0−2 m and the vertical levee breaches were levels were between -5 and -6 m.

ACKNOWLEDGEMENTS

We express our gratitude to the Information Provision Support Team of the Major Disaster Management Headquarters of the GSI for providing the aerial photographs used in this research in order to support the recovery project implemented by the Okayama Prefecture.

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Research article

Cover Crop Mixtures Effects on Soil Physical and Chemical Properties in Japan

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Abstract Agricultural management practices such as cover crop could restore soil physical and chemical properties, and in turn positive effect of crop productivity. However, it can vary with soil type, climate, and type of cover crop species. In addition, different cover crops provide different benefits to agricultural land. For instance, legumes (e.g. clover (*Trifolium repers* L.)) fix atmospheric nitrogen (N) for their own use. After terminating the legume cover crop, it will release N into the soil as the residues decompose and provide available N to the main crops. Some of cover crop (e.g. phacelia (*Hydrophylloideae*)) are able to suppress weeds or prevent insect damages by competition, shading, and allelopathy. Recently, researchers reported that cover crop mixture may provide greater diversity of benefits than monoculture cover crop. Therefore, the objective of this study was to demonstrate soil physical and chemical properties assessment under cover crops (clover, phacelia, and their mixture) vegetation.

Keywords cover crop, mixture, soil organic carbon, soil physical and chemical property

INTRODUCTION

Cover crops have numerous benefits for agriculture practices (Murrell et al., 2017). According to the Soil Science Society of America (SSSA), cover crops are defined as a "close-growing crop that provides soil protection, seeding protection, and soil improvement between periods of general crop production, or between trees in orchards and vines in vineyard, and when plowed under and incorporated into the soil, cover crops could be referred to as a green manure crop" (SSSA, 2008).
In addition, cover crops have the potential to enhance ecosystem services such as 1) increasing food, feed, fiber, and fuel productivity 2) soil organic carbon and other nutrient and water cycling, and 3) soil, water, and air quality/health improvement (Blanco-Canqui et al., 2015). Cover crop may be alternative for chemical fertilizer and pesticide. While actively growing, cover crops increase solar energy harvest and carbon flux into the soil, providing food for soil microorganisms, while simultaneously increasing evapotranspiration from the soil (Dabney et al., 2007). Moreover, cover crops have been proposed in the United State to increased soil organic carbon (SOC) stock of eroded and degraded soils and sequester SOC and according to the research, the result showed that cover crop management could increase SOC by 1.12 Mg-C ha^{-1} yr^{-1} with no-tillage agricultural practices (Olson et al., 2014).

Different cover crops provide different benefits to agricultural land. For instance, legumes (e.g. clover (*Trifolium repers* L.)) fix atmospheric nitrogen (N) for their own use. After terminating the legume cover crop, it will release N into the soil as the residues decompose and provide available N

to the main crops. Some of cover crop (e.g. phacelia (*Hydrophylloideae*)) are able to suppress weeds or prevent insect damages by competition, shading, and allelopathy. Cover crop may be alternative for chemical fertilizer and pesticide.

Recently, researchers reported that cover crop mixtures could provide greater diversity of benefits than monoculture cover crop (Murrell et al., 2017; Tribouillois et al., 2016). Cover crop mixtures increase plant species diversity, in turn, potentially increasing ecosystem services that directly or indirectly improve main crop productivity (Zhang et al., 2007; Clark et al., 1994; Murrell et al., 2017). Yet the effects of cover crop mixtures on soil physical and chemical properties vary by climate, soil type, management practices, and a species of cover crops. Thus, there is a need for site, soil, and cover crop species-specific research on cover crop mixtures.

OBJECTIVE

The objective of this study was to demonstrate soil physical and chemical properties assessment under cover crops (clover, phacelia, and their mixture) vegetation.

METHODOLOGY

Experimental Design

The experiment was carried out at the field research plot, Tokyo University of Agriculture (35°38’29’’N, 139°37’56’’E, 40.3m elevation) during July to October in 2018 (Fig. 1). On average this site received 1464 mm of precipitation annually and mean annual temperature was 15.0 ℃, respectively. Treatments included four cover crop systems: clover (*Trifolium repers* L.), phacelia (*Hydrophylloideae*), their mixture (clover and phacelia), and control (without cover crop) using Wagner pot (diameter = 256 mm, height = 297 mm, 1/2000a-scale). In this study, soils were taken from subsoil under arable land and were relatively the sterile soils. Soil are classified as Andosol and silty loam (sand 69.1 %, silt 19.9 %, and clay 11.0 %) by IUSS (International Union of Soil Sciences) classification.

