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

Contents

Research article

The Influence of External Environment on Operation Strategy and Corporate Performance in Indonesian Garment Industry

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Abstract This study examined the phenomenon of production and competition of the garment Industry in Indonesia. Indonesian garment products have not been competitive in the international market. The quality of the resulting garment products have not been able to comply with the international quality standards. In addition, Indonesia has not been included in the Trans-Pacific Partnership community that provides reduction of import duties for its member. This research extends the work performed by other researchers by performing the study in a diferent environment not studied before and by expanding the environment dimension. The study used the management approach and integrating the strategic management, operation management, human resource management and marketing management. The purpose of this study is to describe and analyse 1) The external environment, operation strategy and corporate performance of Indonesian garment industry; 2) The influence of external environment towards operation strategy; and 3) The influence of operation strategy towards the corporate performance. The types of this research are descriptive and verificative while the methods used both descriptive and explanatory surveys. Using the random sampling technique from collection data, the sample size were 71 companies with 395 respondences which consist 71 operation managers, 71 agents and 253 employees. The using interview as a technique from collection data with three questionaire models. The data collected at February until July 2013, using the descriptive analysis and path analysis. The results show 1) The external environment (supplier, technology, and consumer), operation strategy and company performance generally good enough; 2) The external environment have significant influence simultaneously and partially towards operation strategy, the consumer influence on the operating strategy is greater than the influence of technology and suppliers; 3) The operation strategy have a significant influence towards corporate performance and the operating strategy has a huge influence on company performance and there is any other influence.

Keywords external environment, operation strategy, corporate performance

INTRODUCTION

Recently, Indonesian garment industry (IGI) face a fiercer challenge due to increasing number of imported products and great demand by consumers, in addition to the several weaknesses of the national garment products. For example, in the case of the design product, Indonesia does not have enough expertise, so it must pay higher salary for foreign designers. Indonesian garment products actually have the potential to grow because people cannot be separated from garment products, and Indonesia is a big market.

Indonesian textile and garment market share in the international market (Asosiasi Pertekstilan Indonesia, 2012) is only about 1.82% and there has never been a significant increase. Indonesian textile and garment products are not competitive in United States (US) and Europe market, and one of the reasons is because Indonesia has not been included in the Trans-Pacific Partnership (TPP) community, which provides a reduction of import duties for its member. In comparison, after

Vietnam joined the TPP they get 5% - 12% of import duty reduction for the products that are exported to America, while Indonesia according to the Chairman of the Indonesian Textile Association (April 2014), burdened with 12% - 31% duty, even though has become textile and garment producer earlier than Vietnam.

The fact of the national garment industry nowadays is that it faces a fierce competition with imported products that dominate the national market. The main competition is in the garment design; imported products have better design that is preferred by consumers than local products. This condition is cause by the limited ability of local manufacturers to design the products as well as the used machinery which is still a constraint. Ultimately this situation leads to the national garment industry acts as a 'tailor' for foreign manufacturers.

As one of the economic center in Southeast Asia, Indonesia has a dynamic economic growth. According to World Bank's data, Indonesia's Gross Domestic Product (GDP) growth in 2013 reached 5.8% and Gross National Income Indonesia grew from US $ 2,200 in 2000 to US $ 3,563 in 2013. The problem then arises on the challenges of free trade, especially in Southeast Asia. Indonesia as a member of Association of Southeast Asian Nations (ASEAN) will face the implementation of the ASEAN Economic Community (AEC), but the government has not held a discussion on this subject to gain opinions from the public, entrepreneur and academics. There is concern that when the AEC is enacted, Indonesian producer will have great difficulties to compete with the foreign products and services, because of the legal and economic policies do not exist or are not ready to face the sophistication of free trade mechanism.

To measure the industry's performance, one of the benchmarks used by the Indonesian government is the achievement of value added, so that the effort to increase the added value along the chain of events is one of the strategies to increase the competitive advantage. Meanwhile, according to Johnson and Scholes (1993), strategy is the direction and scope of the organization to achieve excellence through the configuration of the existing resources to adjust to environmental changes.

Lowe (1995) stated that in order to implement the strategy of technology, companies can conduct an analysis of the position held technology. The analysis is about market capability and the possessed technological capability that is reflected in the production function.

OBJECTIVES

This study aims to reveal and analyse the external environment (suppliers, technology and consumer), operating strategy, and the performance of the garment industry in Indonesia. This study is a continuation of the prior research that has been done in 2007. In addition, it also aims to reveal the problems faced by the garment industry, particularly related to the performance.

In order the company can compete favourably with industry domestically and abroad, the industry needs a good competitive strategy, such as determining the operating strategy that will be implemented in the company. Porter (1980) stated that if a company can achieve and maintain overall cost advantage, then it will perform above average, as long as it can maintain the price around the industry average.

METHODOLOGY

The method used in this study is descriptive and verificative, which aims to get an idea about the external environment and operations strategy, as well as to observe their effects on the performance of the garment industry. The population target is the garment industry in Indonesia especially those that are listed as a members of the Indonesian Textile Association. A sample withdrawal technique with simple random sampling is used, with a sampling frame made first. Using the random sampling technique from collection data, the sample size were 71 companies with 395 respondences which consist 71 operation managers, 71 distributor/agents and 253 employees. The using interview as a technique from collection data with three questionaire models. The data collected at February until July 2012, using the descriptive analysis and path analysis. There are

three variables that become the object of research; external environment that includes suppliers, technology and consumer; operations strategy; and performance of the company. Data analysis has been conducted using path analysis, which is used to analyze the causal correlation between the variables studied. Path diagram is used to describe causal correlation between variables under study, which graphically depict the structure of a causal correlation between the independent variables, the intervening variables and the dependent variable. Data processing is conducted using Lisrel 8.7 with an ordinal scale.

RESULTS AND DISCUSSION

The garment industry is a clothing company that produces apparel, namely shirts, t-shirts, blouses, sport shirts, polo shirts, under wear, trousers, jackets and rock & blouses. Various types of products produced by the garment industry can be classified into men's apparel, ladies apparel and children's apparel. Textile and garment industry in Indonesia began to grow since 1920 (Asosiasi Pertekstilan Indonesia, 2012) but Indonesia does not have a factory in the country yet. The development of this industry was started from the development of Indonesian traditional batik clothes.

The external environments referred in this study are the factors that are beyond the company which can affect the development of Indonesian garment industry. In this study, the external environment is consists of suppliers, technology and consumer. Based on the eight indicators of suppliers, it can be concluded that these suppliers belong to intermediate level. It means that suppliers of raw materials have yet to reach the performance level expected by the garment industry in general.

The majority of Indonesian garment industry is facing the competitors that have a relatively good marketing strategy and performance, especially in achieving sales growth, profitability, and customer satisfaction (Atty, 2012). Companies that deal with such situations need to systematically collect information of the main competitors or industry averages and analyze it. The results are then used as a basis for developing appropriate strategies, so that it can be used to overcome and minimize the threat of competitors or even can be utilized to seek for a new opportunity in the market.

Approximately, there are about 11 types of machines with a variety of functions that are generally used in the garment industry. Technology that is used heavily affects the garment production quality (e.g. when machines used are relatively old and not using the latest technology, the result will not be satisfactory). The results obtained indicate that the influence of consumers on the operating strategy is greater than the influence of technology and suppliers for operating strategy. The results of data analysis that has been conducted to test the hypothesis are based on the diagram and mathematical model approach. Influence of the external environment on the operating strategy and its impact on the performance of the garment industry in Indonesia is shown in Fig. 1. The test is conducted by calculating the path coefficient of each variable studied.

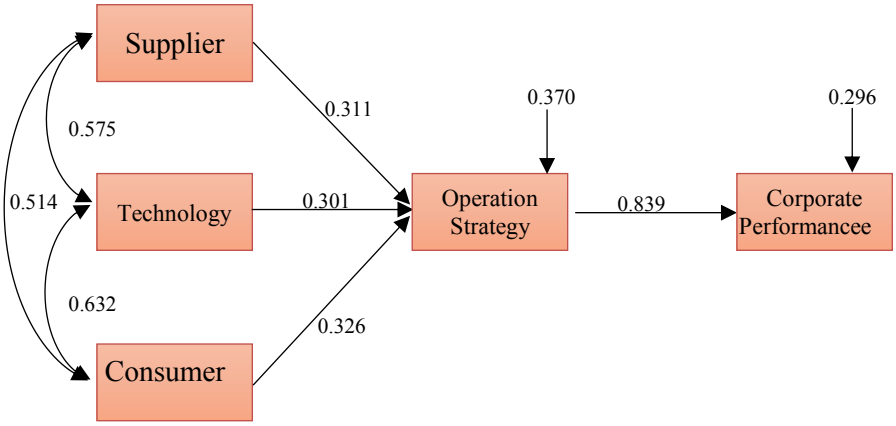

Fig. 1 Path diagram

Fig. 1 shows that each external variable (suppliers, technology and consumers) has a positive correlation. It can be said that all the three sub-variables of the external environment are supporting each other as they are interconnected.

The results of the path analysis calculation were obtained using following equations:

$$Y = 0.311\ X_1 + 0.301\ X_2 + 0.326\ X_3 + €_1 \quad (1)$$

$$Z = 0.839\ Y + €_2 \quad (2)$$

Where Y=Operation strategy, X_1=Supplier, X_2=Technology, X_3 =Consumer, Z=Company performance and €=Epsilon/out of research scope.

The amount of influence from the external environment, i.e., suppliers, technology and consumer to the operating strategy is then calculated. The results are as shown in Table 1.

Table 1 The effect of external environment of operations strategy and influence on company performance

Variable	Direct Impact	Indirect Impact			Total Indirect Impact	Total Impact
		Supplier	Technology	Consumer		
Supplier	9.7%		5.4%	5.2%	10.6%	20.3%
Technology	9.1%	5.4%		6.2%	11.6%	20.6%
Consumer	10.6%	5.2%	6.2%		11.4%	22.0%
Total	29.4%	10.6%	11.6%	11.4%	33.6%	63.0%
Strategy	70.4%					70.4%

Source: Author's evaluation based on field research

Table 1 shows that the greatest influence on the operating strategy in the garment industry have consumers (22%), followed by the influence of technology (20.6%) and the influence of suppliers (20.3%). This happens because consumer is the direct user of the product.

The result of this study indicates that consumers have strong impact on the operating strategy of the garment industry in Indonesia due to their strong bargaining position. As a consequence, if the products of Indonesian garment industry cannot meet costumers' requirements, they can easily switch to another similar imported product by other world companies. The operating strategy should be proposed to accommodate the tastes, purchasing power and requirement of customers. If Indonesian garment industry could fulfil the requirements, the probability to be abandoned by the consumer is lower.

In addition, this study also shows that Indonesian garment industry should concern more on customer demand rather than on technology or supplier in terms of composing their operation strategy. The result of this study shows that technology and supplier are also important factor that should be considered in preparing the operating strategy, because the effect of these factors are not small, even though not as big as the influence of consumer. Consumers of Indonesian garment industry have good taste, but their requirement has not been fulfilled by domestic manufacturers yet. Indonesian consumers will be interested and feel more prestigious if they can use imported garment products. If consumer is willing to purchase and use clothes from the domestic garment industry, it will significantly reduce the consumption level of the imported clothes. Kreitner and Kinichi (2001) stated that trust is the belief of a party concerning the purpose and behaviour of the other party.

The technology used in the garment industry in Indonesia nowadays (especially the machinery technology) is still an old technology, therefore it has big influence on the production process result. It means that existing technology is still not capable enough to produce garments to meet customer expectations and compete with imported products. Technology plays an important role in encouraging industrial structure changes and the creation of new industries. Nevertheless, the influence of technology to the operation strategy is not too significant due to the fact that the existing operation strategy has already consider the technological capabilities of the current industries. Advance in technology encourages domestic garment industry to improve their products

continuously which would lead to consumers higher demand on the product and value of the product itself.

Respondents response on operation strategy indicates that Indonesian garment industry tend to implement flexibility and quality operation strategy. Quality strategy is a condition in which the production process of a product meet the specifications or consumer expectations (Atty, 2012). Demand for Indonesian garment products is getting higher, where the quality is not limited to the usage of its products, but also evolving towards consumers needs explicitly. In other word, consumer will state that product has a good quality if it can meet their needs explicitly. The results also show that the garment industry needs to be more concern about products quality by implementing continuous improvement in that matter. Eventually, the results of this study indicate that the garment industry in Indonesia should not have been confronted with the difficulties to produce a good quality product, since the employees have already understood the importance of product quality and continuous quality improvement. The quality of a product will be depends on the production process. In order to produce a good quality garment product, better machinery technology is a must, in addition to well qualified and creative employees.

Flexibility strategies used in the garment industry in Indonesia are intended to meet the customer demand in both volume and the variety of products. Production process of IGI use an operating strategy with a flexible approach, which means that production is adjustable to the consumers desires. In this rapidly changing business environment, flexibility strategies play more important role due to technology advancement and flexible manufacturing system (FMS). These strategies are used to respond to the rapid changes of a product or process which often expressed as a combination of volume. According to Wheelwright (1984), flexibility strategy is a plan that supposed to change from one product to another or almost suddenly from one part to another. Krajewski and Ritzman (2005) stated that some companies give top priority to flexibility as a mean of beating competitors.

In addition, this study also found that consumers easily switch from one brand to another brand, thus in these conditions the consumer has strong bargaining power. This is supported by the opinion of most direct empirical research by Ward et al. (1995) and Swamidass and Newell (1987) have provided supportfor a connection among operations strategy, environment and performance. Similarly, business strategy researchers have provided evidence that business unit performance is related to competitive strategy choicefor particular environment.

This is another indication that consumers have high expectations on every garment products and services. Sucherly (2003) stated that the demands shifts of customer are relatively dynamic, whereas the level of flexibility and adaptability of the company to respond was relatively low. Therefore, the level of consumers expectations or demands needs to be further analysed.

The findings from this study also pointed out that flexibility and quality strategy requires more intensive efforts to successfully face the global competition. Management of the garment industry dynamically change according to the demands of the environment, both internal and external. Performance measurement in this study only focuses on financial performance by looking at the level of production achievement, efficiency, targeted sales and profit. The financial performance should be seen from the indicators of funds allocation in each activity, structure and value of the assets, the ease of obtaining credit, support of financial resources and its efficient usage. The results also stated that not all of the garment industry in Indonesia can allocate funds effectively so it would impact the efficiency of these funds. Moreover, the result suggests that industry that has a good asset value and structure will get the ease of obtaining credit and financial support. The level of efficiency achievement is relatively lower than the production target, lead to high prices of garment product.

The implication of this study is that every garment industry in Indonesia should review the applied policies in order to achieve the company's performance, target efficiency and in line with the production targets achievement. The relatively high price of these garments would certainly impact on purchasing power, buying interest and consideration of the quality and design of products to be bought by consumers, then lead consumer do reconsideration to make purchase decisions.

According to Badri et al. (1999), dimension of uncertainty affects the environment and the

operating strategy of the company's performance. In addition, the results of Daniel and Reitsperger (1991) found out that if a company uses an iterative strategy, it will provide more feedback to improve company performance.

The implication of this research is that the product development should refer to the real conditions and consumer demand, particularly design and product quality has to be able to lower the price, in order to reduce lagging behind the competitors. This garment industry eventually has huge potential in developing products, as long as they can develop more innovative and varied products, there is improvement in fashion strategy to increase consumer demand and retain both domestic and foreign customer to keep on using the diversified product from the garment industry in Indonesia. At last, it is important to cultivate on how to make the garment products become the 'host' in exist own country.

CONCLUSION

The external environment affects the performed operating strategy. Furthermore, the operating strategies also influence the performance of the garment industry in Indonesia. The most influential factors of external environment on the operating strategy are supplier and consumer, whereas technology has the lowest effect. The implemented operating strategy in the garment industry in Indonesia recently is the flexibility and quality strategy, aimed to create product flexibly in accordance with the development of consumer taste and purchasing power. Moreover, it is also intended to create competitive cloth products in an excellent quality as a result of this garment industry. The performance of the garment industry is still limited to the capability to produce targeted clothing product but has not reach the target of efficiency yet, hence it will make the price of per unit product become more expensive and not meet the standard quality requirements.

REFERENCE

Asosiasi Pertekstilan Indonesia. 2012. The data and statistic of textile & garment industry. 9th edition. Indonesian Textile Association West Java District Committee. Indonesia.

Atty, T.J. 2012. Strategi operasi dalam persaingan bisnis. CV. Utomo Bandung. West Java, Indonesia.

Badri, A., Masood, D.D. and Donna D. 1999. Operation strategy, environmental uncertainty and performance: A path analytic model of industries in developing countries. Omega, International Journals of Management Science.

Daniels, S. and Reitsperger, W. 1991. Linking quality strategy eight management control system: Empirical evidence from Japanese industry. Accounting, Organizations and Society Journal.

Johnson, G. and Scholes, K. 1993. Exploring corporate strategy text and cases. 3rd edition. Prentice Hall. New York, USA.

Krajewski, L.J. and Ritzman, L.P. 2005. Operation management, processes and value chains. 7th ed., Pearson Education, New Jersey.

Kreitner, R. and Kinichi, A. 2001. Organizational behaviour. 5th edition, McGraw Hill, USA.

Lowe, P. 1995. The management of technology: Perception and opportunities. Chapman & Hall, New York, USA.

Porter, M.E. 1980. Competitive strategy: Techniques for analysing industries and competitors. Free press, New York, USA.

Sucherly, S.E. 2003. Pidato pengukuhan guru besar ilmu ekonomi. Program pascasarjana universitas, Padjadjaran Bandung.

Swamidas, P.M. and Newell, W.T. 1987. Manufacturing strategy, environmental uncertainty a path analitical model. Management Science.Vol. 33.

Ward, P.R. Leong, G. and Sum, C. 1995. Business environment, operation strategy and performance an empirical study of singapore manufacturers. Journal of Operation Management. 13, 99-115.

Wheelwright, S.C. and Hayes, R.H. 1984. Competing through manufacturing, Harvard business review, January-February, 99-109.

Research article

Applicability of Estimation Method for Soil Moisture in Mongolian Grasslands using a Pattern Decomposition Method

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Abstract The objective of this research is to develop a method that will allow remotely sensed data to be used for estimating soil moisture and distinguishing vegetated and bare ground areas in Mongolia. The study was conducted in central Mongolia, where climate conditions and human impacts are resulting in degradation of grassland and damage to grazing stock. The method employed was a pattern decomposition method using flat pattern model for estimation soil moisture, which is developed by authors. A total of ten survey plots were established in grasslands, and a spectroradiometer was used to measure spectral characteristics of the soil in the visible and near-infrared wavelengths. Spectral reflectance of the soil was measured, and used to derive the pattern decomposition coefficient and estimate soil moisture. These results were then compared to actual field measurements of soil moisture to verify the accuracy of the method. In addition, photographic images were used to estimate the vegetation coverage for each survey plot, and the effects on vegetation on the accuracy of soil moisture were examined. The results showed a strong negative correlation between water content in soil and the pattern decomposition coefficient for flat model, indicating that this method is capable of accurately estimating soil moisture regardless of soil type. A strong correlation was also found between the vegetation coverage and the pattern decomposition coefficient for vegetation, suggesting that the method can be used to estimate vegetation coverage. A high level of accuracy, however, was achieved only for bare ground, indicating that the vegetation reflectance influences the spectral reflectance of the soil, and the current method is thus not applicable to vegetated areas.