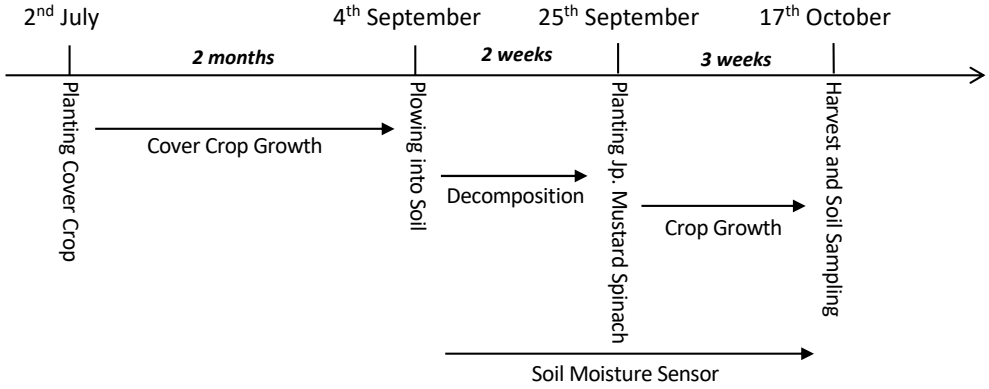

Fig.1 Experimental Schedule

Soil Analysis

Soil pH and electrical conductivity (EC) were determined using 1:1 soil to water ratio (Glendon and Dani, 2002). Concentration of SOC and total nitrogen (TN) were measured following the dry combustion method (960℃) using an automatic nitrogen-carbon analyzer (Sumika Chemical Analysis Service, Ltd., Tokyo, Japan). Briefly, the soil samples preparation was as follow; oven-dried (below 60℃) samples were ground with a mortar and pestle to allow passage through a 250 μm sieve, and then roller ground to yield a fine and homogeneous sample. Soil hardness was measure

using yamanaka soil hardness tester (Daiki Rika Kogyo Co., Ltd, Tokyo, Japan). Saturated hydraulic conductivity (K_s) was measured with a mini disk infiltrometer (METER Group Inc., USA). Temporal changes of water content were measured by TDR (time-domain reflectometer) (5TE, METER Group Inc., USA).

Statistical Analysis

Analysis of variance was conducted comparisons between clover, phacelia, mixture, and control. The data were analyzed statistically using Tukey's test in R-Studio (Studio 2012). Statistical significance was computed at $p \leq 0.05$, unless otherwise stated.

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties

Data of soil physical and chemical properties of different cover crop treatments (clover, phacelia, and mixture, and control vegetations) are shown in Table 1. Cover crop vegetation did not significantly affect pH. A similar trend in EC was observed at different cover crop treatments. Cover crop treatments significantly affect SH ($p < 0.05$). Cover crop with Mixture can alleviate soil compaction by penetrating compact layers and acting similar to tillage tools or bio drill. Blanco-Canqui et al (2015) stated that cover crop can alleviate compaction and reduce the susceptibility of the soil compaction. this benefit depends on the length of cover crop, and the amount and characteristics of the length and the size of roots. In addition, cover crop may improve soil compatibility by improving soil aggregation and increasing SOC concentration. Cover crop treatments significantly affected the K_s ($p < 0.05$). K_s under Control treatment was higher than other treatments. Cover crop may have intact bio-channel (e.g. root) which increase the subsurface channel network and may enhance the K_s. Cover crop mixture can positive impacts on Japanese Mustard Spinach. However, weather conditions (e.g. precipitation and temperature) and soil type are also important factors impacting vegetable yields response to cover crop management. The cover crop treatment especially Mixture improved the overall soil physical and chemical properties and Japanese Mustard Spinach in this study.

Table 1 Effects of cover crops on soil, pH, electrical conductivity (EC), Soil hardness (SH), Saturated hydraulic conductivity (K_s), and Yield of Japanese Mustard Spinach

	pH	EC	SH	*Ks*	Japanese Mustard Spinach
	-	mS cm^{-1}	mm	cm s^{-1}	Mg ha^{-1}
Clover	6.82^{a}	0.129^{a}	19.5^{b}	2.36×10^{-3}	13.6^{ab}
Phacelia	6.83^{a}	0.136^{a}	19.5^{b}	2.51×10^{-3}	8.52^{b}
Mixture	6.87^{a}	0.131^{a}	20.8^{ab}	3.69×10^{-3}	15.6^{a}
Control	6.80^{a}	0.125^{a}	26.5^{a}	6.63×10^{-4}	10.8^{ab}

**Means with different letters among before vs. after logging soil for each depth are not significantly different at $p \leq 0.05$.*

The data in Fig. 2 show the soil organic carbon and total nitrogen contents under clover, phacelia, their mixture, and control treatments. The largest SOC concentration was observed in Mixture treatment, while the lower SOC concentrations were observed in Control and Clover. Similarly, the greatest TN concentration was obtained in Mixture treatment, while lower TN concentrations were obtained Clover, Phacelia, and Control. In general, cover crop residues and root accumulate on the soil surface layer. It leads to increase SOC concentration. Moreover, belowground biomass such as root inputs may particularly be important to increase SOC concentration (Blanco-Canqui et al., 2015). In turn, for the long-term strategy, cover crop mixture increases the SOC concentration, and it may improve the vegetable production.