Keywords pattern decomposition method, spectroradiometry, visible and near infrared wavelength

INTRODUCTION

In recent years, a winter disaster known as *Dzud*, characterized by heavy snow and low temperatures, has caused widespread freezing and starving damage to livestock in Mongolia. In addition, it has also been suggested that sparse summer precipitation and resultant lack of soil moisture has depressed vegetation growth (Kondoh et al., 2005). This lack of soil moisture leads to grassland degradation, which weakens livestock and makes them more susceptible to damage from the *Dzud*. Therefore it is important that the continuous monitoring for spatial distribution of soil

moisture in the summer, and in addition, a method for estimating both soil moisture as well as distinguishing between vegetated and bare areas, is needed for conserving grassland and predicting and preventing livestock damage from the *Dzud*.

Satellite remote sensing is useful for retrieving information regarding surface conditions iteratively and over a wide area. There are many remote sensing studies dealing with vegetated area, such as predicting plant diversity by vegetation condition from MODIS (Ranjeet et al., 2008), the estimation of biomass production using AVHRR-based vegetation health indices (Kogan et al., 2004), and the evaluation of the vegetation phonological pattern using NDVI (Lee et al., 2002). Few studies, however, deal with soil moisture.

For bare soil, many studies estimate soil moisture using microwave remote sensing. This is a useful wavelength that can be employed either day or night, and is not affected by clouds. In recent years, a synthetic aperture radar (SAR) active sensor has been frequently used with space resolution enhancement (Zribi et al., 2010). In conservation of Mongolian grasslands, however, it is also important to distinguish between bare and vegetated areas. Some preliminary research using the microwave method for this purpose has been implemented, but at present the system is still in the developmental stage.

Some studies have also achieved high accuracy in estimating soil moisture using water absorption in the near and mid infrared wavelengths (Ishiyama et al., 1992; Liu et al., 2003). Water absorption bands, however, occur in a narrow width of the near and mid infrared wavelengths, and many satellites do not have sensors that operate in these wavelengths.

To develop a method for estimating soil moisture that is both widely applicable to remotely sensed data and capable of distinguishing between vegetated and bare areas, Sekiyama et al. (2010) conducted an open-air experiment employing a spectroradiometer, and achieved highly accurate estimates of soil moisture using spectral characteristics of the soil in the visible and near-infrared bands. The reflectance in each band was normalized by the sum of the reflectance in four bands: blue, green, red, and near infrared, and an obtained curve of the band reflectances (band reflectance pattern) was utilized. By applying a pattern decomposition method for analyzing mixel decomposition proposed by Fujiwara et al. (1996), Sekiyama et al. (2010) developed a method for using the pattern decomposition coefficient for flat model calculated from the band reflectance pattern as the index of soil moisture. This method is described in detail in the next section.

In this study, we applied the method of estimating soil moisture developed by Sekiyama et al. (2010) to field data acquired by spectrometer in the Mongolian grasslands. We attempted this method's ability to accurately estimate soil moisture and to distinguish between bare and vegetated areas. Furthermore, we verified the upper limit of vegetation coverage at which soil moisture can be accurately measured by this method.

METHODOLOGY

Estimation of Soil Moisture by the Pattern Decomposition Method

The pattern decomposition method is an un-mixed analysis, in which the measured band reflectance pattern is expressed as the linear sum of three typical band reflectance patterns which are water, vegetation and soil. Several studies have applied this method to estimation of vegetation coverage (Zhang et al., 2007a; Muramatsu et al., 2007) and to classification of land cover and land cover changes (Muramatsu et al., 2000). Zhang et al. (2007b) have also applied the method to datasets of various satellite sensors. Until recently, however, there have been no studies that use this method to estimate the soil moisture condition.

Sekiyama et al. (2010) first applied the pattern decomposition method to the soil spectral reflectance obtained by spectroradiometer in open-air experiments. The soil samples were collected from 8 sampling sites in Japan, Mongolia and Malaysia. Reflectance measurements were taken for each sample at 4-8 different values of water content in soil (WC), ranging from 0%-22.9% (N= 53). Four multi-spectral bands of blue (band 1: 470–502 nm), green (band 2: 539–580 nm), red (637–668 nm) and near-infrared (band 4: 802–870 nm) were calculated from the measured hyper-spectral

reflectance data, with a view to application in satellite imagery. The measured spectral radiance was calibrated using the spectral radiance of a white calibration board to convert into spectral reflectance. The soil spectral reflectance in each band was normalized by dividing by the sum of the four bands (Ono et al., 2002), thus defining the normalized band reflectance for soil S_i (band number: i = 1 to 4), which has the property that $S_1 + S_2 + S_3 + S_4 = 1$.

Generally, the spectral reflectance of soil in bands 1–3 (visible) and band 4 (near infrared) decreases with increasing soil moisture creating a spectral reflectance that increases with increasing wavelength. The normalized band reflectance for soil, however, decreases slightly in the visible bands with increasing soil moisture, but increases in the near infrared band. The change of reflectance in the near infrared band with increasing soil moisture is large compared to that in the visible bands, and the slope of the band reflectance (i.e., the reflectance pattern) between bands 3 and 4 may thus be used to estimate soil moisture. The slope between bands 3 and 4 is steep when the soil moisture is high, and flattens when the soil moisture is low. In the pattern decomposition method, the flat model pattern P_{fi} (P_{fi} = 0.25) is defined as the pattern that corresponds to completely dried soil, and each normalized band reflectance for soil S_i is the linear sum of two patterns (flat model and soil). Explicitly,

$$S_i = C_{sf} P_{fi} + C_{ss} P_{si}, \quad (1)$$

where C_{sf} and C_{ss} are the pattern decomposition coefficients, which are the relative weights of the two patterns. The decomposition coefficients are calculated from S_i using the least squares method, the flat model pattern P_{fi}, and the typical soil pattern P_{si}.

In Sekiyama et al. (2010), a negative correlation (r^2= 0.56) was found between WC and C_{sf} (Fig. 1), suggesting that C_{sf} is an effective index for estimating soil moisture.

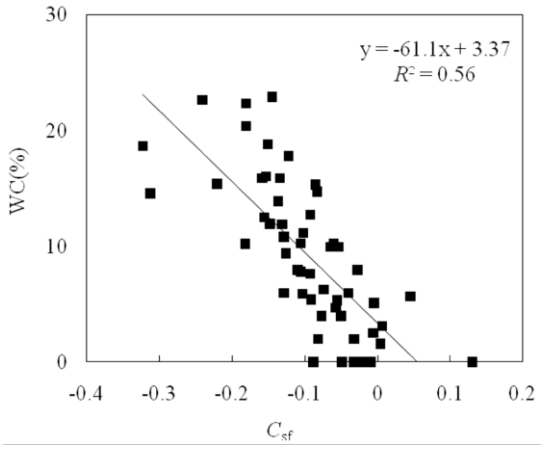

Fig. 1 Relation between water content in soil (WC) and pattern decomposition coefficient for flat model (C_{sf}) (Sekiyama et al., 2010)

Field Survey

Survey area: In this study, ten 40 m × 40 m plots, including pasture and semi-desert areas in three prefectures around the city of Ulan Bator in central Mongolia were investigated (Fig. 2a). The field survey was performed from 9:00 at 12:00 (local time) on August 9 to 16, 2006 and August 8 to 14, 2007, on clear days (Table 1) with sun elevation ranging from 40 to 50 degrees.

The vegetation of Mongolia is predominately grassland. Annual precipitation is below 400 mm, 70% to 80% of which occurs from June to August in central Mongolia. Kondoh et al. (2005) have reported that the growth of plants depends heavily on summer precipitation. Although grassland degradation due to overgrazing and the expansion of cultivated land has become a problem in recent years near Ulan Bator (Yoshihara et al., 2008).

Each plot was taped off into a grid with 10 m intervals (Fig. 2b). At each grid point we measured the spectral radiance of the surface, photographed the surface, and collected soil samples.

The surfaces of all the plots were covered with herbaceous plants. Therefore, the spectral radiance of vegetation and soil both contributed to the measured spectral radiance.

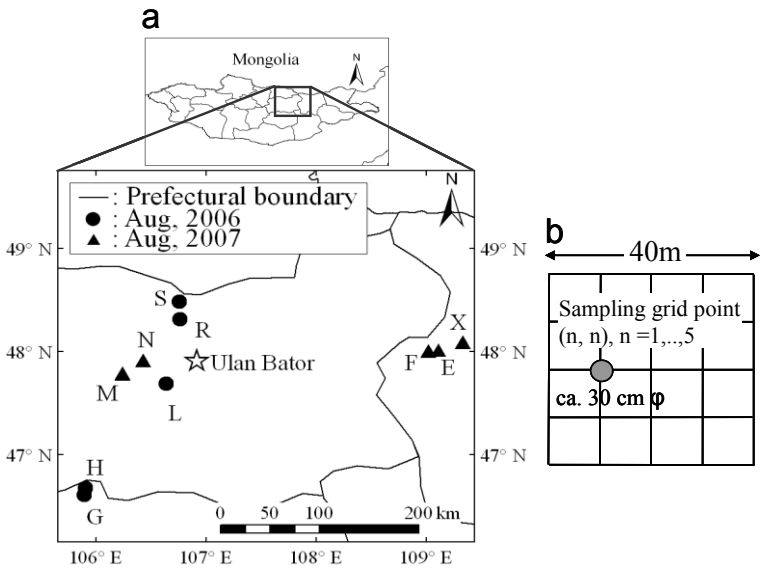

Fig. 2 Map of Mongolia showing the surveyed district (a) and 10 lettered survey plots (b)

Table 1 Location of survey plot and land use

Plot	Latitude (N)	Longitude (E)	Land use	Year
E	48°01’ 04.2”	109°06’ 53.7”	Pasture land	2007
F	48°00’ 09.7”	109°01’ 30.4”	Pasture land	2007
G	46°36’ 28.8”	105°53’ 57.8”	Pasture land	2006
H	46°40’ 39.2”	105°54’ 51.2”	Pasture land	2006
L	47°40’ 59.9”	106°38’ 46.6”	Pasture land	2006
M	47°46’ 59.2”	109°14’ 51.7”	Pasture land	2007
N	47°54’ 55.0”	109°26’ 09.6”	Pasture land	2007
R	48°18’ 41.3”	106°46’ 16.7”	Abandoned farmland	2006
S	48°28’ 42.3”	106°45’ 58.0”	Pasture land	2006
X	48°05’ 16.4”	109°20’ 16.8”	Pasture land	2007

Spectral Radiance Measurement

The spectral radiance of the surface for each grid point (25 samples per plot) was measured using a spectroradiometer (Eko Instruments Co., Ltd, MS-720, with a wavelength range of 350– 1050 nm). The field of view (FOV) of the sensor is 25 degrees, and the measurement was taken at a height of 70 cm above the ground, so the measured area was a 30 cm diameter circle. At each grid point, the spectral radiance was measured three times and the average value was used as the datum for the grid point. The measured spectral radiance was converted into spectral reflectance dividing by the spectral radiance of a white calibration board, and the normalized band reflectance was calculated from the spectral reflectance. The reflectance from a mixed surface of vegetation and soil at each grid point was defined as the normalized mixed-band reflectance M_i. In addition, the sensor FOV was changed to 10 degrees to measure the pure spectral radiance from the bare soil and from the dominant plants (e.g., *Poaceae*, *Rosaceae*, *Fabaceae*, and *Asteraceae*) in each plot. The reflectance values of the bare soil and the vegetation (i.e., the dominant plants) were defined as the normalized band reflectance for soil S_i and the normalized band reflectance for vegetation V_i, respectively, for each plot.

Calculation of Vegetation Coverage and Soil Sampling

Photographs of each plot were taken using a digital camera set at almost the same position as that of the spectral radiance measurement described in the preceding paragraph. The vegetation coverage VC was calculated by extracting pixels of vegetation from the photographic image (N= 250).

In 2006, 50 cm^3 of surface soil were taken at each grid point for four plots (25 samples per plot). In 2007, soil samples of the same volume and depth were taken from 15 grid points (column numbers of the grid are 1, 3, and 5) in four different plots. No soil samples were taken in plot E or plot R (Fig. 2). The total number of sampled plots was N= 160. The WC for each sample using the oven-dry method, the soil was kept under dry conditions (WC = 0 %).

Calculation of Pattern Decomposition Coefficient

The normalized band reflectances for soil S_i and the normalized mixed-band reflectance M_i of all plots were analyzed using the pattern decomposition method. S_i was decomposed using the flat model pattern P_{fi} (= 0.25) and the typical soil pattern P_{si} via Eq. (1), where soil pattern P_{si} is the average value of the S_i (band number: i= 1 to 4) from all plots (P_{s1}, P_{s2}, P_{s3}, P_{s4}: 0.13, 0.19, 0.27, 0.41).

Similarly to S_i, M_i was decomposed using the flat model pattern and the soil pattern. Explicitly,

$$M_i = C_{mf}P_{fi} + C_{ms}P_{si}, \quad (2)$$

where C_{mf} is the pattern decomposition coefficient for flat model and C_{ms} is the pattern decomposition coefficient for soil.

RESULTS AND DISCUSSION

Spectral Reflectance

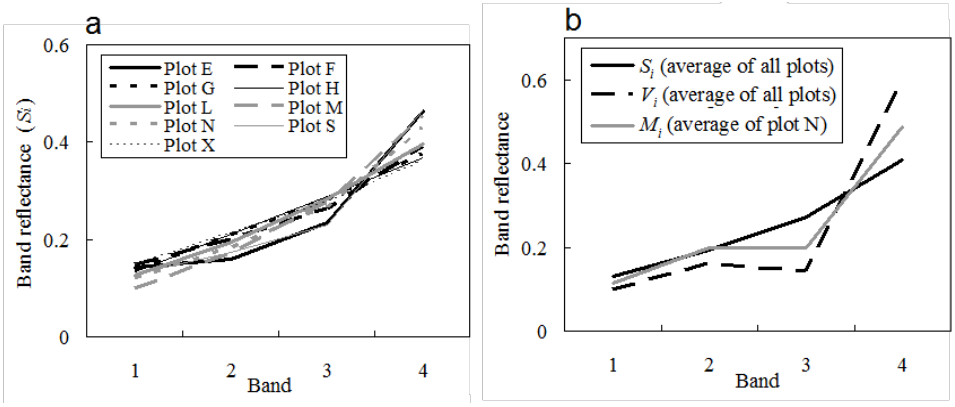

Fig. 3 Soil reflectance pattern (S_i) in each plot (a); and measured reflectance pattern (b)
Reflectance pattern (V_i) of soil and vegetation are average values of all plots, mixed reflectance pattern (M_i) is an average value of all grid points in plot N

The soil reflectance patterns were upward-sloping and linear, and the slopes of the reflectance patterns differed among the plots (Fig. 3a). To indicate the tendency of each reflectance pattern, the soil and vegetation reflectance pattern averaged over all the plots is shown in Fig. 3b. Although vegetation was strongly reflected in bands 2 and 4, absorption in bands 1 and 3 showed the characteristic reflectance pattern of vegetation. M_i was the reflectance from mixed soil and vegetation and was located near the mean value of the reflectance of soil and vegetation in bands 3 and 4. The reflectance patterns for plot N are shown in Fig. 3b, but the same tendencies were observed in the other plots as well.

Vegetation Coverage and Soil Moisture

The average value of vegetation coverage (VC) and water content in soil (WC) in each plot is shown in Table 2. The vegetation coverage was comparatively high for surfaces covered with rich vegetation. In plot M, for example, the surface was bare soil sparsely dotted with *Poaceae*, while in plot X the surface was densely covered by *Poaceae* and *Asteraceae*.

Table 2 Vegetation coverage (VC), water content in soil (WC) (The maximum, minimum and average value) and dry density in each survey plot

	VC (%)			WC (%)			Dry density (g/cm^3)
Plot	Min	Max	Average	Min	Max	Average	
E	18.5	72.5	52.2	—	—	—	—
F	2.0	11.4	6.6	1.6	3.3	2.6	—
G	13.6	47.0	32.3	1.5	3.1	2.3	1.4
H	15.2	69.2	42.0	1.0	1.9	1.3	1.4
L	37.2	94.0	54.5	0.9	4.4	2.9	1.1
M	6.6	51.2	19.4	5.3	15.8	9.7	—
N	5.0	66.3	38.1	5.8	10.8	8.0	—
R	28.5	85.0	54.7	—	—	—	—
S	52.2	93.4	81.6	4.5	20.8	13.4	0.7
X	2.1	32.5	13.9	1.0	23.4	1.5	—

Estimation of Soil Moisture and Effect of Vegetation on Estimation Accuracy

Soil moisture estimation from the pattern decomposition coefficient for flat model: Many studies have been done with visible and near-infrared wavelengths to estimate soil moisture using a soil line. In the scatter diagram of soil spectral reflectance values, where red is plotted on the horizontal axis and the near-infrared on the vertical axis, the data form a straight line (the soil line; Baret et al., 1993). Points on the scatter diagram that correspond to low water content in soil (WC) are located near the origin. However, the soil type must be classified in order to accurately estimate the soil moisture using this method because the slope of the soil line depends on the soil type. The soil line method is thus difficult to apply over a wide area utilizing remotely sensed data.

In contrast, the pattern decomposition method using flat model pattern depends less on the physical characteristics of soils. In our study, the regression analysis between WC and C_{sf} indicated a negative correlation ($WC = -26.6\ C_{sf} + 6.73$, $r^2 = 0.89$) across various soil types (Fig. 4). These results show that the C_{sf} derived from field survey data is also an effective index for soil moisture estimation, and high accuracy can be obtained without needing to classify the soil type.

Relationship between pattern decomposition coefficient and soil moisture: The pattern decomposition coefficient for flat model C_{mf} was calculated from M_i using Eq. (2), and the regression analysis performed using and WC and C_{mf}. No relationship between WC and C_{mf} ($r^2 = 0.27$) was found. In order to verify whether WC information is included in other coefficients, the following additional pattern decompositions were conducted using patterns of flat model, soil, and vegetation:

$$M_i = C_{ms3}P_{si} + C_{mv3}P_{vi}, \quad (3)$$

$$M_i = C_{mf4}P_{fi} + C_{mv4}P_{vi}, \quad (4)$$

$$M_i = C_{mf5}P_{fi} + C_{ms5}P_{si} + C_{mv5}P_{vi}, \quad (5)$$

where the typical vegetation pattern P_{vi} is the average over all the plots of V_i (band number: $i = 1$ to 4) from all plots data (P_{v1}, P_{v2}, P_{v3}, P_{v4}: 0.10, 0.16, 0.14, 0.60).

No significant correlation between WC and the pattern decomposition coefficients was found. A strong correlation, however, was found between VC and the pattern decomposition coefficient for vegetation (C_{mv3}, C_{mv4}, and C_{mv5}) (Fig. 5a). Although a correlation between VC and the

normalized difference vegetation index: [NDVI, (band 4 − band 3) / (band 3 + band 4)] was noted, (Fig. 5b), the determination coefficients of NDVI were almost the same as that of C_{mv}. These results suggest that C_{mv} is also a valuable index for estimating VC.