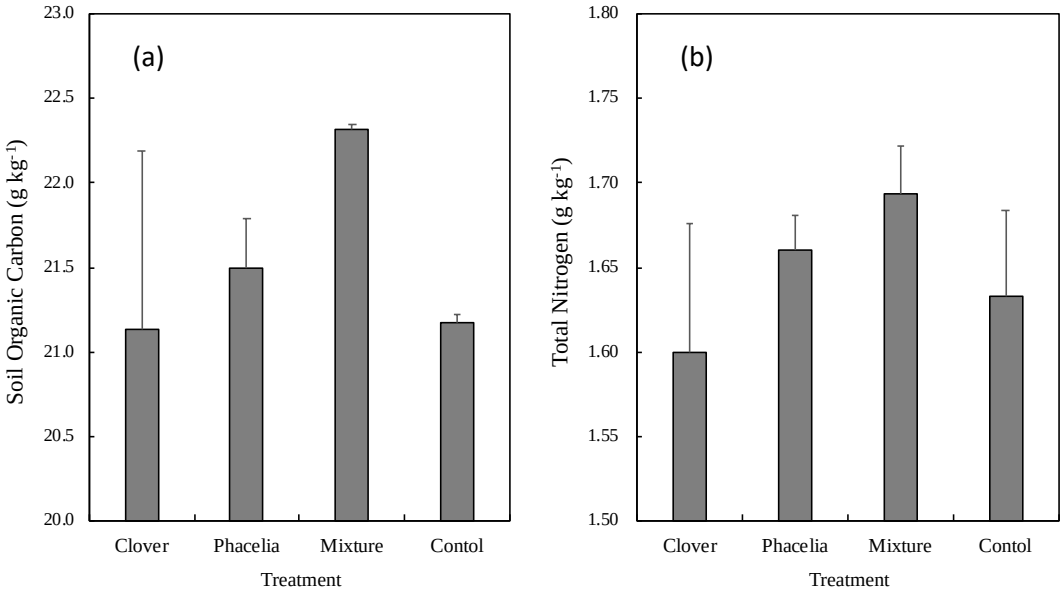

Fig. 2 Soil organic carbon (a) and total nitrogen (b) contents under clover, phacelia, their mixture, and control treatments. Means with same letter within treatments do not differ significantly with $p \leq 0.05$. Error bars represent ± one standard deviation

Figure 3 shows that temporal changes of water content under clover, phacelia, and their mixture treatments. Phacelia and Mixture had higher the volumetric water content than Clover during the experiment. In general, cover crop roots and surface residues improve soil macro-porosity which increase water retention capacity (Blanco-Canqui *et al.*, 2015). Cover crop also can improve soil hydraulic properties such as water infiltration, water retention capacity, and saturated hydraulic conductivity through improved the soil structure, especially, soil aggregation.

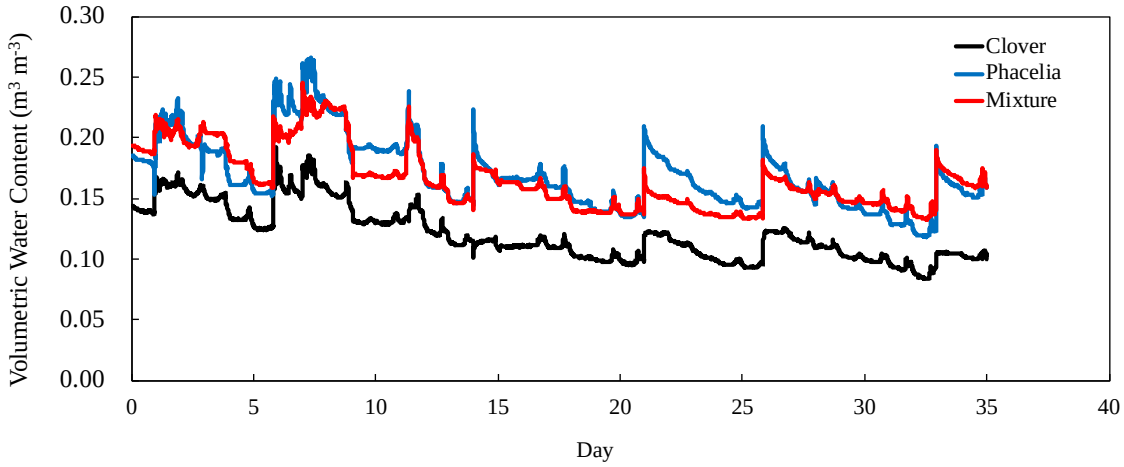

Fig. 3 Temporal changes of water content under clover, phacelia, and their mixture treatments

CONCLUSION

The hypothesis that that the cover crop mixtures could provide greater diversity of benefits than monoculture cover crop and increase plant species diversity, in turn, potentially increasing ecosystem services that directly or indirectly improve main crop productivity is proven. The data also support

following conclusions: 1) Cover crop with Mixture can alleviate soil compaction by penetrating compact layers and acting similar to tillage tools or bio drill 2) Cover crop mixture can positive impacts on Japanese Mustard Spinach 3) Cover crop also can improve soil hydraulic properties such as water infiltration, water retention capacity, and saturated hydraulic conductivity through improved the soil structure, especially, soil aggregation.

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Research article

Does the Downward Trend of the Farming Population in Remote and Mountainous Areas increase the Average Farm Size? A Community Level Data Analysis in Tohoku Region, Japan

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Abstract Over the last several decades, Japan's farming population has gradually decreased and the average age of farmers has risen. The recent agricultural census 2015 indicated that there were 2.09 million people engaged in agriculture, which is a reduction of 60% compared to three decades earlier. The decline in farming populations is robust and is taking place in many agricultural communities in Japan. However, the impacts of the declining farming population differ significantly on the basis of the conditions of farming land. Retirement of aged farmers provides farming opportunities for young, local farmers, consequently leading to an expansion in the size of farms. In fact, the average farm size per household in Japan doubled from 1.05 ha in 1985 to 2.20 ha in 2015. This represents a positive aspect of aging and the decreasing farming population. On the other hand, farmland abandonment has been prominent in the last 30 years, accounting for nearly 10% of total farmland. In the remote and mountainous areas of Japan, maintaining agricultural activities is increasingly difficult, thereby casting doubt on the sustainability of agricultural production and rural communities. In such a case, the average farm size does not increase, weakening rural economies and communities. This study uses approximately 14,000 community-level data in the Tohoku region of Japan and examines the land conditions that induce an increase in average farm size. The land conditions we consider are (1) steepness, (2) elevation, and (3) time-distance from a city. Quantile regression analysis is carried out to identify land conditions and other socio-economic variables associated with average farm size. Our regression analysis indicates that farm size does not necessarily increase where farm sizes are initially small, even in the case of declining farming population. Discussion within agricultural communities to build trust and consensus on distributional conflicts are considered to be an effective countermeasure to increase farm sizes in remote and mountains areas. The empirical evidence suggests the need for varied policy interventions in accordance with land conditions.