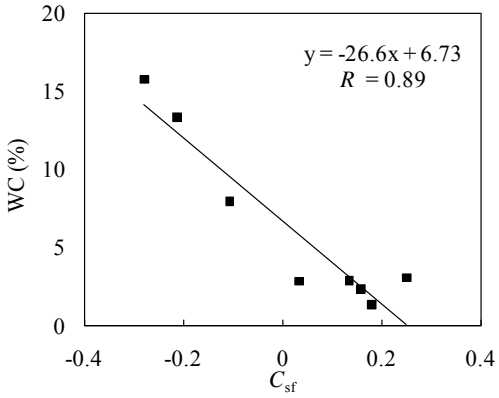

Fig. 4 Relation between water content in soil (WC) and pattern decomposition coefficient for flat model C_{sf}

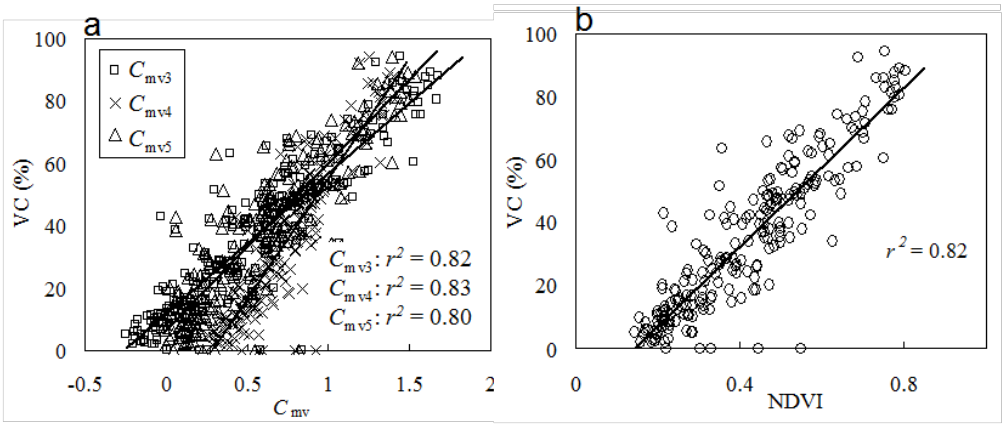

Fig. 5 Relation between vegetation coverage (VC) and pattern decomposition coefficient for vegetation C_{mv} (a)

Three combinations, C_{mv3}, C_{mv4}, and C_{mv5}, are calculated by the pattern decomposition method using soil and vegetation pattern, flat model and vegetation pattern, flat model and soil and vegetation pattern, respectively

Effect of Vegetation on Estimation Accuracy

The upper limit of vegetation coverage at which the pattern decomposition method using flat model pattern is viable was determined. Sekiyama et al. (2010) reported that estimation of soil moisture by this method was not possible when VC was over 50%. In this research, estimations were obtained for VC ranging from 0-50% (Table 3), and regression analysis was conducted using the WC and C_{mf} for each VC class. The results show that accuracy was high in the no-vegetation class (VC = 0%), but lower among the vegetated classes (VC > 0%). This leads to the conclusion that the pattern decomposition method using flat model pattern as developed by Sekiyama et al. (2010) can be effectively used only on bare soil with no vegetation. As a cause of no effectively method for mixed surface of vegetation and soil, it is supposed that physical and chemical characteristics of vegetation to spectrum is too strong compared with soil, and there is also a possibility that this coefficient is not able to estimate the water content because water content information of vegetation and soil is mixed. Thus, this coefficient is an inadequate indicator for water content when samples are contaminated by vegetation signals. Furthermore this method may not have been able to detect soil water content due to slight difference of soil water content in each plot. In fact, soil water

content was 3 % or less in almost plots but soil samples were controlled various water content from 0 % to 20% in experiment for developing estimation method of soil content

For VC > 0%, the decomposition of M_i into the flat model pattern was affected by the high reflectance of vegetation in band 4 and the low reflectance in band 3. As a future refinement of this method, a separation (pre-decomposition) of the vegetation reflectance from the mixed data, which may be achieved using the relationship between VC and C_{mv}, is required. Such a refinement would allow the method to accurately extract WC from areas of mixed soil and vegetation.

Table 3 Relation between water content in soil (WC) and the pattern decomposition coefficient for flat model (C_{sf}) at each vegetation coverage (VC)

VC (%)	Estimate accuracy of WC (r^2)	P value
0	0.89	$P < 0.01$
0-5	0.10	$P > 0.05$
5-10	0.29	$P > 0.05$
10-20	0.02	$P > 0.05$
20-30	0.01	$P > 0.05$
30-50	0.006	$P > 0.05$

CONCLUSIONS

In this study, a method for estimating soil moisture developed by Sekiyama et al. (2010) was applied to field data acquired in the Mongolian grasslands. The following conclusions were obtaind:

・The bare soil of the Mongolian grasslands exhibits a negative correlation between water content in soil (WC) and the pattern decomposition coefficient for flat model C_{sf}, which was calculated using the pattern decomposition method modified by Sekiyama et al. (2010). This indicates that C_{sf} is a useful indicator of WC in bare soil.

・A strong correlation was found between the vegetation coverage and the pattern decomposition coefficient for vegetation C_{mv}. This indicates that C_{mv} be used not only to extract bare soil information, but to estimate the vegetation coverage and NDVI as well.

No significant relationship between WC and the pattern decomposition coefficient for flat model C_{mf} was found in the decompositions of the reflectance patterns from vegetated surfaces. This indicates that the method as proposed by Sekiyama et al. (2010) is influenced by vegetation, and is thus capable of accurately estimating soil moisture only on bare soil.

ACKNOWLEDGEMENTS

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REFERENCES

Baret, F., Jacquemoud, S. and Hanocq, J.F. 1993. The soil line concept in remote sensing. Remote. Sens. Rev. 13 (5), 281-284.

Fujiwara, N., Muramatsu, K., Awa, S., Hazumi, T. and Ochiai, F. 1996. Pattern expand method for satellite data analysis. J. Remote Sens. Soc. Japan. 16 (3), 17-34. (In Japanese with English abstract)

Ishiyama, T., Sugihara, S., Tsuchiya, K., Liu, P.J. and Lu, G.F. 1992. Variation of sand reflectance with moisture content. J. Arid Land Stud. 2, 39-43.

Kogan, F., Stark, R., Gitelson, A., Jargalsaikhan, L., Dugrajav, C. and Tsooja, S. 2004. Derivation of pasture biomass in Mongolia from AVHRR-based vegetation health indices. Int. J. Remote. Sens. 25-14, 2889-2896.

Kondoh, A., Kaihotsu, au-Chavez, L.L., Rober, R.A., Wyatt, H.K., Waddington, M.J., Turetsky, R.M.I., Hirata, M. and Dorgorsuren, A. 2005. Interannual variation of biomass in mongolian herbaceous vegetation. J. Arid Land Stud. 14-4, 209-218. (In Japanese with English abstract).

Lee, R., Yu, K., Price, K.P., Ellis, J. and Shi, P. 2002. Evaluating vegetation phenological patterns in Inner Mongolia using NDVI time-series analysis. Int. J. Remote Sens. 23 (12), 2505-2512.

Liu, W., Baret, F., Gu, X., Zhang, B., Tong Q. and Zheng, L. 2003. Evaluation of methods for soil surface moisture estimation from reflectance data. Int. J. Remote Sens. 24 (10), 2069-2083.

Muramatsu, K., Furumi, S., Fujiwara, N., Hayashi, A., Daigo, M. and Ochiai, F. 2000. Pattern decomposition method in the albedo space for Landsat TM and MSS data analysis. Int. J. Remote Sens. 21 (1), 99-119.

Muramatsu K., Xiong Y., Nakayama S., Furumi S., Ochiai F., Daigo M ., Hirata M., Oishi K., Bolortsetseg B., Oyunbaatar D. and Kaihotsu I. 2007. A new vegetation index derived from the pattern decomposition method applied to Landsat-7/ETM+ images in Mongolia. Int. J. Remote Sens. 28 (16), 3493-3511.

Ono, A., Fujiwara, N. and Ono, A. 2002. Suppression of topographic and atmospheric effects by normalizing the radiation spectrum of Landsat/TM by the sum of each band. J. Remote Sens. Soc. Japan. 22 (3), 318-327. (In Japanese with English abstract)

Ranjeet, J., Chen , J., Lu, N., Guo, K., Liang, C., Wei, Y., Noormets, A., Ma, K. and Han, X. 2008. Predicting plant diversity based on remote sensing products in the semi-arid region of Inner Mongolia. Remote Sens. Environ. 112 (5), 2018–2032.

Sekiyama, A., Shimada, S., Toyoda, H. and Yokohama, M. 2010. Estimation of soil water content using visible and infrared spectral reflectance characteristics. J. Arid Land Stud. 19 (4), 525-535. (In Japanese with abstract)

Yoshihara, Y., Chimeddorj, B., Buuveibaatar, B., Lhagvasuren, B. and Takatsuki, S. 2008. Effects of livestock grazing on pollination on a steppe in eastern Mongolia. Biol. Conserv. 141 (9), 2376-2386.

Zhang, L., Furumi, S., Muramatsu, K., Fujiwara, N. and Daigo M. 2007a. A new vegetation index based on the universal pattern decomposition method. Int. J. Remote Sens. 28 (1), 107-124.

Zhang, L., Fujiwara, N., Furumi, S., Muramatsu, K., Daigo M. and Zhang L. 2007b. Assessment of the universal pattern decomposition method using MODIS and ETM+ data. Int. J. Remote Sens. 28 (1), 125-142.

Zribi, M., Paris, A.T., Duchemin, B., Lili, Z., Wagner, W., Hasenauer, S. and Chehboun, A. 2010. Relationship between soil moisture and vegetation in the Kairouan plain region of Tunisia using low spatial resolution satellite data. Water Resource. Res., 46 (6), 1343-1357.

Research article

Peatland Tank Model for Evaluation of Shallow Groundwater Table Data without Height Reference from Benchmark

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Abstract Long-term monitoring of shallow groundwater table (GWT) is essential for the evaluation of hydrologic conditions of peatlands, which is meaningful for their conservation and restoration, especially in certain rural areas. Although there has been research in this field, a simple and effective method for the evaluation of GWT fluctuation has not been developed. Peatland Tank Model (PTM) is a one-dimensional water balance model that represents fluctuations of shallow GWT in peatland. The model contains several parameters, i.e., *C* (coefficient of GWT increase), *Ai* (coefficient for the size of plugholes, with *i* =1, 2, 3), and *HAi* (coefficient for the height of each plughole, *i* =1, 2, 3). We used PTM with 29 years' GWT data from Ochiai, Sarobetsu Mire, northern Hokkaido, Japan. These GWT data do not have a height reference from a benchmark, so that the data have no common meaning or information in relation to the ground surface or elevation above sea level. Observation was conducted at three sites; Site D near a drainage ditch along a peat mining location; Site M at the edge of the peat mining area; and Site U in an unused area far from the drainage. A few sets of parameters were obtained on the basis of simulation results. Smaller simulation errors were attained using the PTM. The 29-year GWT fluctuations at Site D were the greatest and could be characterized by the largest parameter values. Parameter trends at three sites varied, and were able to reflect the various drainage conditions. Thus, the PTM is a promising method for the evaluation of long-term variations and site differences of hydrologic conditions in peatland.

Keywords mire, groundwater table, peatland hydrology, drainage

INTRODUCTION

In recent years, a large number of peatlands have been exploited and converted to agricultural land. Examples can be found in Canada (Bhatti and Tarnocai, 2009), Sumatra and Kalimantan in Indonesia (Page et al., 2011), and Hokkaido, northern Japan (Umeda, 1980; Fujita et al., 2009). As a unique terrestrial system, peatland requires proper means of conservation and restoration. Consequently, balancing agricultural development and peatland conservation has become a research subject. The hydrologic environment, especially shallow groundwater table (GWT) fluctuation, is the most important determinant of the formation and existence of peatland. Long-term monitoring of shallow GWT is essential for the investigation and evaluation of the hydrologic environment. Nonetheless, in the past, the majority of monitoring GWT data has been assembled in form of groundwater depth or groundwater level which are not measured with respect to certain benchmarks (sea level or ground surface). A simple and effective method for evaluating the hydrologic environment using such GWT data has not been developed. In view of this situation, this paper proposes a simple evaluation method for shallow GWT fluctuation in peatland, based on Peatland Tank Model (PTM). The model provides satisfactory simulation accuracy and flexibility.

OBJECTIVE

The objective of this study is to show how the PTM detects the spatial variability and temporal changes of GWT fluctuation patterns even if the GWT data are not measured with respect to certain benchmarks. The usefulness and effectiveness of the PTM for the shallow peatland GWT are discussed. The meaning and function of each parameter used in the PTM are also explained.

METHODOLOGY

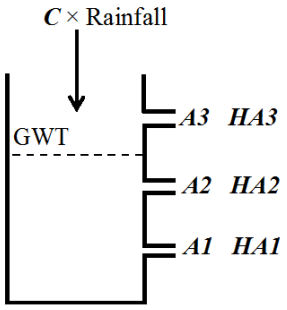

Fig. 1 Peatland Tank Model

The PTM is a water balance model for simulating the fluctuations of the shallow GWT in peatland (Umeda and Inoue, 1985). In this model, the peatland system is analogous to a water storage tank. GWT fluctuations can be represented by variations of water levels in the tank. For a bog fed by rainfall, rainwater is the sole inflow and there are almost no other water inputs from the surrounding environment. Evapotranspiration (ET) and discharge from the bog to surrounding areas are the main outflows. The PTM (Fig. 1) has three outlet plugholes on the sidewall of the tank.

In theory, the PTM can be characterized by Eqs. 1 and 2.

$$GWT_n = GWT_{n-1} + C \times R_n - \left(\sum_{i=1}^{3} QAi_{n-1} \right) \quad (1)$$

$$QAi_{n-1} = Ai \times \left(GWT_{n-1} - HAi \right) \quad (2)$$

Here, GWT_n and GWT_{n-1} represent the GWT at times n and $n-1$, respectively. C is the coefficient of GWT increase owing to rain. R_n is the amount of rainfall during time period $(n-1)$ to n. QAi_{n-1} is the amount of groundwater drawdown from the each plughole (i =1, 2, 3) during the same period. Coefficients Ai ($0 \leq Ai \leq 1$) and HAi are the size and height of each plughole, respectively. The time unit (data sampling interval) of 2 hours was used for estimating GWT by the PTM.

Constant discharge of the peatland and ET were incorporated into water loss from the bottom plughole. Based on such concept, parameter *A1* represents the basic discharge (constant discharge and ET) from the peat layer above height *HA1*. Similarly, parameters *A2* and *A3* are introduced to represent water losses of the layer above heights *HA2* and *HA3*, respectively. These two parameters are used to characterize more rapid water losses in the shallow surface layer of the peat (Fig. 1). Parameter *C* shows the magnitude of GWT increase in response to rainfall in the peatland.

Two simulation methods were implemented (Table 1). Because it is difficult to adjust simultaneously all seven parameters and this may make the contribution of each parameter ambiguous, we did not manipulate all seven. Without an explicit principle, determining the parameters is meaningless. Therefore, several rules (mentioned in the footnote of Table 1) were established. Based on these rules, the number of parameters in the PTM was reduced from the original seven to three (Method 1) or two (Method 2).

Table 1 Simulation methods

Method	Manipulated Parameters	Fixed or Automatically Determined Parameters	Remarks
1	*C*, *A1*, *A2*	*A3*, *HA1*, *HA2*, *HA3*	*1, *2
2	*C*, *HA1*	*A1*, *A2*, *A3*, *HA2*, *HA3*	*2, *3
			In all cases, *A3* = 1.

*1: *HA1* = *HA2*−40 cm, *HA3* = *HA2*+10 cm or *HA3* = GWTm (if (*HA2*+10 cm) > GWTm).
*2: *HA2* is equal to the value of upper tertile of GWT data calculated via the following steps. In the first step, all observed GWT data within the calculation period at each site were sorted numerically, in descending order. This set should include every datum, even if there are overlaps. Then, the value found one third of the way down from the maximum in the organized dataset is defined as the upper tertile.
*3: *A1* = 0.0003, *A2* = 0.03, *HA3* = *HA2*+10 cm or *HA3* = GWTm (if (*HA2*+10 cm) > GWTm). GWTm: the maximum GWT.

We adopted PTM with 29 years of GWT data recorded (1983–2012, except for 1998) at Ochiai, Sarobetsu Mire, northern Hokkaido (approximately 45°8′N, 141°44′E). GWT was observed at three sites: Site D near a drainage ditch along the peat mining location; Site M at the edge of the peat mining area; and Site U in an unused area far from the drainage (from 2006 onwards, the measurement of Site U could not be continued due to the problems of instrument). Annual average temperature in this area is ~6.1 °C, varying from −6.5 °C in February to 19.6 °C in August. Annual average precipitation is 1,073 mm (Japan Meteorological Agency). On average, the warm period without snow cover lasts from mid-April through late October. All calculations were performed for July through September. Due to the limitation of equipment and manpower, the observed GWT data were measured without reference height such as ground surface or elevation above sea level. Compared with the absolute ground water tables, GWT without reference height are more difficult to evaluate, because the data have no common meaning.

In PTM computations, the parameters were adjusted repeatedly until the optimum simulation result was attained, where the chi-square value of GWT was minimized and the Nash-Sutcliffe efficiency coefficient and correlation coefficient (r) were maximized. Values of each parameter were compared by site and examined by one-way analysis of variance (ANOVA). ANOVA significance levels were set to 0.05 and 0.01. Based on 29 years' GWT observations at each site, long-term trends of each parameter were evaluated by the coefficient of determination (R^2). All statistical tests were conducted using SPSS 16.0 statistical software (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Throughout the results from 1983 to 2012, parameter *C* was in the order Site D > Site M > Site U, from both methods (Fig. 2). This indicates that the magnitude of GWT increase in response to rain events was maximum at Site D and minimum at Site U. A larger value of *C* means less effective porosity for water storage in peat (Umeda and Inoue, 1985). Therefore, it is concluded that the effective porosity of peat at the three sites was in the order Site D < Site M < Site U. At the three sites, changes of parameter *C* over the last 29 years do not show clear trends ($P > 0.05$) (Fig. 2). However, there is a strong negative regression relationship between *C* and total amount of rainfall from July through September at all sites (Fig. 3). From Method 1, R^2 at Site D exceeded 0.80 ($P < 0.01$). This relationship can be explained by the fact that effective porosity increases in peat near the ground surface. When the amount of rainfall increases, the GWT may spend more time in the upper part of peat layer, where the effective porosity of peat is relatively large and the ratio of water table increase (*C*) becomes small.

In Method 1, GWT fluctuations can be characterized by variations of parameters *C*, *A1*, and *A2*. The difference of *A1* between Sites M and U was not obvious (n=21, $P > 0.05$); however, this difference was significant between Site D and the other two sites (n=28 for Site D and M, n=21 for Sites D and U, $P < 0.01$) (Fig. 4). Differences of *A2* among the three sites were not obvious ($P > 0.05$). The average *A2* at site U (n=21, average = 0.03) is smaller than those at the other two sites (n=28 for Site D, n=29 for Site M, average of both sites = 0.04). Parameters *A1* and *A2* at all sites

over the last 29 years do not show clear trends ($P > 0.05$). The fact that the value of *A1* at Site M was similar to that at Site U means that characteristics of basic and constant water losses from the peat layer (mainly from the catotelm) were similar at those two sites. In contrast, a larger *A1* at Site D means that the amount of water loss was greater than at the other two sites. Similarly, *A2* at the three sites was nearly identical, which indicates that water losses from the upper peat layer (part of the acrotelm) at the three sites were similar. In conclusion, Site D had greater water loss compared with the other two sites, but water loss of the upper peat layer at all three sites were similar.

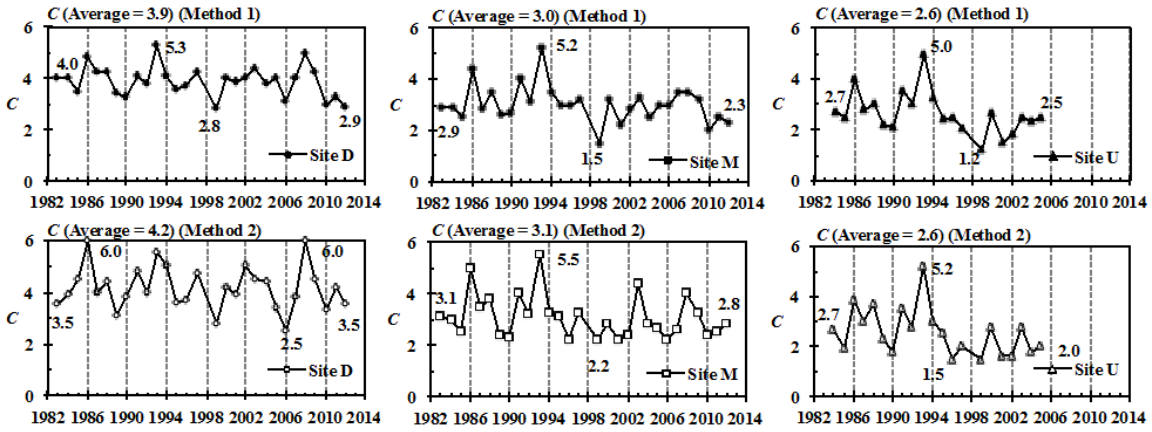

Fig. 2 Variation of parameter *C* at three sites from 1983 to 2012

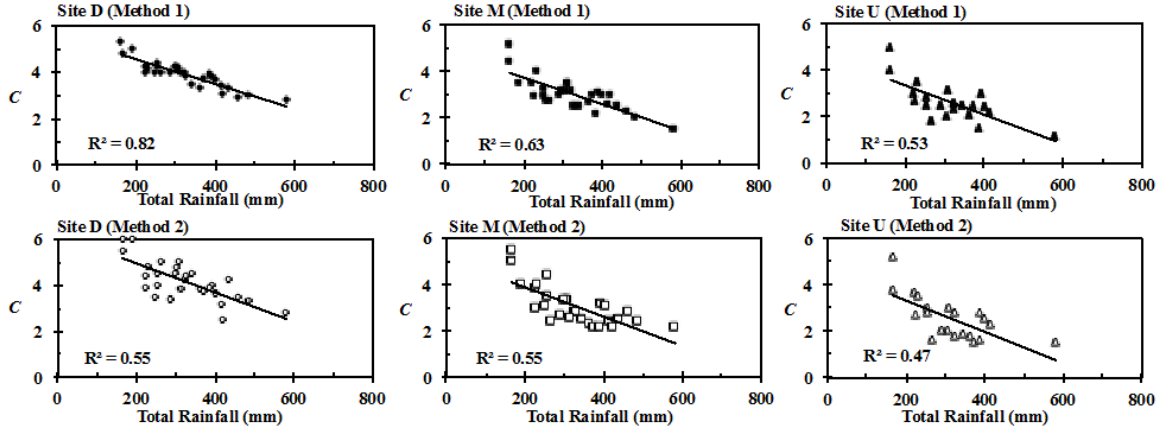

Fig. 3 Relationship between parameter *C* and total rainfall (July through September) at three sites from 1983 to 2012

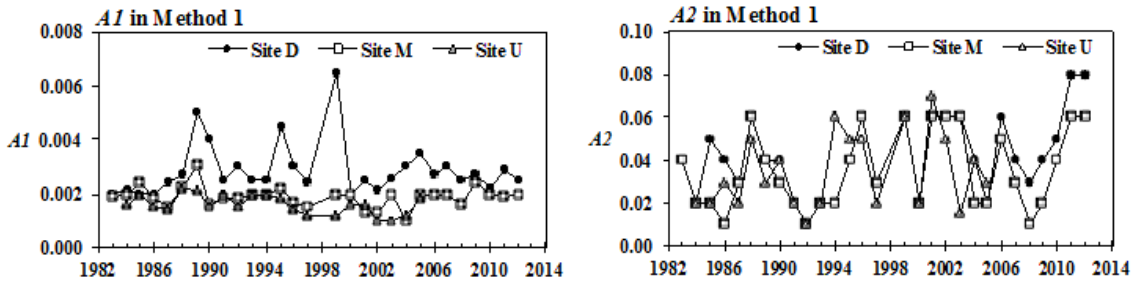

Fig. 4 Variation of *A1* and *A2* in Method 1 at three sites from 1983 to 2012

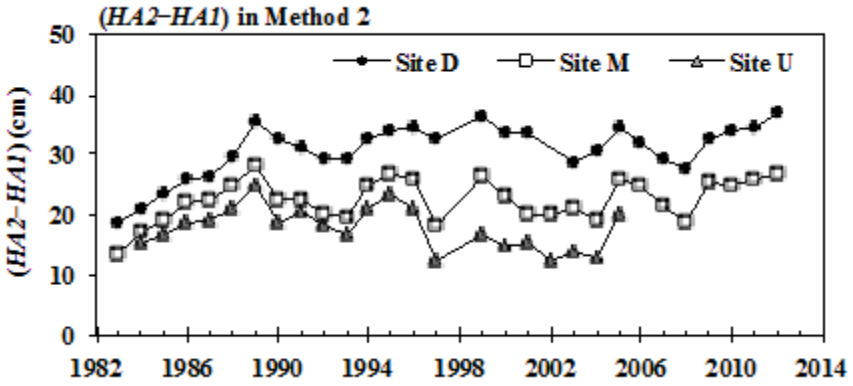

Fig. 5 Trends of (*HA2*–*HA1*) over 1983–2012 at three sites, from Method 2

In Method 2, GWT fluctuations are represented by parameter *C* and (*HA2*–*HA1*). Figure 5 shows variations of vertical distances between the lower two outlet plugholes (*HA2*–*HA1*) at the three sites. Under the same condition of *A1* = 0.0003, *A2* = 0.03, and *A3* = 1 for the three plugholes, there were significant differences in (*HA2*–*HA1*) among the three sites. Average values of (*HA2*–*HA1*) during the last 29 years at sites D, M, and U were 30.7 cm, 22.5 cm, and 17.9 cm, respectively. The greater vertical distance (i.e., depth of bottom plughole) at Site D means that the unit-time GWT drawdown from the bottom plughole *QA1* (cf. Eq. 2) at Site D was larger than those at sites M or U. Thus, the larger value of (*HA2*–*HA1*) indicates more rapid discharge. Over the same period, (*HA2*–*HA1*) at site D increased, with slope 0.29 cm/year ($P < 0.01$). (*HA2*–*HA1*) at Site M increased by 0.14 cm/year and decreased by –0.22 cm/year at Site U, but the trend was not significant for either ($P > 0.05$) (Fig. 5).

The reason for such a change may be inferred as follows. In summer 1983, the drainage ditch near these three sites was dredged and deepened. In the following few years (1983–1989), leakage of water by piping from the adjacent mining pool to the ditch was observed. In terms of parameter variation, (*HA2*–*HA1*) increased yearly in this period. In the last 29 years, drainage intensity at Site D clearly increased. However, at sites M and U, variations of drainage intensity were not as significant. This fact indicates that drainage changed the water loss characteristics of peat and its influence persisted in the following years.

The three observation sites have different drainage conditions. However, it is difficult to distinguish the difference of GWT fluctuations visually, so these fluctuations appeared similar. Using the PTM, various characteristics of GWT increase could be represented by parameter *C*, and GWT decrease could be described by parameters *Ai* and (*HA2*–*HA1*). Large values of parameters *C*, *Ai* and (*HA2*–*HA1*) indicate that GWT may response to rain and dry events greatly. Moreover, differences of *Ai* among observed sites were able to reflect site differences of drainage characteristics in various peat layers (Method 1). Variations of (*HA2*–*HA1*) could depict long-term trends of drainage characteristics at each site (Method 2). In addition, the parameters could also represent peat properties. A larger *C* value indicates less effective porosity and less water storage of peat. Larger *Ai* and (*HA2*–*HA1*) values indicate that the GWT decreases rapidly so that the peat becomes drier during rain-free periods.

There is a strong regression relationship between parameter *C* and total amount of rainfall. Therefore, this amount during the simulation period gives hint to the determination of *C*. For instance, the value of *C* in a year with greater rainfall would be smaller. In the case of greatly changed drainage conditions, simulation by Method 1 was unable to match actual GWT fluctuations, because the distance between *HA1* and *HA2* was fixed at 40cm. For instance, if a drainage channel was renewed or newly excavated near the observation site, drainage may have intensified and the drop of GWT from the height of *HA2* may have exceeded 40cm. Under such circumstances, Method 2 is considered more suitable than Method 1. In practical use of the PTM, the vertical distance and size of each plughole could be adjusted according to peatland conditions at

individual sites. Additionally, the principle of computation, such as simulation rules and methods, could be adjusted to meet specific peatland conditions.

Average simulation errors of all calculations are shown in Table 2. By applying the rules in the footnote of Table 1, Method 2 could simplify the computation by decreasing the number of parameters to be fit, but simulation error might become slightly larger than that of Method 1. Moreover, through Method 2, site differences were shown more clearly by the obvious differences of (*HA2–HA1*) at the three sites, and the trend of long-term drainage effects also became apparent through yearly decline of the depth of the bottom plughole at Site D.

Table 2 Average errors of all simulations by site for each method

Method	Site D (n=28)			Site M (n=29)			Site U (n=21)		
	r	CHI	NSE	*r*	CHI	NSE	*r*	CHI	NSE
1	0.91	9.2	0.84	0.93	5.5	0.86	0.93	5.1	0.86
2	0.89	12.6	0.83	0.92	6.0	0.84	0.93	5.9	0.85

r: *correlation coefficient; CHI: chi-square value; NSE: Nash-Sutcliffe efficiency coefficient*
n*: number of observed years*

CONCLUSSIONS

The present study proposed a PTM-based evaluation method for shallow GWT fluctuations of peatland, especially bogs. This method can simulate the GWT with accuracy of a few centimeters. Further, subtle differences in fluctuation patterns can be distinguished by model parameters for different locations or time series.

The observed GWT data used herein were not measured with respect to certain elevation references or benchmarks (i.e., sea level or ground surface). In this study, we provide a solution to evaluate the changes in GWT fluctuation patterns or site differences of GWT conditions of peatland, when the ground water table data were measured without height reference. Through use of the PTM, such observed GWT data were effectively used for evaluating such changes and differences. Especially via Method 2, variations and trends of parameters revealed the site differences and long-term changes of GWT condition.

The seasonal response of ET and amount of soil moisture in the unsaturated peat surface layer were not considered in the current version of the model. Hence, improvement could be made in the near future to achieve more accurate simulation results.

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REFERENCES

Bhatti, J. and Tarnocai, C. 2009. Soil carbon sequestration and the greenhouse effect. Soil Science Society of America, 64.

Fujita, H., Igarashi, Y., Hotes, S., Takada, M., Inoue, T. and Kaneko, M. 2009. An inventory of the mires of Hokkaido, Japan-their development, classification, decline, and conservation. Plant Ecology, 200, 9-36.

Japan Meteorological Agency. (http://www.jma.go.jp/jma/menu/report.html. Accessed 20 May 2014).

Page, S., Rieley, J. and Banks, C. 2011. Global and regional importance of the tropical peatland carbon pool. Global Change Biology, 17, 798-818.

Umeda, Y. 1980. Present status and problems for agricultural use of peatland in Hokkaido, Northern Japan. Proc. 6th Int. Peat Congr. Duluth, Minnesota, USA., 501-505.

Umeda, Y. and Inoue, T. 1985. The influence of evapotranspiration on the groundwater table in peatland. Journal of the Faculty of Agriculture, Hokkaido University, Japan, 62 (2), 167-181.

Research article

Ecotoxicology of Copper on Local Freshwater Organisms in Mekong River Cambodia

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Abstract The protection of aquatic habitat from damage and understanding of both sensitivity of aquatic organisms to contaminant and ecological effects. Mekong River quality criteria of aquatic life for metals are largely driven by the extremely sensitive small organisms toxicity which are the Mekong native species. In this study we assessed the toxicity of Copper in the Mekong river water with Chironomids Species (*Chironomus javanus*) and Nile tilapia (*Oreochromis niloticus*). Acute toxicity effect of copper concentration to freshwater animals occur after the exposure at tested with Mekong water was studied by observing mortality and LC_{50} over a 24 hours test period. The LC_{50} with 95% confidence limit of the 96-hours toxicity was performed to contrast responses of Chironomids Species *(C. javanus)* and Nile tilapia (*O. niloticus)*. The result showed that the LC_{50} with 95% confidence limit obtained were 742 µg/L in Chironomids Species *(C. javanus)* and 853µg/L in Nile tilapia *(O. niloticus)*. Copper (Cu) is a big concern for environment, human and aquatic organisms because it can accumulate in to plant and animals via food web. The out coming of this series of laboratory experiment will provides a worst-case scenario and useful for determine the risk assessment of copper on local freshwater organisms in Mekong River Cambodia as well as Mekong River Basin.

Keywords ecotoxicology, acute toxicity, copper, local freshwater animals, Mekong River

INTRODUCTION

The resources of the Mekong Basin, such as fishes, other aquatic resources and plants are play main role in food security, income and livelihood for many people across the Lower Mekong Basin. Around 60 million people live in the lower Mekong Basin and most of people in the basin are closely linked to the Mekong and resources of it to support their livelihood (MRC, 2007; Ferguson et al., 2011). The development activities during the past decade and up to now, including mining, agriculture, deforestation, grazing and urbanization have caused of extensive soil erosion and contribute increasingly to environmental levels of heavy metals especially copper (Cu) into water body (Ti and Facon, 2004; Coates et al., 2006)

Copper mining was known as the important sector for economics. Therefore, it represents an essential in all living organisms that is required in small amounts (Heath, 1995). Humans, other animals, fish and shellfish require 5-20 micrograms per gram (µg/g) for carbohydrate metabolism and the function of more than 30 enzymes. However, too much of copper concentration which exceed 20 microgram per gram (µg/g) will be toxic, was explained by Wright and Welbourn (2002) and Bradl (2005). Copper has been documented as one of the most toxic metals to aquatic organism and ecosystem (Scudder et al., 1998; Bradl, 2005; Carreau and Plye, 2005). Heavy metal

contamination of copper (Cu) is a big concern for environment, human and aquatic organisms. Copper (Cu) does not break down in the environment because of that it can accumulate in to plant and animals.

The United States Environmental Protection Agency (US.EPA) has issued a guideline for conducting early-life-stage toxicity test suitable for acute and chronic toxicity tests used for measuring the aggregate toxic chemicals in an effluent or receiving water to freshwater and marine organisms (US. EPA, 2002). In Cambodia, the information on the impact of toxicity effects of soluble copper on the tropical aquatic biota is limited. Therefore, many research papers were designed and conducted on ecotoxicology on copper everywhere in the world, but most them were the different species and different from local species in the Mekong River. The out coming of toxicity tests for copper will contribute data to aquatic environments and ecotoxicological freshwater system for environmental quality standard in order to help and protect the Mekong River in Cambodia as well as Mekong River Basin.

OBJECTIVES

The objective of studying is focus on ecotoxicology of copper on freshwater biota of Nile tilapia *(Oreochromis niloticus)* and Chironomids species *(Chironomus javanus)* with Mekong River in Cambodia.

METHODOLOGY

Sampling

This study was conducted in the Lower Mekong Basin of Cambodia which located in the Kampong Cham Province (Fig. 1).

Fig. 1 Map showing the sampling location

Organisms

Native species of Mekong River fish Nile tilapia *(O. nileticus)* larvae were obtained from the Department of Fisheries, Khon Kaen, Thailand. The tested fish larva was immediately collected after hatching in oxygenate bags to the laboratory and handle properly to minimize injury and stress physiological in order to reduce the number of dead organisms. The test was conducted at Ecotoxicology laboratory in Khon Kaen University. Average weight of Nile tilapia was

9.717±0.040 mg which used for acute toxicity testing. Young organisms are often more sensitive than adults. For this reason, the use of early life stages such as fish fingerling is required for all tests. In a given test, all organisms should be taken from the same source in order to minimize the organisms diversity of response to experimental materials (US.EPA, 2002).

Chironomids Species *(C. javanus)* midge larvae were cultured at ecotoxicology laboratory of Khon Kaen University, Thailand. Organisms were cultured in a glass container, covered with a net to trap emerging adults. Since the aquarium already contains male and female species, mating and production of eggs is possible. To produce eggs of similar age, each egg mass collected was placed on the beaker containing 25 mL of tap water that was aged overnight. After two days, when all eggs were hatched, larvae were transferred on a 14 inches x 10 inches x 6 inches aquarium and given fish flakes for food. This was used as substrate. Overlying water was being replaced every three days. The second instar organisms were placed individually in micro test tubes file with test solutions. Tube was added, just enough for the organisms to create their own tubes.

Chemical and Test Procedure

The standard stock solution (100 mg/L) for studied metals was freshly prepared by dissolving of copper sulfate $CuSO_4$ $5H_2O$. The test organisms were subjected to different concentrations (450, 500,600 1000, 1500 µg/L) for the fish and (500, 800, 1000, 3000, 5000 µg/L) for *C. javanus* of the stock copper solution in each container. The control was kept in experimental water without adding copper. Water quality parameters (temperature, DO, alkalinity, hardness and pH) used in containers were periodically determined before toxicity test (table 2). In addition, the experimental medium was aerated in order to keep the amount of DO not less than 6 mg/L (Ezeonyejiaku et al., 2011).

Acute Toxicity Test

Acute copper toxicity experiments were performed for a 4-d period (96h) using small fishes at 5 days old and the second instar larva of *(C. javanus)*. The number of dead organisms were counted every 24 hours and removed from aquarium as soon as possible. During the toxicity test, organisms were not fed. The experimental were performed at room temperature of 25± 1 °C, with a Photoperiod of 12h light: 12 darkness. All control result in lower mortality, less than 10% which revealed the acceptability of the test (US. EPA, 2002).

Water Quality

The water quality parameters measured during the test were pH 7.77 ± 0.02, Conductivity 191± 1.53 µS/cm, TDS 45±005mg/L, dissolve oxygen 10.46±0.05mg/L, and total hardness (mg^{2+} and Ca^{2+}) 88±4 mg/L as $CaCO_3$. The mean value of other water quality parameters such as DOC, BOD and alkalinity were 5.74 ±0 mg/L, 1.33±0.20 mg/L and 104±0 mg/L, respectively (Table 1).

Table 1 Water quality parameter of Mekong River for acute toxicity of copper on Nile tilapia and *C. javanus*

Parameters	Result Water quality of Mekong River	US. EPA, 2002
pH	7.77±0.02	6.8-8.4
Temperature (°C)	28±0.03	25±1
DO (mg/L)	10.46±0.05	Above 80%
EC (µS/cm)	191±1.53	-
TDS (mg/L)	45±0	-
Alkalinity (mg/L)	104±0	-
Hardness (mg/L)	88±4	-
BOD (mg/L)	1.33±0.20	-
DOC (mg/L)	5.74± 0	-

Statistical Analysis

All the results were carried out by analysis of variance (ANOVA) with Duncan's Multiple Rang Test (DMRT) by Statistic 8 software (version 8, USA) on the Factorail experiment in Completely Randomized Design (CRD). The significance was reported at $p<0.05$ levels. Toxicological dose-response data involving quintal response (mortality) following toxicity of copper on the test species, Nile tilapia and *C. javanus* larvae were determined by use of Probit Analysis LC_{50} Determination Method (SPSS, version 19 software). The rate response determined at the end of the 96th hour. Significance in 95% confidence interval (95%CI) of detected 96 hours LC_{50} value was determined using the Chi-Square technique (Ezeonyejiaku et al., 2011).