Keywords farm size, agricultural community, quantile regression, farmland abandonment

INTRODUCTION

Family farmers in different locations face different constraints to agricultural development. In Asia, it can be generalized that land scarcity has been the most serious constraint, although this can be addressed through increasing land productivity at an initial stage of agricultural development (FAO, 2014). As land productivity increases with the use of fertilizer, pesticide, irrigation, and the use of

modern technology, labor scarcity becomes the next most serious constraint, to which mechanical technologies are adapted to reduce labor cost. As labor moves from the agricultural sector to non-agricultural sectors, increasing labor productivity of the remaining farmers becomes vitally important to maintain farm incomes. This is the second phase of agricultural development. Many Asian countries, including Japan, are now in the second phase of agricultural development (FAO, 2014). Priority has shifted from increasing land productivity to increasing labor productivity and farmers' incomes, which requires increasing farm size. The question to be asked is whether the average farm size has been increasing in accordance with the downward trend of the farming population.

The recent agricultural census 2015 indicated that 2.09 million people engaged in agriculture, which represents a decrease of 60% compared to three decades earlier (MAFF, 2018). The decline in the farming population is robust and is taking place in many agricultural communities in Japan. A declining farming population has both positive and negative impacts on rural communities. On the positive side, there are increased opportunities to expand the farming size because the retirement of aged farmers generally provides farming opportunities with neighborhood and/or young farmers, consequently leading to an expansion in farming size. In fact, the average farm size per household in Japan doubled from 1.05 ha in 1985 to 2.20 ha in 2015 (MAFF, 2018). However, farmland abandonment has also been prominent in the last 30 years, accounting for nearly 10% of total farmland (MAFF, 2018). When farmland is not taken over by farmers of the next generation, maintaining agricultural activities becomes increasingly difficult, thereby casting a doubt on the sustainability of agricultural production and rural communities. It is highly important to preserve the farm and possibly to increase the farm size. Only a few studies have been carried out to examine the correlation among farm size, socio-economic variables, and community variable (Akimowicz. et.al, 2013), empirical analysis with larger datasets is still insufficient. Therefore, this study examines the socio-economic conditions under which farmers in rural communities increase farm sizes. Utilizing GIS datasets for the Tohoku Region of Japan, including elevation, slope, and time-distance to the city, along with other community variables such as the number of community meetings and the percentage of rural population over 65, we investigate the determinants of farm size.

MATERIALS AND METHOD

Data and Agricultural Community

Table 1 Basic statistics

Variable	notation	Mean	s.d.	min	max
Average Farm Size					
Farm size in 2015	y_{2015}	2.38	1.68	0.075	25
Farm size in 2010	y_{2010}	2.12	1.42	0.1	25
GIS Variables					
Elevation (100m)	z1	1.425	1.357	0.004	9.055
Slope	z2	2.57	2.58	0	20
Time-distance: 30 to 60 minutes	z3	0.26	0.44	0	1
Time-distance: 60 to 90 minutes	z4	0.04	0.20	0	1
Time-distance: over 90 minutes	z5	0.01	0.08	0	1
Community Variables					
# of community meetings (CM)	x1	14.14	12.02	0	99
# of issues discussed at CM	x2	4.42	1.70	0	6
% of rural population over 65	x3	0.34	0.08	0	1
# of incorporated farm	x4	0.07	0.30	0	5

This study uses Agricultural Census Datasets for 2015 and 2010 for the Tohoku Region of Japan (see

Table 1). The total sample is 14,253. The datasets include average farm size, elevation, slope, time-distance to the nearest city, and community variables. Community variables are included to identify socio-economic characteristics that induce an expansion in farming size. We hypothesize that that the number and quality of community meetings, as well as mutual trust within the community, make land transactions easier, thereby contributing to increases in average farm size.

Table 2 shows the average farm size by elevation and slope. It indicates that the average farm size is larger at lower elevations and where farmland is flatter. It also shows smaller increases in average farm size for farmland located in steeper mountainous area. This implies that farmland located in the remote and mountainous areas is more likely to be abandoned rather than handed to the next generation.

Table 2 Change in average farm size by elevation and slope from 2010 to 2015

			Slope (θ): z2			
			(flat)			(steep)
Elevation (m)：z1	A: Farm Size (ha) in 2015	(high)	2.59	2.14	1.59	1.38
			2.54	1.83	1.68	1.44
			2.08	2.23	1.88	1.63
		(low)	2.76	2.34	1.94	1.82
	B: Farm Size (ha) in 2010	(high)	2.35	1.98	1.54	1.31
			2.26	1.69	1.57	1.31
			1.84	2.03	1.74	1.53
		(low)	2.40	2.07	1.84	1.57
	(A-B)/B*100 (% Change)	(high)	10.2	8.1	3.7	5.8
			12.3	8.4	6.6	10.2
			13.3	10.1	7.9	6.9
		(low)	14.9	13.0	5.5	16.5

Statistical Analysis

The distribution of farm sizes across agricultural communities is highly skewed and asymmetrical. Therefore, the results from a standard regression analysis (i.e. ordinary least squares) are biased and cannot provide a comprehensive picture of the effect of the independent variables on the dependent variable. In this study, quantile regression analysis is employed to observe the different effects of each explanatory variable along the distribution of the dependent variable. The estimated equation is defined as (1).

$$y_{2015} = \alpha + \beta \cdot y_{2010} + \sum \gamma_i z_i + \sum \delta_j x_j + \varepsilon \qquad (1)$$

α is a constant term, and β captures the effect from average farmland size in 2010. γ_i measures the effect of GIS variables on the average farmland size in 2015. x_j represents socio-economic community variables. These are included to examine socio-economic characteristics that are associated with farmland size. Since community variables might be considered as endogenous variables, we report the estimation results with and without the community variables.

RESULTS AND DISCUSSION

Table 3 shows the results of the quantile regression analysis. The effects of average farm size in 2010 on the average farm size in 2015 are dependent on the quantile estimated. With a smaller farm size (quantile 25%), the estimated coefficients turn out to be 0.96-0.97, less than 1.0, meaning that average farm size is more likely to decrease by 3 to 4% every five years. On the other hand, with a larger farm size (quantile 75%), the estimated coefficients are more than 1.0, which indicates that the

average farm size increases by about 22% when assuming other variables are constant. Thus, the aged population and general decrease of the farming population contributes only to agricultural communities where the average farm size is already high. In other words, agricultural communities in the remote and mountainous areas, often with their smaller farm sizes, do not make use of additional farming opportunities, weakening overall agricultural activity.

Table 3 Results of quantile regression

	Dependent variable: Average farm size in 2015					
	With community variable			Without community variable		
	Quantile			Quantile		
Variable	25%	50%	75%	25%	50%	75%
Average farm size in 2010	0.960***	1.081***	1.222***	0.967***	1.083***	1.223***
	(177.06)	(187.98)	(160.64)	(166.13)	(188.37)	(161.94)
Elevation	-0.007***	-0.009***	-0.013***	-0.008**	-0.009***	-0.013***
	(-2.79)	(-3.24)	(-3.03)	(-2.46)	(-3.02)	(-3.18)
Slope	-0.008***	-0.006***	-0.007***	-0.009***	-0.007***	-0.006***
	(-7.03)	(-4.78)	(-3.14)	(-6.4)	(-4.64)	(-3.11)
Time-distance: 30 to 60	0.008	-0.005	-0.007	0.005	-0.007	-0.004
	(1.02)	(-0.58)	(-0.57)	(0.6)	(-0.84)	(-0.32)
Time-distance: 60 to 90	-0.007	-0.001	0.016	-0.031	-0.003	0.031
	(-0.29)	(-0.08)	(0.51)	(-1.26)	-0.19	1.06
Time-distance: over 90	0.017	0.033	0.045	0.019	0.037	0.054
	(0.36)	(0.93)	(0.64)	(0.52)	(0.7)	(0.66)
# of meetings	0.002***	0.001***	0.0005			
	(8.71)	(3.69)	(0.90)			
# of issues discussed	0.006***	0.002	0.001			
	(2.80)	(0.91)	(0.37)			
% of population over age 65	-0.239***	-0.063	0.092			
	(-6.25)	(-1.65)	(1.34)			
# of incorporated farmland	0.025*	0.012	0.006			
	(1.85)	(0.75)	(0.36)			
Constant	0.046***	0.011	0.008	0.009	0.015	0.049***
	(2.62)	(0.61)	(0.26)	(0.81)	(1.40)	(3.03)
Pseudo R^2	0.561	0.617	0.632	0.559	0.616	0.632
N	14,235			14,235		

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

This study investigates geologic and socio-economic conditions that induced an increase in farm size in rural Japan. Community level data analysis indicates that the average farm size does not necessarily increase as the farming population decreases, particularly where the average farm size is initially small. Some farmland in the remote and mountainous areas of Tohoku Region has been abandoned rather than passed down to the next generation. Farmland on steeper slopes at higher elevations is more expensive to operate than in the lowland, meaning that consolidating farmland does not provide sufficient economic benefits in mountainous areas. Our regression analysis also shows that frequent community gatherings to discuss local issues and the establishment of incorporated farmland within the community would help increase the farm sizes. Fostering trust through engagement reduces transaction costs and encourages the establishment of cooperatives or

incorporated farms, which may account for an increase in farm size.

Furthermore, the effects of elevation and slope on average farm size are always negative and significant, particularly at the 25% quantile (smaller farm size). Land condition represented by steepness and a mountainous locale always impair the expansion of farm size. Lower elevation and flatter farming areas are key conditions that accelerate land transactions, thus resulting in higher average farm sizes.

The sign of the percentage of people above 65 years of age is positive at the 75% quantile and negative and significant at the 25% quantile. The retirement of aged farmers generally provides opportunities for younger farmers. Such opportunities are not taken advantage of where the average farm size is generally smaller (25% quantile). The sign of the number of incorporated farms turns out to be positive and significant only at the 25% quantile, indicating that the small number of incorporated farms in the highlands may contribute to the expansion in farm size through consolidating farmland within the community.

Both the number of community meetings and the number of issues discussed in these meetings have a positive effect on the average farm size at the 25% quantile. It is important to note that discussion within the agricultural community allows for building mutual trust and mitigating distributional conflict, thus leading to a reduction of overall transaction costs.

CONCLUSION

This study investigates geologic and socio-economic conditions that fostered an increase in average farm sizes in rural Japan. Community level data analysis indicates that the average farm size does not necessarily increase as the farming population decreases, particularly where average the farm size is still small. Some farmland in the remote and mountainous areas have been abandoned rather than handed to the next generation. Farmland on higher slopes at higher elevation is more expensive to operate than in the lowlands, meaning that consolidation of farmland does not provide sufficient economic benefit. Our regression analysis also shows that frequent community gatherings to discuss local issues and establishment of incorporated farms within the community would help increase the farming size. Fostering trust through discussions has reduced transaction costs and encouraged the establishment of cooperatives or incorporated farm, possibly resulting in an increase in farming size.