RESULTS AND DISCUSSION

The data from acute toxicity test of copper for Nile tilapia *(O. niloticus)* and *C. javanus* larvae released that the mortality of organisms increased with increasing copper concentration and exposure time (Table 2). Copper was found toxic to Nile tilapia responding higher than *C. javanus*. The Mean value 24, 48, 72 and 96 hr LC_{50} for $CuSO_4$ $5H_2O$ in the Nile tilapia were 1228, 1052, 939 and 742 µg/L. Hence, the acute test of 96, 72, 48 and 24 hr showed an opposite relationship between LC_{50} and exposure time, increase in the concentration reduces the time to kill 50% of the tilapia fish. Previous studies (Taweel et al., 2013) showed the LC_{50} 96 hr value for copper was 1093 µg/L on the fingerline Tilapia fish *(O. niloticus)*. However, this result is higher than present study. Various authors in different parts of the world including tropical (Shuhaimi-Othman et al., 2013; Mastin and Rodgers, 2000, Taylor et al., 1991) have observed same and recorded differential toxicity of heavy metal compounds against different test animals. Cusimano et al., (1986) and Solbe (1984) also reported that the acting metal (copper) might be due to the physicochemical characteristics of the test medium, species and ages of fishes used and their susceptibility rates to the test chemical.

Mean 24, 48, 72 and 96 hr LC_{50} values for Cu as $CuSO_4$ $5H_2O$ in the *C. javanus* are presented in the table 2. The 24 hr LC_{50} for $CuSO_4$ was 8237 µg/L which sharply declined to 5033, 2206 and 853 µg/L at 48, 72 and 96 hr, respectively. Also, it could be noted that Copper effect to the *C. javanus* in the long time exposure. The 48 hr LC_{50} for $CuSO_4$ was 1073 µg/L in *C. ramousus* third instar larvae (Majumdar and Gupta, 2012) and the 96 hr LC_{50} in *C. tentans* and *C. ramousus* 170 and 183µg/L, respectively (Shuhaimi-Othman et al., 2013; Majumdar and Gupta, 2012). These values are considerably lower than responding value in *C. javanus*, indicating higher vulnerability to Cu in the former two species. Mastin and Rodgers (2000) reported that 48 hr LC_{50} of midge larvae *C. tentans* exposed to Clearigate and Cutrine-Plus were 373.5 and 460.9 µg/L, respectively. On the other hand, Copper sulfate was an order of magnitude less toxic to *C. tentans* than Clearigate and Cutrine-Plus with a mean 48 hr LC_{50} 1,136.5 µg/L (Mastin and Rodgers, 2000).

Percentage mortality of Nile tilapia (*O. niloticus*) and *C. javanus* larvae to copper solution with Mekong River water for 96 hours are presented in Fig. 2. From the concentration- response obtained, it could be seen that *C. javanus* was more sensitive than Nile tilapia. Lower threshold responses of *C. javanus* and Nile tilapia were 538 and 462.5 µg/L, respectively. And upper thresholds of response of $CuSO_4$ with 100% mortality were observed for *C. javanus* and Nile tilapia at 5095 and 1595 µg/L, respectively.

Table 2 LC_{50} Value of $CuSO_4$ $5H_2O$, for Nile tilapia and *C. javanus*

Species	LC_{50} with 95% CL (µg/L)			
	24h	48h	72h	96h
Nile tilapia	1228 (1138-1340)	1052 (890-1296)	939 (771-1185)	742 (562-981)
C. javanus	8237 (5471-32105)	5033 (3035-88359)	2206 (-)	853 (-)

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

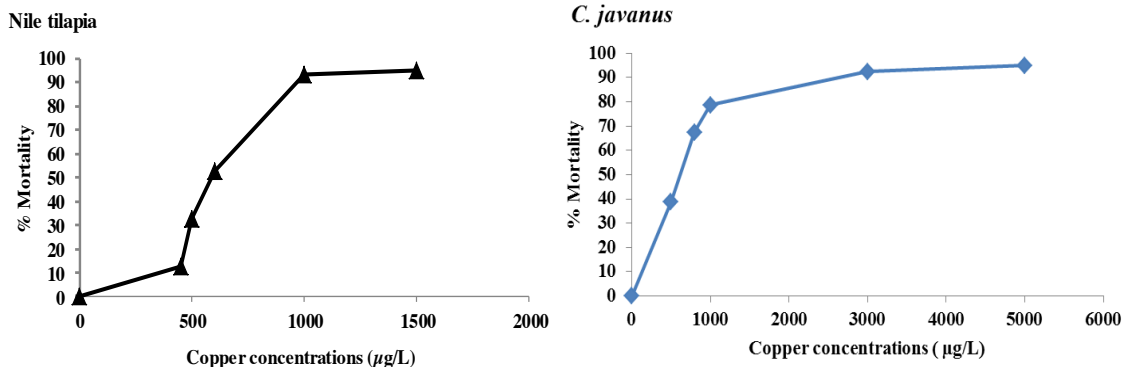

Fig. 2 Percentage mortality of Nile tilapia and *C. javanus* larvae to copper solution with Mekong River water for 96 hours

CONCLUSION

Present study indicated that mortalities for both species increase with increasing copper but LC_{50} value decreased as more toxic on Nile tilapia and *C. javanus*. The 96 hr LC_{50} for $CuSO_4$ $5H_2O$ in the Nile tilapia and *C. javanus* were 742 and 853 µg/L, respectively. *C. javanus* was found more sensitive than Nile tilapia to copper.

Copper sulphate is still commonly used in the study area and in many developing countries to control the water pollution. It is also used as fungicide in agricultural fields study area where from it could be transported into the freshwater ecosystems via surface run off. Therefore, the high toxicity of $CuSO_4$ to non- target organisms like aquatic organisms needs to be taken into careful consideration before applying it indiscriminately in freshwater system. Due to the lack of the data on ecotoxicology of copper on the local species of Mekong River, The further studies on the concentration of heavy metals in other tropical freshwater should be studied.

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REFERENCES

Bradl, H. 2005. Heavy metals in the environment: Origin, interaction and remediation. Elsevier/Academic Press, London.

Carreau, N.D. and Pyle, G.G. 2005. Effect of copper exposure during embryonic development on chemosensory function of juvenile fathead minnows. Ecotoxicology and environmental safety, 61 (1), 1-6.

Coates, D., Poeu, O., Suntornratnana, U., Nguyen, T.T. and Viravong, S. 2006. Biodiversity and fisheries in the Mekong River Basin. Mekong development series (2).

Cusimano, R.F., Brakke, D.F. and Chapman, G.A. 1986. Effects of pH on the toxicities of cadmium, copper, and zinc to steelhead trout *(Salmo gairdneri)*. Canadian Journal of Fisheries and Aquatic Sciences, 43, 1497-1503.

Ezeonyejiaku, C.D., Obiakor, M.O. and Ezenwelu, C.O. 2011. Toxicity of copper sulphate and behavioral locomotor response of tilapia *(Oreochromis niloticus)* and catfish *(Clarias gariepinus)* species. Online J Anim Feed Res, 1 (4), 130-134.

Ferguson, J.W., Healey, M., Dugan, P. and Barlow, C. 2011. Potential effects of dams on migratory fish in the Mekong River: Lessons from salmon in the Fraser and Columbia Rivers. Environmental Management, 47 (1), 141-159.

Heath, A.G. 1995. Water pollution and fish physiology. Lewis, Boca Raton.

Majumdar, T. and Gupta, A. 2012. Acute and chronic toxicity of copper on aquatic insect *Chironomus ramosus* from Assam, India. J Environ Biol. Jan, 33 (1), 139-42.

Mastin, B. and J. Rodgers J. 2000. Toxicity and bioavailability of copper herbicides (Clearigate, Cutrine-Plus, and copper sulfate) to freshwater animals. Archives of environmental contamination and toxicology, 39 (4), 445-451

MRC. 2007. Diagnostic study of water quality in the lower Mekong Basin. Mekong river commission, Vientiane . 70 pp.

Scudder, B.C., Carter, J.L. and Leland, H.V. 1988. Effects of copper on development of the fathead minnow. Aquatic Toxicology, 12 (2), 107-124.

Shuhaimi-Othman, M., Nadzifah, Y., Nur-Amalina, R. and Umirah, N.S. 2013. Deriving freshwater quality criteria for copper, cadmium, aluminum and manganese for protection of aquatic life in Malaysia. Chemosphere, 90 (11), 2631-2636.

Solbe J.F. 1984. The toxicity of zinc sulphate to rainbow trout in very hard water. Water Research, 8, 389-391.

Taweel A., Shuhaimi-Othman, M. and Ahmad A.K. 2013. *In vivo* Acute toxicity tests of some heavy metals to Tilapia fish (*Oreochromis niloticus*). Journal of Biological Science, 13 (5), 365-371.

Taylor, E., S. Maund and D. Pascoe 1991. Toxicity of four common pollutants to the freshwater macro invertebrates *Chironomus riparius* Meigen (Insecta: Diptera) and *Gammarus pulex* (L.) (Crustacea: Amphipoda). Archives of environmental contamination and toxicology, 21 (3), 371-376.

Ti, L.H. and Facon, T. 2004. From vision to action - A synthesis of experiences in least-developed countries in Southeast Asia. Rap publication (FAO) (2004/32).

U.S.EPA. 2002. Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms: Environmental Monitoring Systems Laboratory, Office of Research and Development, US Environmental Protection Agency.

Wright, D.A. and Welbourn, P. 2002. Environmental toxicology (Vol. 11), Cambridge University Press. USA.

Research article

Application of Biodegradable Film from Yam (*Dioscorea alata*) Starch in Thailand for Agriculture Activity

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Abstract Starch sample obtained from water yam (mun lued) by wet milling process. Yam starch films were prepared by thermal gelatinization technique casting using glycerol as plasticizer. The effect of different glycerol (1.65 and 2.00 g/100 g of filmogenic solution) starch concentration (3.30 g/100 g of filmogenic solution) was evaluated for some characteristic of these films. The effect of different surfactant Span80 (1 ml/100 g of filmogenic solution) and Tween 20 (1.5 ml/100 g of filmogenic solution) was studied. Suitable characteristic of biodegradable film from yam starch are glycerol 1.65 and span 80 (1 ml/100 g) as filmogenic formulation. The temperature for obtaining gelatinized starch solution was 70-80 °C and then dried at 45 °C for 4 hours. Film sample was molding in plastic bag form by simple sealing machine in average size 6x9 square inch. The samples expected to be applied as agriculture bag for agriculture activity. As a result, the appearance of film sample was smooth, transparence and glossy, with average moisture content of 25.96% and thickness of 0.01 mm. Puncture deformation and flexible increased with glycerol content. The starch and glycerol concentration were significant factors for yam starch film characteristic. Surfactant Span80 increased smoother and reduce sticky properties of film than Tween 20. Yam starch film as biofilms could be applied and developed in qualities, and with the advantage of biodegradability.

Keywords biodegradable film, yam starch in Thailand, *Dioscorea alata*, agricultural activity

INTRODUCTION

Water yam (mun lued) or greater yam (*Dioscorae alata*) belonged to Family Dioscoraeceae is a food crop of economic value in Africa and Asia. The yam produces tubers, bulbils or rhizomes as a starch staple food. Edible yams being most frequently cultivated in tropical area. Originaly from Southeast Asia, yam tubers were distributed in all regions of Thailand. However, the main utilization of yams tubers in Thailand only for home consumption and local economic food, not in industrial scale. Yam also used for extraction starch in commercial scale when compare with other starch source such as cassava, potato, maize, wheat and sweet potato. Yam starch can be extracted from tubers by wet milling using water as the extracting solvent. The starch extracted by this method are very pure. One starch content was 97-98.53% (dry basis) when estimated by enzymatic method. The granular size of yam starch averages is 26.68 μm. Some physic-chemical characteristics of yam starch are difference from cassava starch so it could be applied not only for food industry but also non-food industry (Rugchati et al., 2013).

Edible and/or biodegradable films are made from renewable and natural polymers. Among the natural polymers, biodegradable films are not meant to totally replace synthetic packaging films. However, they do have potential to replace the conventional packaging in some applications. The

use of edible films and coatings has been constantly increasing in the food industry. Coatings help meet many challenges related to the storage and marketing of food products. The functionality and performance of edible films and coatings depend on their barrier and mechanical properties, which in turn depend on film composition, its formation process, and the method of application onto the product. Edible films include lipids, proteins, and carbohydrates, such as cellulose, starch, and their derivates in their formulation (Falguera et al., 2011; Carvalho, 2013). The use of a biopolymer, such as starch can be an interesting solution as one of the most promising candidates for future materials because this polymer is cheap, abundant, biodegradable, and edible with thermoplastic behavior and this is important for film production because amylose is responsible for the film-forming capacity of starches (Rugchati and Thanacharoenchanaphas, 2010; Hoover, 2001; AOAC, 1990). Plasticizers, such as glycerol, are often used to modify the mechanical properties of the film. Plasticizers decrease intermolecular attractions between adjacent polymeric chains increasing film flexibility, but they may also cause significant changes in the barrier properties of the film (Bertuzzi et al., 2007; Brandelero et al, 2010; Carvalho, 2008 and 2013). Starch is one of the most commonly used agricultural raw materials since it is a renewable source, inexpensive (even cheaper than polyethylene), widely available, and relatively of the most promising candidates for future materials because this polymer is biodegradable and edible with thermoplastic behavior that easy to handle.

Yam starch is one alteration for polymeric carbohydrate composed of anhydroglucose units. It is not a uniform material and most starch contains two types of glucose polymers: a linear chain molecule termed amylose and a branched polymer of glucose termed amylopectin (Falguera et al., 2011). The ratio of amylose to amylopectin content is critical for technological applications. Yam starch (*D*. *alata*) contains about 24-26% amylose; the ratio of amylose to amylopectin content is 0.32, and this is important for film production because amylose is responsible for the film-forming capacity of starches (Al-Hassan and Norziah, 2012; Alves et al., 2007). The potential of starch as a material for edible films and for biomaterials has been widely recognized. It is an appropriate matrix-forming material and it provides a good barrier to oxygen and carbon dioxide transmission but a poor barrier to water vaporation (Maliet al., 2002; Bertuzziet al.,2007). One of the most important limitations of the use of starch for films and coatings is the hydrophilicity of this material. Preponderance of amylose in starches gives stronger film. The branched structure of amylopectin generally leads to films with different mechanical properties, such as decreased tensile stress. Surfactants could be incorporated into the film formulation to reduce surface tension of the solution, improving the wettability and adhesion of the film. These chemicals components are characterized for being amphiphilic. The lipophilic part of the molecule tends to be in a nonpolar environment and the hydrophilic part prefers to be in a polar (aqueous) environment. The balance between two governs the functionality of the surfactant at interfaces and also its influence on the properties of the resulting films. With surfactant addition to film formulation, it is expected a decrease in water vapor permeability values, because some hydrophobic characteristic were incorporated with components. Sorbitan fatty acid esters (Spans) and the corresponding polyoxyethylene (POE) adducts (Tweens) applied in a wide range of food, pharmaceutical and other industries. In some formulations, mixtures of Span surfactants and Tween surfactants are required, but some of the physical properties of these mixtures are not well defined (Alves et al., 2007; Brandelero et al., 2010).

OBJECTIVE

The objectives of this study were to evaluate the influence of the presence of plasticizers (glycerol), and the influence of different surfactant (Span80 and tween 20) on *Dioscorae alata* film characteristics, and the mechanical properties of starch films for suitable formulation of yam starch film products that could be applied and developed in qualities, and with the advantage of biodegradability in agricultural activities.

METHODOLOGY

Raw Material

Fresh tubers of water yam or mun lued (*Dioscorae alata*), with uniform size and shape, without any mechanical and pathological injuries were obtained from a local farm in Phitsanulok, Thailand.

Sample Preparation

Yam starch was extracted in the wet milling process (Rugchati and Thanacharoenchanaphas., 2010). Amylose and amylopectin contents of yam starch were determined simultaneously by the Knutson method (Knutson, 1986).

Film Preparation

Yam starch film was prepared by thermal gelatinization technique (Mali et al., 2002) with different glycerol, Span80 (Arlacel 80: Sorbitan monooleate (oily liquid) HLB 4.3) and Tween 20 (Polysorbate 60: Polyoxyethylene (20) Sorbitan monolaurate (yellow liquid) HLB 16.7) yam starch concentration (3.30 g /100 g of filmogenic solution) (Brandelero et al., 2010; Rugchati et al., 2013). The four filmogenic solution formulations selected were milligram of surfactant/100 g of filmogenic solution and gram of glycerol/100 g of solution (Table 1).

Table 1 Filmogenic solution formulations (100 g of solution)

Formulation	Glycerol (g)	Surfactant (ml)
a	1.65	Span80 (1 ml)
b	1.65	Tween 20 (1.5 ml)
c	2.00	Span80 (1 ml)
d	2.00	Tween 20 (1.5 ml)

The films were prepared by casting; yam starch (dry basis) and glycerol were directly mixed with distilled water to make batches with a total weight of 500 g. The filmogenic solutions were transferred quantitatively to the cup of a Brabender Viscograph, and its were heated from 30 to 80 °C at a constant heating rate (2 °C/min) and maintained at 80 °C for 10 min, with regular shaking (75 rpm). Gelatinized suspensions were immediately poured on rectangular acrylic plates (20x20 cm). For each experiment, the quantity of starch suspension poured onto the plate was calculated to obtain a constant weight of dried matter of approximately 12.25 mg/cm^2. The starch suspensions were dried (45 °C) in a ventilated oven (about 4 h). The result was translucent films, which can be easily removed from the plate. The films were equilibrated at room temperature and a relative humidity (RH) of 70 % for 48 h before being tested (Mali et al., 2005 and 2006).

Characterization of Starch Films

Yam starch films were characterized by using electron microscopy scanner (SEM), JEOL JSPM 100 electron microscope (Japan). Water vapor permeability (WVP) ASTM E96-80 (ASTM, 1980) with water vapor permeation tester: Lyssy L80-4000, Oxygen gas transmission (OGT) ASTM D3985-81(ASTM, 1981) with Oxygen permeation tester Illinois 8000 (TISI Standard 1136-2536) (Rugchati et al., 2013).

Physical and Mechanical Properties

Thickness measurements: The thickness of the films was determined using a manual micrometer at 10 random positions on the films. The mean standard deviation within the film was about 5% of the average thickness by micrometer (EDP63191 The L.S. Starrett Co., Athol, MA Micrometer). Moisture content of film wasmeasured by infrared automatic moisture meter (MA 40 SARTORIUS), and color measurement by Hunter Lab (model DP9500) (Rugchati et al., 2013).

Mechanical properties: The tensile properties and puncture tests were studied to determine force using an Instron 4411 (Instron Ltd., Canton, USA) (Rugchati et al., 2013).

Statistical Analysis

Statistical analyses were conducted by one-way analysis of variance. Means were compared using the Duncan's new multiple range test. Data analyses were performed using the SPSS 11.5 for Windows.

RESULTS AND DISCUSSION

Raw Material

Some morphologilcal characteristics of the water yam tuber, leaf, starch sample, and starch granule shape (SEM 1000X) can be seen in Fig. 1.

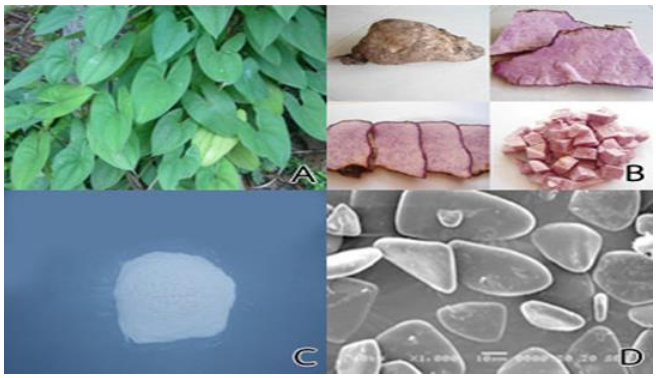

Fig. 1 Some morphologilcal characteristics of the water yam tuber A. leaf, B. whole tuber and pulp, C. starch sample and D. starch granule

Table 2 Some physic-chemical characteristic of yam starch film

Treatment	Moisture (%)	Thickness (µm)	L*	WVP(g/m^2/day)	OGT(cm^3/m^2/day)
a	26.00±0.04ns	0.01	25.09±0.54a	2105±0.5a	13.10±0.5a
b	25.99±0.70ns	0.01	24.99±0.54a	2099±0.8a	12.95+0.5a
c	25.97±0.10ns	0.01	24.29±0.54b	2087±0.3b	11.42±0.5b
d	25.89±0.74ns	0.01	24.19±0.54b	2079±0.8b	12.00±0.5b

Note: All values are mean±standard deviation
a–b Means within a column with different letters are significantly different (p≤ 0.05)

Table 3 Mechanical characteristic of yam starch film

Formulation	Max load (mm)	Max SIR (Kgf)	Toughness (Kgf/mm^2)
a	0.54±0.09a	1.08±0.00a	0.025±0.00ns
b	0.41±0.12b	0.99±0.58a	0.023±0.05ns
c	0.37±0.10c	0.29±0.54b	0.025±0.5ns
d	0.40±0.74b	0.25±0.54b	0.024±0.5ns

Note: All values are mean ±standard deviation
a–c Means within a column with different letters are significantly different (p≤ 0.05)

The fresh root of the water yam consisted mainly of starch (65%), and the purple tuber pulp is high in moisture content (82%). Starch was extracted and purified from the fresh root. The color of the starch was slightly white and fine powder. The starch granular shape was triangular and the average size was 26.68 µm (Rugchati et al., 2013).

Characterization of Yam Starch Films

The appearance of yam starch film for most of the formulations was transparent, smooth, and glossy and some physic-chemical characteristic has shown on tables 2 and 3.

CONCLUSION

This research showed the characterization of yam starch film. Starch from water yam mixed with and glycerol 1.65 and span80 (1 ml/100 g) were used as filmogenic formulation. The appearance of yam film is clearly smooth and glossy. In other characteristics, the concentration of glycerol and surfactant were a significant factor. In mechanical properties, type and concentration of surfactant enhanced the puncture properties and a higher concentration of glycerol and surfactant decreased puncture and tensile properties. Glycerol concentration was a significant factor for WVP and O2.

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REFERENCES

Al-Hassan, A.A. and Norziah, M.H. 2012. Starch–gelatin edible films: Water vapor permeability and mechanical properties as affected by plasticizers. Food Hydrocolloids, 26 (1) 108-117.

Alves, V.D., Mali, S., Beleia, A. and Grossman, M.V.E. 2007. Effect of glycerol and amylose enrichment on cassava starch film properties. Journal of Food Engineering, 78 (3), 941-946.

Association of Official Analytical Chemists (AOAC). 1990. Official method of analysis Vol. 2. The Association of Official Agricultural Chemists, 163,Virginia, USA.

Bertuzzi, M.A., Vidaurre, E.F.C., Armada, M. and Gottifredi, J.C. 2007. Water vapor permeability of edible starch based films. Journal of Food Engineering, 80 (3), 972-978.

Brandelero, R.P.H., Yamashita, F. and Grossmann, M.V.E. 2010. The effect of surfactant Tween 80 on the hydrophilicity, water vapor permeation, and the mechanical properties of cassava starch and poly (butylene adipate-co-terephthalate) (PBAT) blend films. Carbohydrate Polymers, 82 (4), 1102-1109.

Carvalho, A.J.F. 2008. Starch: Major sources, properties and applications as thermoplastic materials. *in* Monomers, Polymers and Composites from Renewable Resources. Elsevier, 321-342, Amsterdam, Netherland.

Carvalho, A.J.F. 2013. Starch: Major sources, properties and applications as thermoplastic materials. *in* Handbook of Biopolymers and Biodegradable Plastics. William Andrew Publishing, 129-152, Boston, U.S.A.

Falguera, V., Quentero, J.P, Jiménez, A., Muñoz, J.A. and Ibarz, A. 2011. Edible films and coatings: Structures, active functions and trends in their use. Trends in Food Science and Technology, 22 (6), 292-303.

Hoover, R. 2001 Composition, molecular structure, and physiochemical properties of tuber and starches: Review. Carbohydrate Polymers, 45, 253-267.

Knutson, C.A. 1986. A simplified colorimetric procedure for determination of amylose in maize starches. Cereal. Chem, 63 (2), 89-92.

Mali, S., Grossmann, E.V.M, Garcia, M.A, Martino, N.M. and Zaritzky, N.E. 2002. Microstructural characterization of yam starch films. Carbohydrate Polymers, 50 (4), 379-386.

Mali, S., Grossmann, E.V.M., Garcia, M.A., Martino, N.M. and Zaritzky, N.E. 2005. Mechanical and thermal properties of yam starch films. Food Hydrocolloids, 19 (1), 157-164.

Mali, S., Grossmann, E.V.M., Garcia, M.A., Martino, N.M. and Zaritzky, N.E. 2006. Effects of controlled storage on thermal, mechanical and barrier properties of plasticized films from different starch sources. Journal of Food Engineering, 75 (4), 453-460.

Rugchati, O. and Thanacharoenchanaphas, K. 2010. Comparison in some characteristic of yam tubers starch (*Dioscoreaceae* spp.) from Thailand. International Journal of Environmental and Rural Development, 1 (2), 102-106.

Rugchati, O., Mahawongwiriya, K. and Thanacharoenchanaphas, K. 2013. Some characteristics of biodegradable film substituted by yam (*Dioscorea alata*) starch from Thailand. World Academy of Science, Engineering and Technology, International Journal of Agricultural Engineering, 7 (9), 53-56.

Research article

Long-Term Effects of Spent Wash Liquor on Soil Bacterial Population in Sugar Cane Production Systems

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Abstract Spent wash liquor (or Distillery Slop) is an agro-industrial wastes generated during alcohol distillery production. Its application to the soil for agriculture is highly beneficial due to rich in plant nutrients, organic carbon, less toxic and easily amenable for microorganisms. An advantage is made to direct apply the spent wash liquor as a supplement fertilizer to enhance crop yield in agricultural field. Therefore, long-term effects of spent wash liquor on soil bacterial population in agricultural crop production system is still poorly understood. In this research, the effect of long-term application of spent wash liquor on bacterial decomposers was investigated in sugar cane production systems in Nam Phong watershed. Eight treatments in this research including soil with no spent wash liquor applied (control), soil applied with spent wash liquor for 1, 2, 3, 4, 5, 7, and 8 years were conducted. The results showed that bacterial population at 1 year after application was significantly higher than those from control soil then, the population declined until 8 years after application the population can reach up to 2.04 x 10^6 CFU/g soil. This study suggested that application of spent wash liquor can affect the bacterial decomposer under sugar cane field. However, the application of spent wash liquor need to be tested in longer time under farmer's field conditions before further recommendation can be given.

Keywords spent wash liquor, sugar cane, bacterial population

INTRODUCTION

Nam Phong watershed is the most important watershed in the upper northeast region of Thailand. Its catchment covers approximately 1,518,900 ha, extending to the five provinces of Chaiyaphum, Khon Kaen, Loei, Nong Bua Lumphu, and Petchaboon (Sthiannopkao et al., 2007). Nowadays, Nam Phong watershed is threatened by a variety of human activities. Besides problem of soil

erosion from agricultural areas around Nam Phong watershed, sediments and wastewater from industrial areas consist of large and medium scale factories such as sugar mill, distillery mill, paperboard mill, tapioca mill are also become a pollutant in the watershed.

Removing pollutants from wastewater by wastewater treatment is the preliminary way to remediate water and reduce soils contamination before discharging it into the river and watershed. Among wastewater from industrial areas, spent wash liquor, agro-industrial wastes generated during alcohol distillery production, becomes the most promising wastewater using for agricultural production due to it contains high concentration of organic load, high amount of nutrients such as nitrogen, phosphorous, potassium, sulphur and a large amount of micronutrients (Suganya and Rajannan, 2009). There have been many studies done investigation the effect of spent wash liquor on plant growth and yield (Rath et al., 2011; Suganya and Rajannan, 2009). However, there is limited knowledge on how spent wash liquor can shape the abundance of bacterial communities in agricultural area. Therefore, this study was designed to investigate how long-term spent wash liquor affected the bacterial populations as well as soil properties for successful application of spent wash liquor under sugar cane production systems to reduce chemical fertilizer application and also recycle treated wastewater for agricultural use.

OBJECTIVE

The purpose of this study was to investigate the influence of spent wash liquor on the bacterial population in sugar cane production system in Nam Phong watershed.

METHODOLOGY

Study Sites and Soil Sampling

Study sites were selected from Nam Phong watershed, Nam Phong district, Khon Kean province between latitude 16°42' N to 16°48' N and longitude 102°53' E to 102°57' E. The soil is characterized as a Chakkarat soil series. Soil samples were collected from sugar cane plantation which cultivated sugar cane cultivar K92 on soil depth 0-15 cm. Year of the experiment was in 2013. Eight treatments were used in this research, including soil with no spent wash liquor applied (control), soil applied with spent wash liquor for 1 year (1Y), soil applied with spent wash liquor consecutively for 2 years (2Y), soil applied with spent wash liquor consecutively for 3 years (3Y), soil applied with spent wash liquor consecutively for 4 years (4Y), soil applied with spent wash liquor consecutively for 5 years (5Y), soil applied with spent wash liquor consecutively for 7 years (7Y) and soil applied with spent wash liquor consecutively for 8 years (8Y). The spent wash liquor was used for pre-sowing irrigation at rates of 6.4 m^3/ha (40 m^3/1600 m^2).

Analysis of Chemical Properties of Spent Wash Liquor

Spent wash liquor characteristic analyses were done by studying the chemical properties of spent wash liquor (Table 1). Chemical properties studied include pH, electric conductivity (EC), total alkalinity (as $CaCO_3$), total dissolved solids (TDS), total solid, total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO) and salinity were investigated by APHA standard methods (APHA, 1995). Organic matter was studied by wet oxidation method (Walkley and Black, 1934), total nitrogen (as N) by micro Kjedahl method (Bremner, 1960), total phosphorus (as P_2O_5) by Bray II and colorimetric method (Bray and Kurtz, 1945), total potash (K_2O) by extracting with ammonium acetate 1*N*, pH 7.0 and measured by flame photometer.

Soil Analyses

Soil studies were conducted after spent wash liquor was used for pre-sowing irrigation 6 months by

digging for three replications in each treatments of sugar cane production system. Soil characteristic analyses were done by studying the physical and chemical properties of the soil (Table 2). Physical properties studied include soil moisture and bulk density through the core method. Particle-size distribution and soil texture by hydrometer method. Chemical properties studied include soil reaction by pH meter in ratio of 1:2.5 with water, EC by EC meter, cation exchange capacity (CEC) by the 1.0 M ammonium acetate (NH_4OAC) method (Chapman, 1965), total nitrogen (Total N) by micro Kjedahl method (Bremner, 1960), available phosphorus concentration by colorimetric method (Bray and Kurtz, 1945), exchangeable potassium level measured by flame photometer, organic carbon and organic matter in soil by wet oxidation method (Walkley and Black, 1934).

Bacterial Population Analysis

Bacterial population analysis was done by serial dilution plating technique on nutrient agar medium (NAM) (Dubey and Maheshwari, 2002). Plates with serial dilution plating were incubated at 28 $^{\circ}$C for 1-2 days. Bacterial populations were enumerated from the plates and expressed as CFU (colony forming units) per gram soil.

Statistical Analysis

This experiment has been designed as the completely randomized design (CRD). F-test along with method of Duncan's multiple range test (DMRT) was used to analyze the differences of the average on each experiment.

RESULTS AND DISCUSSION

Spent Wash Liquor Characteristic Analysis

The data of chemical properties of spent wash liquor are shown in Table 1. The results showed that spent wash liquor used in this study were rich in organic matter and available certain nutrients. In addition, spent wash liquor contained high pH and showed low values of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) suggesting that using of spent wash liquor is safe for agricultural application.

Table 1 Chemical properties of spent wash liquor

Spent wash liquor	Results	Unit
pH	7.83	-
Electric Conductivity; EC	6.89	dS/m
Total Nitrogen (as N)	0.11	%
Total Phosphorus (as P_2O_5)	0.01	%
Total Potash (K_2O)	0.36	%
Total Alkalinity (as $CaCO_3$)	2647.19	mg/L
Total Dissolved Solids (TDS)	10503.33	mg/L
Total Solid	12900.00	mg/L
Total Suspended Solids (TSS)	373.33	mg/L
Organic matter (OM)	0.58	%
Biochemical Oxygen Demand (BOD)	<5	mg/L
Chemical Oxygen Demand (COD)	45	mg/L
Dissolved oxygen (DO)	0.33	mg/L
Salinity	3.44	ppt

Soil Analysis

The data of physical and chemical properties of soil are shown in Table 2. Being very rich in organic matters, the utilization of spent wash liquor in agricultural fields creates organic

fertilization in the soil which raises the pH of the soil, increases availability of soil nutrients and capability to retain water and also improves the physical structure of soil. The results of nutrient contents analysis showed that application of spent wash liquor into soil significantly increased the exchangeable potassium content in the soil. Likewise, the previous report found that the application of spent wash liquor into Sansai soil series significantly increased the available potassium content in the paddy field (Chatchaisiri et al., 2003).

Table 2 Physical and chemical properties of soil

Soil properties	Treatments								F-test	CV (%)
	Control	1Y	2Y	3Y	4Y	5Y	7Y	8Y		
Organic matter; OM (%)	0.603^{a}	0.333^{e}	0.473^{c}	0.358^{e}	0.337^{e}	0.535^{b}	0.515^{b}	0.440^{d}	*	21.64
Total N (%)	0.027^{a}	0.013^{d}	0.02c	0.014^{d}	0.013^{d}	0.023^{b}	0.023^{b}	0.018^{c}	*	29.14
Available P (mg/kg)	48.64^{a}	36.19^{c}	24.96^{e}	36.53^{c}	42.3^{b}	20.37^{f}	13.44^{g}	33.58^{d}	*	35.26
Exchange-able K (mg/kg)	79.10^{c}	80.48^{c}	38.85^{e}	72.29^{d}	39.32^{e}	116.34^{a}	81.87^{c}	108.91^{b}	*	35.20
Organic carbon; OC (%)	0.344^{a}	0.194^{e}	0.256^{c}	0.215^{d}	0.198^{e}	0.309^{b}	0.306^{b}	0.263^{c}	*	20.85
Soil pH	4.85^{d}	5.50^{b}	5.30^{c}	6.41^{a}	5.63^{b}	5.69^{b}	4.85^{d}	4.74^{d}	*	10.19
Electrical conductivity; EC (dS/m)	0.042^{a}	0.029^{d}	0.015^{g}	0.020^{f}	0.039^{b}	0.035^{c}	0.039^{b}	0.023^{e}	*	32.43
Cation exchange capacity; CEC (cmol/kg)	3.371^{b}	3.627^{b}	5.051^{b}	3.559^{b}	4.612^{b}	1.190^{c}	8.088^{a}	1.272^{c}	*	57.59
Bulk density (g/cm^3)	0.890^{bc}	0.960^{a}	0.910^{b}	0.910^{b}	0.950^{a}	0.950^{a}	0.860^{c}	0.855^{c}	*	4.59
Soil moisture (%)	3.860^{d}	4.420^{b}	3.300^{f}	3.550^{e}	4.150^{c}	5.880^{a}	3.415^{ef}	4.265^{bc}	*	19.48
Soil texture	sand	sand	sand	sand	sand	sand	sand	sand	-	-

Treatment: soil with no spent wash liquor applied (control), soil applied with spent wash liquor for 1 year (1Y), soil applied with spent wash liquor consecutively for 2 years (2Y), soil applied with spent wash liquor consecutively for 3 years (3Y), soil applied with spent wash liquor consecutively for 4 years (4Y), soil applied with spent wash liquor consecutively for 5 years (5Y), soil applied with spent wash liquor for consecutively 7 years (7Y) and soil applied with spent wash liquor consecutively for 8 years (8Y). In column, means followed by the same letter do not differ statistically from each other at p≤0.05 according to DMRT test.

Effect of Spent Wash Liquor on Bacterial Population in Sugar Cane Production System

The highest total count of bacteria was found in soil sample that taken from first year application of spent wash liquor for 2.11 x 10^6 cfu/g soil (Table 3). However, bacterial population tend to decrease when soil were applied with spent wash liquor consecutively for 2-7 years. Interestingly, after 8 years consecutively application of spent wash liquor, result showed increasing in the bacterial count as compared to sugar cane production system without any spent wash liquor application. Jintaridth et al., 2002 reported that application of spent wash liquor into soil showed increasing in bacterial and fungal populations at the rate of 40 m^3/1600 m^2 compared to treatment using chemical fertilizer. Moreover, Thitakamol and Kaewpinthong (2004) also found that, at the rice post-harvesting period, the number of bacteria increased at the application of 40 m^3/1600 m^2 of spent wash liquor and the number of fungi was increased at the using rate of 20 m^3/1600 m^2. The bacterial populations can change due to longer time of spent wash liquor application. The bacterial populations may be affected by changing in soil moisture and some certain soil nutrient such as potassium. The results revealed that significantly higher in soil moisture and exchangeable K value

were found in soil applied with spent wash liquor for 1 year (1Y) and soil applied with spent wash liquor consecutively for 8 years (8Y) (Table 2). These findings suggested that the growth and population of soil microorganisms can be influenced by chemical and physical properties of the soil and the availability of macro nutrient elements can limit bacterial population growth in a particular soil ecosystem.

Table 3 Effect of spent wash liquor on bacterial population

Treatment	Bacterial count (cfu/g soil)
Control	$1.45 \times 10^{6\,b}$
1Y	$2.11 \times 10^{6\,a}$
2Y	$1.48 \times 10^{6\,b}$
3Y	$7.07 \times 10^{5\,d}$
4Y	$1.08 \times 10^{6\,c}$
5Y	$8.67 \times 10^{5\,cd}$
7Y	$7.73 \times 10^{5\,d}$
8Y	$2.04 \times 10^{6\,a}$
F-test	*
CV (%)	40.97

Treatment: soil with no spent wash liquor applied (control), soil applied with spent wash liquor for 1 year (1Y), soil applied with spent wash liquor consecutively for 2 years (2Y), soil applied with spent wash liquor consecutively for 3 years (3Y), soil applied with spent wash liquor consecutively for 4 years (4Y), soil applied with spent wash liquor consecutively for 5 years (5Y), soil applied with spent wash liquor for consecutively 7 years (7Y) and soil applied with spent wash liquor consecutively for 8 years (8Y). In column, means followed by the same letter do not differ statistically from each other at $p \leq 0.05$ according to DMRT test.