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Research article

Empowerment of Rural Community and its Resilience: A Case Study of a Small-Scale Rural Community in a Mountainous Area in Japan

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Abstract Japanese rural communities have experienced an aging population with a drastic decline in its size while more economic functions and workplaces have become concentrated in urban areas. Some rural communities in remote mountainous areas even face the further serious problem of extinction of their own community. Even with such a difficult situation, some rural communities have been successful in achieving the migration of their young generation back to their rural areas, and even in reviving their energy year by year. The objective of this paper, therefore, is to demonstrate how rural communities in remote mountainous areas in Japan can become empowered and resilient regardless of the serious threat of further depopulation and marginal settlement through a case study of a small-scale rural community in a remote mountainous area of Miyazaki Prefecture, Japan. The paper first overviews how rural communities have experienced depopulation over time together with changes in livelihood along with changes in lifestyle. Then, by describing how a small community in the study area was challenged to implement a series of projects by themselves, utilizing their local resources and cultures, it explains how a depopulated community could revive and gain confidence in themselves while receiving a lot of attention from visitors from outside. The study results show that the aged female population in the community is the key human resource as they can actually play an important role in the rural community, producing local valuable products and services. Moreover, the study points out the importance of maintaining and passing on rural communities' identities to the next generations, while explaining why some of the young population now choose to live in such remote rural areas – a shelter from the overly globalized and industrialized modern society.

Keywords community empowerment, resilience of rural community, small-scale community in mountainous area, aged population

INTRODUCTION

This study seeks to stimulate the frank discussion that is required if researchers, practitioners and policymakers of any nation under the economic development stage are to work effectively with rural communities in responding to the possible transitional changes impacting rural declines over time. This paper describes the experience of, and lessons learned from, a small-scale rural community that experienced serious declines in the last 50 years but struggled to sustain the community.

The notion of rural decline in Japan since the 1960s (i.e. due to the rapid economic growth and change in industrial structure that happened around the 1960s) is firmly established in the literature (Ono, 2005; Odagiri, 2009), and is supported by demographic trends that depict many small rural communities in remote, hilly and mountainous areas gradually shrinking in population, making the community age as well. Odagiri (2009) pointed out that the "decline" has been particularly witnessed in three dimensions, namely i) population reduction, ii) abandoned agricultural and forestry land, and iii) weakened community functions, leading to a loss of pride in one's own community. An economic and population imbalance has also been found between large cities and smaller remote rural communities in Japan. There are similar concerns about the fate of small rural communities as

economic and demographic pressures have also been noted in many developed countries in Europe, North America and Australia (Forth & Howell, 2002; McManus et al., 2012).

What this paper wants to focus on is not the decline itself but critical factors involved in sustaining the rural communities regardless of the serious threat of their extinction with gradual emptying and aging at a high rate. To explore the possible efforts made by rural communities to react to the pressures of rural declines, this paper pays close attention to the key concepts of "resilience" and "community empowerment" by analyzing the real case of one small-scale rural community in a mountainous area in Japan.

"Resilience" and "Community Empowerment"

Japan's depopulating rural communities received significant attention when a report, the so-called "Masuda Report," was released in May 2014. The report predicted that almost half of the municipalities might disappear due to a population decline and weakened administrative functions. "Municipalities at risk of extinction," mostly located in rural areas, have been listed and the urgent need to cope with rural community issues cannot be avoided, with words like "revitalization" and "renewal" being used in the policy arena in Japan. Throughout this debate, Japan has experienced other kinds of negative impacts brought about exogenously that have often hit rural communities (such as huge natural disasters, for example the Great East Japan Earthquake), and the concept of "resilience" has been debated (Itonaga, 2012; Hattori, Yanai, & Saito, 2013).

Resilience is a complex concept, being used as an ecological term (i.e. the ability of a system to regain the status quo after a major shock), and extended to other domains and applied in social contexts where resilience is understood as the capacity to adapt seamlessly to largely exogenous events (McManus et al., 2012). The critical feature of the notion of resilience is the idea that there are some factors about a rural community that enable it to cope with changing circumstances. Such "factors" can be social capital (Putnam, 1993) or, more specifically, trust and norms of reciprocity (Bridger & Alter, 2006), but they cannot be simplified and based on a single factor. Rather, this paper suggests that communities are empowered through a number of events involving the participation of all community members, increasing confidence and the mutual respect of people living in a depopulated and aged rural community.

The concept of empowerment originates from the effort of a local community or marginal people to gain power, leaving their voiceless or powerless conditions behind (Sianipar, Yudoko, Adhiutama, & Dowaki, 2013; Sutawa, 2012). To discuss how a rural community can cope with a changing environment, especially when the weakening function of the community is under serious threat, this paper attempts to demonstrate how a community can be empowered even under the situation of depopulation and aging.

OBJECTIVE

The objective of this paper is to demonstrate how rural communities in remote mountainous areas in Japan can become empowered and resilient regardless of the serious threat of further depopulation and marginal settlement through a case study of a small-scale rural community in the remote mountainous area of Miyazaki Prefecture, Japan (see Fig. 1). By looking closely at the case of a small-scale rural community of less than 100 people, this paper tackles the following research questions: 1) How has the depopulation of the community evolved over time?; and 2) What triggered the community to revive themselves, and how has the community been empowered? By analyzing the results, this paper attempts to discuss critical factors for resilience in fighting back from rural declines.