CONCLUSION

The study of long-term effects of spent wash liquor on soil bacterial population in sugar cane production systems has shown that the highest total count of bacteria was found in soil sample that taken from first year application of spent wash liquor and then bacterial population tend to decrease when soil were applied with spent wash liquor consecutively for 2-7 years and raised up in soil sample that taken from eight years consecutively application of spent wash liquor. This finding suggested that bacterial populations may be affected by changing in soil physical and chemical properties such as soil moisture and some certain soil nutrient such as potassium. Therefore, an essential soil element for plant growth influences the microbial population as these nutrient elements are also needed for microbial growth and activity. However, the application of spent wash liquor need to be tested in longer time under farmer's field conditions before further recommendation can be given.

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REFERENCES

APHA, AWWA, WPCF, 1995. Standard methods for the examination of water and wastewater, 16th Edition. American Public Health Association, American Water Works Association and Water Pollution Control Federation, Washington, D.C., USA.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Sci., 59, 39-45.

Bremner, J.M. 1960. Determination of nitrogen in soil by the Kjeldahl method. J. Agr. Sci., 55, 11-33.

Chapman, H.D. 1965. "Cation exchange capacity," in Methods of soil analysis: chemical and microbial properties. Black, C.A. Ed., vol. 9 of Agronomy Series, American Society of Agronomy. USA. 891-901.

Chatchaisiri, K., Chanchareonsook, J., Suwannarat, C. and Panichsukpatana, S. 2003. Utilization of paper mulberry pulping waste water and distillery slop as sources of potassium for rice grown on Sansai soil series. Proceedings of 41th Kasetsart University Annual Conference. Thailand. 26-33.

Dubey, R.C. and Maheshwari, D. K. 2002. Practical microbiology. S. Chand and Co., New Delhi, India.

Jintaridth, B., Kanjanathanaset, K., Inthasothi, T., Leaungvutiviroj, C. and Charoenchamratcheep, C. 2002. Utilization of spent wash liquor for rice production in acid sulphate soils. Presentation: poster 17th WCSS, 14-21 August. Paper No. 2282.

Rath, P., Pradhan, G. and Misra, M.K. 2011. Effects of DSW (distillery spent wash) and fertilizer on growth and chlorophyll contents of sugar cane (*Saccharum officinarum* L.) plant. Recent Res. Sci. Technol., 3, 169-176.

Suganya, K. and Rajannan, G. 2009. Effect of one time post-sown and pre-sown application of distillery spent wash on the growth and yield of maize crop. Bot. Res. Inter., 2, 288-294.

Sthiannopkao, S. Takizawa, S. and Wirojanagud, W. 2007. Assessment of seasonal variations of surface water quality in the Phong Watershed, Thailand. Thammasat Int. J. Sci. Technol., 12, 36-43.

Thitakamol, T. and Kaewpinthong, S. 2004. Utilization of distillery slop for the rice production in Khon Kaen province. Ramkhamhaeng University Research Journal, 7 (Special Issue), 132-151.

Walkley, A, Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci., 37, 29-38.

Research article

Plant Diversity on Slightly Saline Soils in Chi River Basin of Northeast Thailand

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Abstract This research is aimed to documenting the diversity of plant species that are found on slightly saline soils in the Chi river basin of Northeast Thailand. Both in the dry and the rainy seasons of 2013, plant surveys were conducted at selected sites in three provinces (Chaiyaphum, Khon Kaen, and Kalasin) by using a quadrat sampling technique. Soils under the dominant plant species were collected for physical and chemical analyses. From the study, a total of 155 plant species belonging to the 72 families were recorded. Five of those were classified as halophytes, and included *Azima sarmentosa*, *Maytenus diversifolia*, *Synostema bacciformis*, *Pluchea indica* and *Gisekia pharnaceoides*. The dominant species in the selected sites of three provinces were *Cynodon dactylon*, *Heliotropium indicum*, *Melochia corchorifolia*, *Ageratum conyzoides*, *Coldenia procumben*, *Glinus oppositifolius* and *Panicum repens*, respectively. In the dry season, the average soil electrical conductivity under the dominant plant species at Chaiyaphum, Khon Kaen and Kalasin provinces were 2.52, 0.7 and 0.54 dS/m, respectively. In the rainy season, the averaged soil electrical conductivity under the dominant plant species were decreased to 0.61, 0.37 and 0.14 dS/m in Chaiyaphum, Khon Kaen and Kalasin provinces, respectively. In all studied areas during in both seasons, the amounts of exchangeable sodium were in the same direction as the values of electrical conductivity. Soil pH values at all studied areas in both seasons were in an acidic condition. However, the pH values were lower in the dry season than in the rainy season. Soil moisture under the dominant plant species was higher in the rainy season than that in the dry season.

Keywords plant diversity, saline soil, halophytes

INTRODUCTION

The northeast region of Thailand, known as Isan, covers an area of 170,226 sq. km or one third of the entire country. The region situates on Korat plateau which is distinctly raised from the Central region. The plateau tilts downward from the Phetchabun mountain range in the west of the region towards to Mekong River. The plateau consists of two plains: the southern Khorat plain, which is drained by the Mun and Chi rivers, and the northern Sakon Nakhon plain which is drained by the Loei and Songkhram rivers. The two plains are separated by the Phu Phan mountain range. The soil is mostly sandy, with substantial salt deposits. Soils in Northeast Thailand are salt-affected due to

salt bearing rocks (Department of Land Development, 1991), particularly in Nakhon Ratchasima, Khon Kaen, Roi Et, Chaiyaphum and Mahasarakham provinces (Department of Mineral Resources, 1982). Saline soils currently occupy an area of approximately 17% of the region and that area is increasing annually. A rather large part of the arable land in this region is salt-affected to varying degrees. Generally, narrow areas, which are strongly salt-affected, are scattered from the western hilly areas to the undulating regions, and the relatively weakly salt-affected wide areas are spread throughout the low-lying flat regions, especially along the big rivers. The degree of soil salinity in the salt affected areas can be classified into three categories: 1) Severe salt affected soil is the area which more than 50% of the soil exhibits surface salt patches. Soil salinity ranges from high to very high. This area known as deteriorated land, covers about 0.2 million hectares and cannot be used for any agricultural activity. 2) Moderate salt affected soil is the area which 10-50% of the soil surface is covered with salt patches. The area is about 0.6 million hectares and the land is used as rice paddies, but the yield is very low. 3). Slightly salt affected soil is the area which salt patches on the soil surface occur in less than 10% of the area. There are about 2 million hectares, and most of the area is comprised of rice fields with low yields (Arunin, 1984) (Fig. 1). Soil salinity has become one of the major determinants of crop productivity in the Northeast Thailand and has an adverse impact on the physical, chemical and biological properties of soil, as well as on plant growth and yield (Marschner, 1995). To grow crops successfully, these soils must be improved. Investigations carried out at various research locations in the world have shown that salt-affected soils can be improved by the planting of salt tolerant plant species. In an effort to identify and dominant the salt tolerant plant species present on naturally occurring saline soils, it is therefore, necessary to study the soil properties and vegetation cover that are found on saline soil. The gains from this study will be valuable, and the dominant species, that have been observed, will deserve further attention as potential candidates for restoring the salt affected areas. In addition, the presence or absence of certain plants can give valuable clues to indicate the degree of soil salinity.

a) b) c)

Fig. 1 Categories of salt affected areas: a) severe, b) moderate and c) slightly

METHODOLOGY

This study has aimed to documenting the diversity of plant species and investigating the soil properties under the dominant species on slightly saline soils in the Chi river basin of Northeast, Thailand. Plant surveys were conducted on 9 selected sites in 3 provinces (Chaiyaphum, Khon Kaen and Kalasin) during both the dry season (April) and the rainy season (October) of 2013 by using a quadrat sampling technique (Fig. 2). Plant specimens were collected and identified from within 108 sample plots (1x1 m). The dominant species were analyzed by totally averaging each of the plant covers.

To study soil properties, soil samples under each of the dominant species found in the study area were collected separately at the depth of 0-15 cm and were brought back to the laboratory for physical and chemical analyses in both the dry season and the rainy season. The moist soil samples were analyzed for the moisture content, pH (1:2.5 soil: water), ECe (saturation extract), organic matter and exchangeable Na^+. A good indicator of potential salinity problems is the depth and quality of the groundwater table. If groundwater table are both saline and shallow or rising, there is the potential for salinity problems to occur in the future (Kohyama et al., 1993). Therefore, in this

study, the depth of water table has been measured in the middle of both the rainy and dry seasons by using a piezometer. In addition, water samples were collected to determine the salinity in order to determine the quality of the groundwater.

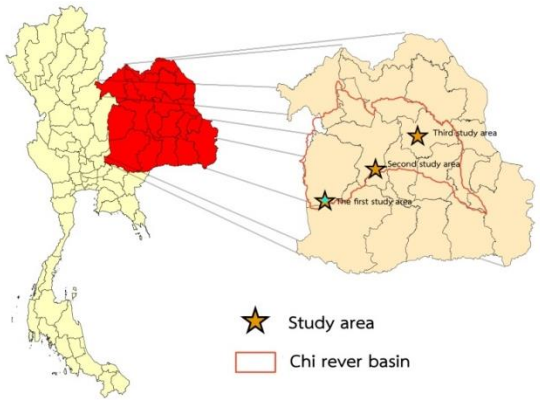


Fig. 2 The study area in 3 provinces (Chaiyaphum, Khon Kaen, and Kalasin) of Northeastern Thailand

RESULTS AND DISCUSSION

For soil properties on slightly saline soil in the dry season, the average soil electrical conductivity under the dominant plant species at Chaiyaphum, Khon Kaen and Kalasin were 2.52, 0.7 and 0.54 dS/m, respectively. In the rainy season, the average soil electrical conductivity under the dominant plant species decreased to 0.61, 0.37 and 0.14 dS/m in Chaiyaphum, Khon Kaen and Kalasin, respectively. The amounts of exchangeable sodium were in the same direction at electrical conductivity values for all areas studied in both seasons. Soil pH at all studied areas in both seasons were in an acidic condition. However, soil pH values were lower in the dry season as compared to the rainy season as found by Topark-ngarm (1990). Soil moisture under the dominant plant species was higher in the rainy season than in the dry season (Table 1).

Table 1 Soil properties in the dry season and the rainy season in the study areas (Mean±SD)

Soil properties	Chaiyaphum Province		Khon Kaen Province		Kalasin Province	
	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season
pH (1: 2.5 H_2O)	5.30 ± 0.19	5.93 ± 0.48	4.31 ± 0.39	4.56 ± 0.26	4.13 ± 0.15	4.41 ± 0.17
ECe (dS/m)	2.52 ± 0.94	0.61 ± 0.57	0.70 ± 0.20	0.37 ± 0.27	0.54 ± 0.34	0.14 ± 0.05
OM (%)	0.83 ± 0.14	0.82 ± 0.22	0.74 ± 0.16	0.85 ± 0.13	0.68 ± 0.01	0.66 ± 0.10
Exchangeable Na^+ (ppm)	12.86 ± 1.90	2.82 ± 2.28	3.00 ± 1.28	1.33 ± 0.96	1.57 ± 0.69	0.31 ± 0.16
Soil moisture content (%)	4.61 ± 0.92	20.24 ± 4.11	5.35 ± 0.63	13.14 ± 5.57	3.30 ± 0.61	11.65 ± 2.38

The water table at the Chaiyaphum site is more shallow than at the other sites. In addition, the groundwater salinity is also higher, and that makes the soil salinity at Chaiyaphum site higher than at the other sites (Table 2).

Table 2 The water table depth and groundwater salinity

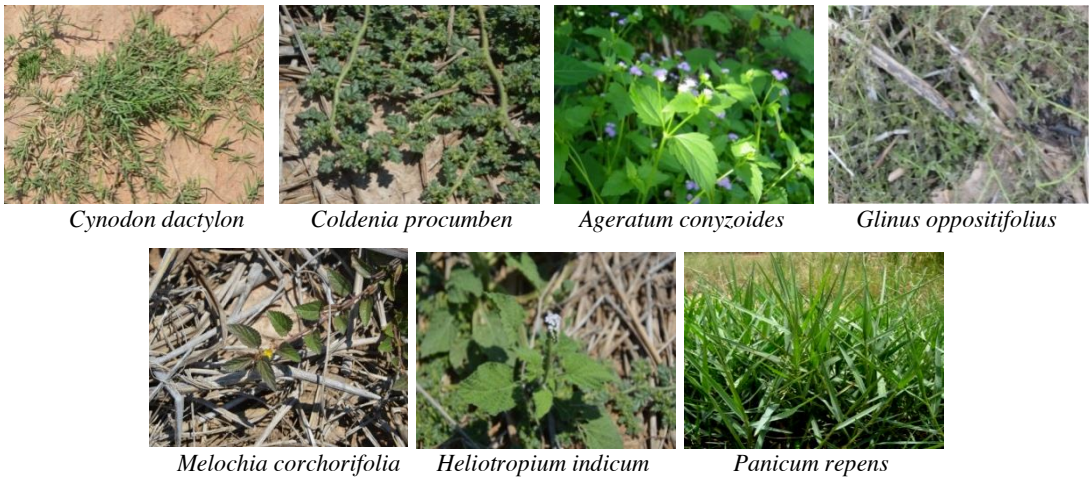
Site	Water table (cm)		Groundwater salinity (dS/m)	
	Dry season	Rain season	Dry season	Rain season
Chaiyaphum Province	194	42	2.82	1.20
Khon Kaen Province	> 200	105	2.16	1.52
Kalasin Province	> 200	116	1.78	0.76

In the plant study, a total of 155 plant species belonging to the 72 families have been recorded. Five of those were classified as halophytes: *Azima sarmentosa*, *Maytenus diversifolia*, *Synostema bacciformis*, *Pluchea indica* and *Gisekia pharnaceoides* (Fig. 3). The dominant species in the selected sites of the three provinces were *Cynodon dactylon*, *Coldenia procumbent*, *Ageratum conyzoides*, *Glinus oppositifolius*, *Melochia corchorifolia*, *Heliotropium indicum* and *Panicum repens*, respectively (Fig. 4). In the rainy season, the number of plant species at every study site was higher due to a decrease in soil salinity as compared to the dry season.

Azima sarmentosa *Maytenus diversifolia* *Synostema bacciformis* *Pluchea indica* *Gisekia pharnaceoides*

Fig. 3 The halophytes found in the study area

The dominant species found on the slightly saline soils were quite different from those found on high saline soils and moderate saline soils. *Azima sarmentosa*, *Maytenus diversifolia*, and *Pluchea indica* were the dominant species found in areas of high salinity (Kulna et al., 2012). *Combretum quadrangulare*, *Imperata cylindrical*, *Cynodon dactylon*, *Panicum repens*, *Sphaeranthus afraricanus*, *Glinus oppositifolius* and *Fimbristylis disticha* were the dominant species dicovered growing in moderate salinity (Chason et al., 2014). Also, *Cynodon dactylon*, *Coldenia procumben*, *Ageratum conyzoides*, *Glinus oppositifolius*, *Melochia corchorifolia*, *Heliotropium indicum* and *Panicum repens* were the dominant species found growing in slightly salinity.



Cynodon dactylon *Coldenia procumben* *Ageratum conyzoides* *Glinus oppositifolius*

Melochia corchorifolia *Heliotropium indicum* *Panicum repens*

Fig. 4 The dominant species found in the study area in the dry season

Table 3 Cover areas and soil electrical conductivity of dominant species in the study area in the dry season

Plant Name	Cover areas (%)	ECe (dS/m)
Cynodon dactylon	16.53	0.87±0.97
Coldenia procumben	14.58	0.86±0.93
Ageratum conyzoides	13.33	0.74±0.80
Glinus oppositifolius	12.92	0.32±0.11
Melochia corchorifolia	12.50	1.03±1.26
Heliotropium indicum	10.83	1.34±1.10
Panicum repens etc.	8.33	0.88±0.85

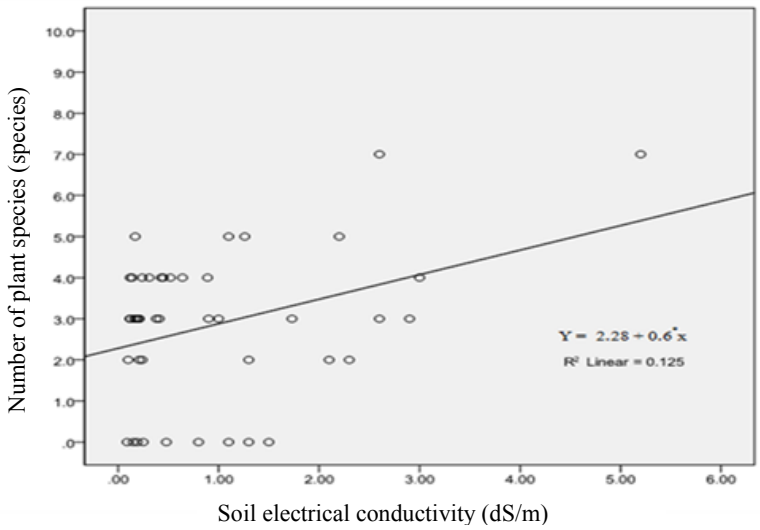


Fig. 5 The relationship between number of plant species and the average soil electrical conductivity (ECe) in the dry season (less salinity more plant species)

CONCLUSION

From the study, some native plants in Northeast Thailand have been found to have become well adapted to saline conditions, and these plants are called halophytes. The presence of some halophytes is generally indicative of a saline soil. There is a natural variation in the ability of plants to tolerate salinity. Most of plant species can grow well when soil ECe is low. On the other hand, some plant species can tolerate in the soil which have high ECe value (Fig. 5). Therefore, the presence or absence of certain plants can give valuable clues to indicate the degree of soil salinity. *Cynodon dactylon*, *Coldenia procumben*, *Ageratum conyzoides*, *Glinus oppositifolius*, *Melochia corchorifolia*, *Heliotropium indicum* and *Panicum repens* are the dominant species in areas of slightly salinity. This study has not experimentally evaluated plant species for their use in the restoration or re-vegetation of salt affected areas. However, comparable salinity levels and species found in the areas suggest that the dominant species observed in this study would be valuable and deserve further attention as potential candidates for the restoration of salt affected areas.

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REFERENCES

Arunin, S. 1984. Characteristics and management of salt-affected soils in the Northeast of Thailand. In: Ecology and Management of Problem Soils in Asia. FFTC Book Series No. 27. Food and Fertilizer Technology Center for the Asian and Pacific Region. Taipei, Taiwan, 336-351.

Chason, S., Trelo-ges, V., Topark-ngarm, B. and Homchuen, S. 2014. Study on plant species diversity with soil properties in moderate saline soil of Chi River, Northeast Thailand. Book of Abstracts. The 5th ICERD-International Conference on Environmantal and Rural Development. 18-19 January 2014. Rajamangala University of Technology Thanyaburi, Thailand.

Department of Land Development. 1991. Distribution of salt affected soils in the northeast region 1:100,000 map. Department of Land Development, Thailand.

Department of Mineral Resources. 1982. Geologic map of Thailand. Department of mineral resources, Thailand.

Kohyama, K., Wichaidit, P., Pramojanee, P., Sukchan, S. and Wada, H. 1993. Salinization in the watershed of Northeast Thailand. In: ADRC (ed.) "Research Activities of ADRC contributed to Agricultural Development in Northeast Thailand", Khon Kaen, Thailand.

Kulna, W., Trelo-ges, V., Topark-ngarm, B. and Homchuen, S. 2012. Study of relationships of some soil properties on plant species diversity in serious saline soil of Chi river basin. The 9th National Conferences of Agricultural Academic. 6-7 December 2012. Kasetsart University, Kamphaeng Sean Campus, Thailand.

Marschner, H. 1995. Mineral nutrition of higher plants. 2nd Edition. Academic Press, UK.