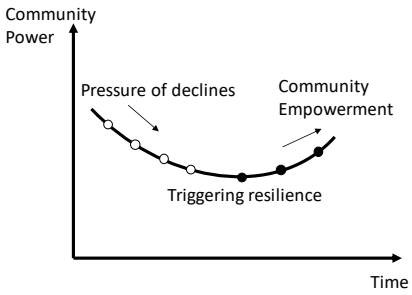

Fig. 1. Rural declines, resilience and community empowerment

RESEARCH METHOD AND THE STUDY TARGET

The study is conducted based on a series of field observations carried out since 2016, interview surveys held in August 2016, July 2019 and September 2019, and documents collected from the target community and village.

When the land of Japan is classified into the four categories of i) urban areas, ii) flat farming areas, iii) hilly farming areas and iv) mountainous farming areas, in accordance with the guidelines of the Ministry of Agriculture, Forestry and Fishery in Japan, hilly and mountainous areas (i.e. iii and iv) account for about 36% of the total farming area and output (MAFF, 2017). The study target community is located in the village of *Nishimera* , Miyazaki Prefecture, in the Kyushu region of Japan. Approximately 88% of the prefectural land is hilly and mountainous and about 37% of the prefectural population reside there (Miyazaki Prefecture, 2019). Among the 26 municipal cities, towns and villages of Miyazaki Prefecture, *Nishimera* village has the smallest population with 1,132 people (580 households) as of October 2019, and 96% of the land is categorized as mountainous areas. The village has eight traditional communities, and this study focuses on one of those, "*Ogawa* Community," which is located about 40 minutes from the village center by car, and it takes more than 1.5 hours to reach the nearest commercial area. The *Ogawa* Community has a population of 92 people. This community has experienced drastic population declines over the last 50 years and has been implementing a number of projects to revive its own community for 20 years. The study focuses on the case of *Ogawa* Community to demonstrate the critical factors required for a small-scale rural community to be resilient regardless of the long-term socio-economic change brought about from outside the community.

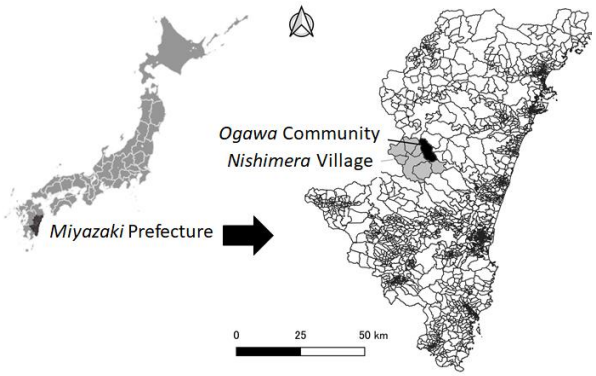

Fig.2 Location of *Ogawa* Community, *Nishimera* Village, *Miyazaki*, Japan

RESULTS

History and Transitional Change of *Ogawa* Community (RQ1: How has Depopulation Evolved Over Time?)

The *Ogawa* Community has a long history as the center of *Nishimera* Village with the feudal lords' residence (i.e. castle) having been there for about 200 years in the *Edo* era with. The shrine of the community is said to have been built about 500 years ago. At the time of the *Meiji* restoration in the 1860s, the landlord (i.e. the feudal lord) had kindly allocated all his forest land to local dwellers equally, making people's livelihood quite stable. With such forestry resources, the community traditionally had a unique way of living with two residences, one in the forest (called a *Sakugoya*) and the other in a residential community center. Table 1 shows the transitional changes experienced in the *Ogawa* Community over the last 50 years. There was a drastic population movement since 1960 from rural communities to urban areas due to changes in the industrial structure in the high economic growth period and the stagnant wood prices due to imported wood caused the forest industry to shrink and the population in forest areas to decrease. The Ogawa Community also followed the trend, and it has about 550 people left from the community in 50 years. As the working-age population migrated out of the community during the high economic growth period, the people who were left in the village 50 years later became old, while less and less children were born in the community, leading to school close, making difficult situation for younger generations to continue to stay or to come back there.

Table 1 Changes in the local situation along with modernization and forestry declines

Year: Population	Local situation, lifestyle, etc.	Events and trends in Japan
1960: about 650	- People had a traditional lifestyle of staying at their cottage for forestry work, and coming back to their official house to live in *Ogawa* Community. - Neighboring communities had been submerged due to reservoir construction. (Many construction workers came to construct the dam.) - 1970s: Rapid forestry decline and forestry work did not require many laborers anymore due to technological improvements.	- Early 1960s: Crude oil imports were liberalized, and petroleum replaced coal as the main player in Japan's energy. - Timber self-sufficiency: 87% - 1970s: Rapid increase in the number of private cars and vehicles.
1980: about 250	- Modern work style with one house, commuting by cars to fields, was commonly found. -1980: % of population aged 65 or older in *Nishimera* village: 13.6%. -1989: Primary and Junior school closed due to lack of students (no high school in the village). -1994: Public bus service to the community has terminated its operation.	- Timber self-sufficiency: 32%. - Continuous decline in timber prices (imported timber becomes dominant in the market).
2000: about120	-2000: % of population aged 65 or older in *Ogawa* Community and *Nishimera* village is 71% and 36%, respectively. => 63% and 41% in 2010, respectively.	- Timber self-sufficiency: 18%.

Note: Source of timber self-sufficiency rate is "Learning Museum of the Forest and Forestry," and source of % of population aged 65 or older is from Nishimera Village documents for Ogawa, and from e-stat.com for Nishimera village.

Community's Initiative and Community Empowerment (RQ2: What Triggered the Community to Revive Themselves, and how the Community has been Empowered?)

In 2000, *Nishimera* village officers came to explain about the estimated future population of the *Ogawa* Community, informing dwellers: "[T]his community will be extinct if the current situation continues." People were shocked and held many meetings, discussing what they should do. Having gained a consensus among all the dwellers of the community that they could not die without taking any action, the local people decided to utilize what they had locally; specifically, they used their hands to collect resources from the forest (i.e. edible wild plants). Having collected these forest resources, they decided to hold a festival, serving the local resources to visitors. All the dwellers of the community participated in the festival, and there were about 300 visitors in the first year. Due to its popularity, the number increased to more than 1000 in the second year. In receiving more visitors from outside communities (10 times more visitors than its population), local people started to realize that their traditional food, culture and even their lifestyle were unique in the view of outsiders, who placed high value on their culture, which led local people to grow in confidence. After several years, they started to say: "Festivals are held once a year, but why can't we hold something every day, and receive more guests?" With this in mind, a preparatory committee to develop community projects was first established among community members in 2005. This was followed by the community's official management organization established in 2007, and finally the launching of restaurants and guesthouses to share their traditional food and lifestyle with guests throughout the year, which were to be operated and managed by local people in 2009. When people began to discuss what was to be started up, they thought they didn't have anything special, and presented the simple idea of opening a restaurant serving popular food, like *Udon* noodles, which are available anywhere in Japan. However, after consulting with various supporters, including village officers, people started to recognize that their traditional food and even their olden-days' lifestyle were absolutely unique outside their community, and therefore of value to the majority of guests coming from cities. With such findings, people decided to name their initiative *Sakugoya*, their traditional work cottage (second house) in the mountains, thereby maintaining and cherishing their traditions and local identities. With this philosophy, people decided to utilize the historical area of the *Ogawa* Community, creating a restaurant and guesthouses built in the traditional way as shown in Fig. 3. Moreover,

community members were stunned by the results of their operation as the number of visitors rose as high as 25,000 in 2012, and economic benefits were also brought to the community, as illustrated in Fig. 4.

It should be noted that as the main community's workforce comprised elderly female dwellers, the restaurant was managed by 10 elderly women with an average age of 72.3 years as of 2016. These old women who used to work in the mountains and on farmland now started to receive guests from many places, even from foreign countries, and they became very busy every day, cooking in the restaurant kitchen, chatting to visitors, coworking with many other neighbors as colleagues and being appreciated by community members. Such people often say that they feel happy to contribute to their own community. In addition to local people's initiatives, the village office supported the community by constructing houses to receive new dwellers, leading to the arrival of 26 migrants since 2009, including three families with children. The peaceful style of traditional living surrounded by nature and forest land attracted a number of younger people who placed importance on quality of life. With these new dwellers, the percentage of the population aged 65 or older was reduced to 58% in 2019.

Fig. 3. *Ogawa Sakugoya*

Source: The author edited the picture taken from https://www. ogawasakugoya-village.com (accessed Jan. 09, 2020).

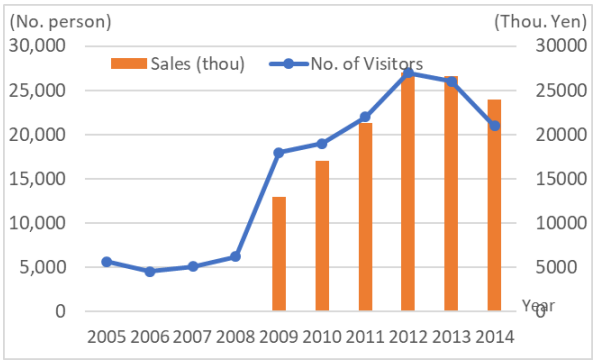

Fig. 4. No. of visitors and sales

Source: Data from 2005 to 2008 are taken from village office document, and data since 2009 from Ogawa Sakugoya.

DISCUSSION AND CONCLUSION

From the experience and lessons learned from the case demonstrated above, at least two important factors are to be pointed out in relation to rural community resilience. When the socio-economic situation changes over time as a result of a weakening forest industry along with progressing globalization and a lifestyle shifted to the modern way, the rural communities can be marginalized to a very small level if local people continue to make their livelihood through business as usual, but such communities can be empowered against such pressures when local people possess the willingness to sustain their community. Such willingness can be turned into a collective power, making the community as a whole change themselves in order to move forwards. The sense of crisis shared unanimously triggers a series of actions taken by local dwellers. The first important factor is the shared vision among all community members that they do not wish to see their community become extinct but rather that their community succeeds into the next generation, as such a shared vision drives the community as a whole to move forward in the same direction.

Second, there existed "unrecognized" local resources, which became the strength for the community to gain power. For instance, local people did not recognize the edible wild plants available in their forest and that their traditional healthy cuisine, which they ate every day, had such value for people in cities. Moreover, there were many old and hard-working women who lived in the community. As many of the female dwellers typically performed unpaid work or did a relatively less well-paid job in the forest, on farms and in houses growing trees, vegetables and cooking, many male decision-makers in the rural community might have not recognize that such old female members could bring such benefits to the community. Having seen the participation of all community members,

the aged female population in the depopulated community is now recognized as a key human resource as they can actually play an important role, producing local valuable products and services.

Last, but not least, the study results indicated that many people in cities were attracted by rural traditional values, with even younger generations migrating back to rural communities in remote mountainous areas. Those young generations now seek to enrich their life by enjoying craftmanship utilizing natural resources, and even being part of a community of members whose connection is based on trust. Rural communities that still retain their local identities are opposed to standardized and regulated norms of a globalized modern society. Such communities may offer places to stay for people who are looking for real richness of human life surrounded by a rich culture and natural resources from which to self-supply their own food and satisfy their needs for their everyday life.

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