Topark-ngarm, B., Patcharapreecha ,P., Goto, I. and Kimura, M. 1990. Studies on saline soils in Khon Kaen Region, Northeast Thailand. II. Seasonal changes of physical and chemical properties. Soil Sci. Plant Nutr., 36, 289-298.

Research article

Circumstances of Survey Education Conducted in Japanese Universities

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Abstract Contents of the survey education conducted in civil engineering departments of universities in Tokyo were investigated by using their syllabus, to grasp the current state of survey education in Japan. As a result, in the order of the number of departments that teach the particular items, "Theory of error", "Traversing", "Leveling", "Plate table surveying", "Global positioning System (GPS) surveying", "Photogrammetry", "Geographic Information Systems (GIS)" and "Remote sensing". It was found that land-based surveying techniques, such as "Traversing", "Leveling" and "Plate table surveying", were treated preferentially over aerial-data based surveying, such as "GPS surveying", "Photogrammetry" and "Remote sensing". Furthermore, to grasp the items taught as university course content reflect the techniques actually used in work situations, the content of 6 textbooks used for lectures at the universities was investigated by comparing with the General Standard of Operation Specifications for Public Surveys (*General Standard*). The *General Standard* is used as the model standard when surveying companies work actually. As a result, not many textbooks cover such operationally demanded techniques. As other problems; given that the latest technique may be a major technique in the future, it is necessary to teach the latest survey techniques. The latest techniques, which have not been described as survey items in the *General Standard*, were also investigated, such as "Mobile Mapping System (MMS)", "3-D laser scanners" and "Photogrammetry with satellite imagery". So as to improve these problems, the authors developed a new textbook for teaching surveying based on an investigation of courses offered in the survey departments of universities. In the developed textbook, the survey techniques described in the *General Standard* and the latest techniques are included.

Keywords survey education, university, operational technique, textbook

INTRODUCTION

The population of the world reached 7 billion in 2012. The populations of Africa and Asia are increasing particularly rapidly. It is predicted that in 2050 the population of Africa and Asia will be 2.2 and 1.2 times that in 2012 respectively (United Nation, 2012). World irrigated area has been also increasing year by year (Earth Policy Institute, 2009). To produce enough food for this increasing population, it is important to conduct land improvement and irrigated land expansion, including the development of agricultural land and the construction of channels for irrigation and drainage of such land. In conducting land improvement projects, surveying techniques to know the coordinates, elevation, gradient, area and topographic features of the agricultural land and the skill to create maps of the surveyed land are indispensable.

From the 1950s through the 1980s, the major surveying techniques used in agricultural land development were angle measurement by using a transit and plate table surveying, which is a simple way of conducting onsite surveying. By 2000, most surveyors were using equipment that was up to date for that time. The Global Navigation Satellite System (GNSS) and the use of total stations (TS) became mainstream. The use of equipment that was up to date for that time changed the surveying techniques from analog-based ones to digital-based ones. At the same time, the precision of observations and the accuracy of results have improved.

In Japan, surveying techniques are taught at engineering and agricultural universities. The qualification of assistant surveyor is granted upon graduation from many such universities. However, the surveying techniques taught at such universities are those that were in the mainstream from the 1950s to the 1980s. Few universities teach the latest techniques that are used in actual working situations (Kunii et al., 2006).

In this study, the syllabus contents of some of the Japanese universities were investigated to clarify the relationship between the technical items taught in the lectures of the universities and the techniques used in actual working situations. The investigation aims at commenting on the surveying techniques that will be required in future university education.

METHODOLOGY

To know what items of surveying are taught at universities, the course content of universities was investigated based on their syllabi. As there are many universities that teach surveying in Japan, we extracted 13 departments of 11 universities in Tokyo that have engineering departments or courses. The surveying items taught in the lectures at these 13 departments were investigated. The items included traversing and leveling. For each technical item, the number of departments that teach the particular item was counted, and the percentage of departments teaching each technical item (the adoption rate) was calculated.

To grasp the items taught as university course content reflect the techniques actually used in work situations, the content of six textbooks used for lectures at the universities was investigated (Ohki, 1998; Ishii et al., 1999; Nakamura and Shimizu, 2000; Fukumoto et al., 2003; Asano and Iba, 2004; Hasegawa et al., 2004). The investigated items were the techniques described in the *General Standard of Operation Specifications for Public Surveys* (*General Standard*), which is used as the model standard by surveying companies. The textbooks were investigated as to whether they have items such as “Connected traverse”, “Detail survey by TS”, “GNSS” and “Digital stereo plotter”.

The latest techniques, which have not been described as survey items in the *General Standard*, were also investigated, such as “Mobile Mapping System (MMS)”, “3-D laser scanners” and “Photogrammetry with satellite imagery”.

RESULTS AND DISCUSSION

Content of Survey Courses at Japanese Universities

Table 1 shows the technical items adopted in the surveying education at the 13 departments.

Departments that taught the "Theory of error" numbered 11, as did those that taught the "Traversing". These are the largest numbers. The "Leveling" was taught by 10 departments, the "Plate table surveying" was taught by 9 departments, the "Global positioning System (GPS) surveying" by 9 departments, the "Photogrammetry" by 6 departments, the "Geographic Information Systems (GIS)" by 5 departments and "Remote sensing" by 4 departments. The most commonly taught items in the 13 departments were "Theory of error and "Traverse survey". The next most commonly taught items were "Leveling", "Plane table surveying", "GPS surveying", "Photogrammetry", "GIS" and "Remote sensing".

The reason that "Theory of error" was found to be so commonly taught is thought to be that the subject is important in the theory of surveying, which includes the processing of observed data and statistics.

The basics of surveying include knowledge of coordinates and topographic maps. There are two groups of techniques for obtaining data for coordinates and topographic maps. There are those conducted on the land, such as TS and leveling, and those conducted using aerial data obtained by satellites and airplanes. It was found that the university lectures emphasize the land-based techniques, such as traverse surveying, leveling and plane table surveying, over the aerial data-based techniques, such as GPS surveying, photogrammetry and remote sensing. It is thought that priority is placed on the land-based surveying because it is directly related to survey training at universities.

Table 1 Technical items adopted in the surveying education at the 13 departments

Technical item	Number of departments teaching the technical items	Adoption rate (%)
Theory of error	11	84.6
Traversing	11	84.6
Leveling	10	76.9
Plane table surveying	9	69.2
GPS surveying	9	69.2
Photogrammetry	6	46.2
Geographic Information Systems (GIS)	5	38.5
Remote sensing	4	30.8

Results of Investigation of the Textbooks Adopted for Surveying Lectures in the Universities

The *General Standard* has been revised in accordance with advances in survey techniques. For example, Global Navigation Satellite System (GNSS) was first described in the *General Standard* in 2011. GPS, which originated in the US, and Global Navigation Satellite System (GLONASS), which originated in Russia, are integrated in GNSS. The plotting instruments for photogrammetry in the 2013 *General Standard* were changed from analog to digital stereo instruments.

Table 2 shows the techniques described in the textbooks adopted for lectures at the universities and those described in the *General Standard*. The textbooks are denoted as Textbook A, B, C, D, E, F, in the order of the year of publication of the first edition. The investigated items of "Connected Traverse", "Detail survey by TS", "GNSS" and "Digital stereo plotter" are described in the *General Standard*.

All of the investigated items are included in the courses that are offered at the departments shown in Table 1. However, some of the textbooks do not have the investigated items. This must be because such items were not described in the *General Standard* when the first editions of the textbooks were published. It is must be meaningful that Textbooks C and D have explanations on digital stereo plotting instruments, which were not include in the standard items at the time of publication of the first editions of the textbooks, because it is possible for the latest techniques introduced in textbooks to become major surveying techniques in later years. The description of GNSS in Textbook F must be added in a later revision.

Based on the above, it is necessary to continuously revise textbooks to include the latest techniques and the techniques that meet the needs of the times.

Table 2 Description of survey techniques in 6 textbooks and the current techniques described in the *General Standard*

Textbooks adopted for lectures in the universities		A	B	C	D	E	F
Year of publication of textbooks A to F (First edition)		1998	1999	2000	2003	2004	2004
Description of survey techniques in the *General Standard*	Connected traverse	○	○	○	○	○	○
	Detail survey by TS*	×	○	○	○	○	○
	GNSS surveying	×	×	×	×	×	○
	Digital stereo plotter	×	×	○	○	×	○

*: Total Station ○: described in textbook ×: undescribed in textbook

Results of Investigation of Six Textbooks used for Surveying Lectures at the Universities

Table 3 shows the results of investigation of textbooks that are used for the lectures of the universities and the latest techniques that are not described in the *General Standard*. Textbook B introduces the latest techniques, such as MMS, even though it is not described in the *General Standard*. From a viewpoint of educating future engineers, it is necessary to adopt textbooks as introducing the latest technologies, because such information is useful in motivating students to learn advanced areas and to start their research.

Table 3 Description of survey techniques in 6 textbooks and the latest techniques that are not described in the *General Standard*

Textbooks adopted for lectures in the universities		A	B	C	D	E	F
Year of publication of textbooks A to F (First edition)		1998	1999	2000	2003	2004	2004
The latest techniques that are not described in the *General Standard*	Mobile Mapping System (MMS)	×	○	×	×	×	○
	3-D laser scanners	×	×	×	×	×	○
	Photogrammetry with satellite imagery	×	×	×	×	×	×

○: described in textbook ×: undescribed in textbook

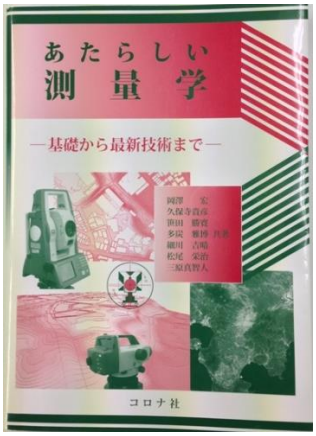

Fig. 1 Newly compiled surveying textbook published in April 2014
Title: Newer surveying -Fundamentals and applications with newest technology- (in Japanese)

Development of Materials for Teaching Surveying at Schools

The authors developed a new surveying textbook to address the problems and tasks identified in the above discussion. The survey techniques described in the *General Standard* and the latest techniques that address the needs of the times were included in this textbook. The new textbook has an impressive 253 pages. The newly compiled textbook, which was highly evaluated by the editors of a publishing company, was published under the title of *Newer surveying -Fundamentals and applications with newest technology-*. (Okazawa et al., 2014) (Fig. 1). However, it is clear that this

new textbook will become obsolete, as survey techniques are continuously developing. While being the evaluation, it is important to continuously revise the textbook to address the changes of the times.

CONCLUSION

The study has clarified the following:
(1) At engineering universities in Tokyo, 84.6% of departments taught theory of error, 84.6% taught transverse surveying, 76.9% taught leveling, 69.2% taught plane table surveying, 69.2% taught GPS surveying, 46.2% taught photogrammetry, 38.5% taught GIS and 30.8% taught remote sensing. It was found that land-based surveying techniques, such as traverse surveying, leveling and plane table surveying, were treated preferentially over aerial-data based surveying, such as GPS surveying, photogrammetry and remote sensing.
(2) Textbooks C and D introduced the technique using a digital stereo plotting instrument even though the instrument was not a standard item at the time of first publication of the two textbooks. Given that the technique later became a major survey technique, it was found that introducing the latest techniques in textbooks is important.

The authors developed a new textbook for teaching surveying based on an investigation of courses offered in the survey departments of universities and the textbooks used at universities. The survey techniques described in the *General Standard* and the latest techniques, which address the needs of the times, have been included in the new textbook. It is thought that continuous revision to address the latest techniques and needs of the time is required, because surveying techniques rapidly develop with the time. It is important to consider the textbook in English, though the published textbook was in Japanese. Because the common language of study is English for students in developing countries.

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REFERENCES

Asano, S. and Iba, H. 2004. Latest surveying primer. Jikkyo Shuppan Co., Ltd. (in Japanese).
Earth Policy Institute. 2009. Data centre -Food and Agriculture-, World irrigation area and irrigated area per thousand people, 1950-2007. Washington, D.C., USA. (available from; http://www.earth-policy.org/index.php?/datacenter/xls /book_pd4_ch2_8.xls. accessed 1st Dec. 2014).
Fukumoto, T., Koga, Y., Saga, A., Ogino, M., Sano, M., Shikada, M., Wada, Y. and Hayakawa, K. 2003. Ace surveying. Asakura Publishing Co., Ltd. (in Japanese).
Hasegawa, M., Kawabata, Y., Ohtsuka, H., Fujimoto, G., Takefuji, S., Sumida, E., Michihiro, K. and Yoshioka, N. 2004. Basic surveying. Denkishoin Co., Ltd. (in Japanese).
Ishii, I., Kamiura, M., Tanaka, S., Himeno, K., Maruyama, T., Motoda, Y. and Kameno, T. 1999. Latest surveying. Morikita Publishing Co., Ltd. (in Japanese).
Kunii, Y., Chikatsu, H., Ohdake, T. and Ono, K. 2006. Computer-assisted surveying education using 3D simulator. International archives of the Photogrammetry. Remote Sensing and Spatial Information Science, XXXVI, 166-170.
Nakamura, H. and Shimizu, E. 2000. Surveying. Gihodo Shuppan Co., Ltd. (in Japanese).
Okazawa, H., Kubodera, T., Sasada, K., Tasumi, M., Hosokawa, Y., Matsuo E. and Mihara, M. 2014. Newer surveying -Fundamentals and applications with newest technology-. Corona Publishing Co., Ltd. (in Japanese).
Ohki, M. 1998. Surveying. Morikita Publishing Co., Ltd. (in Japanese).
United Nation. 2012. World population prospects -The 2012 revision-. (available from; http://www.un.org/en/development /desa/population/, accessed 11th Dec. 2014).

Research article

Circumstances of Surveyor License Acquisition System in Japan

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Abstract The license acquisition system of surveyors in Japan is composed by two levels of national license; the surveyor and the assistant surveyor. The survey Act, which determines the qualifying standard for licensing, accept several routes for acquiring the license, depending on the situations of applicants. Two primary route of license acquisition are by passing the national qualifying examination and by graduating at designated universities, junior colleges, technical colleges and technical schools. The circumstances of surveyor license acquisition system in Japan were investigated from the Survey Act and the national qualifying examination. It became clear that the surveyor has been required the new technologies and a wide range knowledge for survey. So as to clarify the abilities of the surveyors who passed the national qualifying examination and of those who graduated from the above university or technical school, the ability verification test of assistant surveyors was given. As a result, it can be said that the former group performed better than the latter. In order to reduce the difference of difficulties for license acquisition, the contents of current survey educations in higher education should be improved. This paper presented the circumstances of the national license in Japan, including the details of the national qualifying examination and other routes of the license acquisition, and indicated the problems.

Keywords surveying, qualification system, surveyor, assistant surveyor, license

INTRODUCTION

For the sustainable development of developing countries, it is important to make regional development projects and to construct infrastructures. As surveying techniques play a great role in the implementation of sustainable development projects in developing countries, engineers who have basic surveying education are basically required. The knowledge on the present condition and

issues related to acquiring qualifications of surveying in Japan will be certainly helpful to implement training in surveying education in developing countries.

In Japan, there are two national qualifications: one for surveyor, and the other for assistant surveyor. The basic survey by the Geospatial Information Authority of Japan and public surveys, for which the expenses are covered by the national or local governments, are done solely by qualified surveyors and assistant surveyors. It is possible for qualified surveyors to establish their own surveying businesses. In Japan, many national qualifications in the engineering field are obtained through appropriate education and national qualifying examinations. These include the qualifications of consulting engineer, execution manager of civil engineering, and land and house investigator. The qualification of surveyor is given to those who passed the national qualifying examination, or to those who completed education at designated universities, junior colleges, technical colleges and technical schools (hereinafter: relevant schools). There are multiple routes for obtaining the surveyor qualification. It is thought that the present system for qualifying surveyors and assistant surveyors and the problems related to education and the qualifying system for surveyor and assistant surveyors require some investigations.

Koshimizu et al. (2008) investigated the qualification system for surveyors in Germany, France, Canada, the U.S.A. and Australia, and reported that the systems in these five countries were much better developed, qualitatively and quantitatively, than that of Japan. Japanese technical schools have a system whereby foreign students can learn surveying. An according to the interview for foreign students of the technical school (Chuo College of Technology), in Uganda, the surveyor qualification is able to be obtained through studies of surveying and graduation from a university, and through membership in the surveyors' association. In Nepal, the surveyor qualification is also obtained by graduation from a university that provides surveying as a subject. Basically, it is important to learn knowledge and techniques of surveying by attending schools (Dagtekin, 2012; Enemark, 2005). The objectives of this paper are to present the state of licensing in Japan and to discuss the related problems.

METHODOLOGY

The complicated Japanese qualification system for licensing surveyors and assistant surveyors, which has two routes, is investigated based on the Survey Act (Japan Association of Surveyors, 2014). The characteristics of Japan's national qualifying examination for surveyor and assistant surveyor licensing are summarized by investigating the questions of the examinations conducted in 2007 to 2014 and by using the passing rate of the examinations (Geospatial Information Authority of Japan, 2014a).

In order to clarify the abilities of the surveyors who passed the national qualifying examination and of those who graduated from the relevant schools, an ability verification test is given to verify the difference in ability. It is given to 10 assistant surveyors: five who obtained their licenses by graduating from the relevant schools, and five who obtained their licenses by passing the national qualifying examination. The abilities of the two groups are compared by checking the number of correct answers and percentage of correct answers.

The number and percentage of correct answers are used to determine ability. All the examinees are students studying at a technical school (Chuo College of Technology) to obtain the qualification of surveyor. The test is given without advance notice to know their ability without them having special preparation. The test consisted of questions from previous national qualifying examination for assistant surveyors. The national qualifying examination for licensing assistant surveyor has 28 four-choice questions.

RESULTS AND DISCUSSION

Present State of the National Qualifying Examination for the Surveyors (Assistant Surveyors)

The questions on the national qualifying examination for licensing surveyors and assistant

surveyors cover the following: “Traversing”, “Global Navigation Satellite System (GNSS)”, “Leveling”, “Topographic surveying”, “Photogrammetry”, “Map compilation”, “Engineering surveying” and “Geographic Information System (GIS)”. A wide range of knowledge is required for one to obtain a license in this field. Basically, the questions are on the items and surveying techniques described in the General Standard of Operation Specifications for Public Surveys (hereinafter: the *General Standard*).

The required knowledge has been changing with the times. In Japan, “Plane table surveying” was deleted from the *General Standard* in 2008, and the knowledge on “Topographic surveying” by total station (TS) became a requirement for the examinees. The name of the “Global Positioning System (GPS) survey” was changed to “GNSS survey” when the *General Standard* was revised in 2011. In recent years, questions related to such areas as “Digital stereo plotter”, “GIS”, “GNSS survey using GNSS-based control station” and “Airborne laser surveying” have been included in the national qualifying examination in Japan.

As stated above, new technologies and a wide range of questions that meet the needs of the times are included in the national qualifying examination. Because of the above-mentioned changes, the national qualifying examination for licensing surveyor and assistant surveyor differs from other national qualifying examinations, whose questions have not been changed greatly (Masuyama, 2009). A notable characteristic of the qualifying examination for surveyor and assistant surveyor is that the examination reflects new technologies. Therefore, the acquisition of knowledge on new surveying technologies is indispensable.

Table 1 shows the results of national qualifying examination for licensing surveyor and assistant surveyor done in the eight years from 2007 to 2014 (Geospatial Information Authority of Japan, 2014a). The number of applicants, which is about 13,000 in each year, is stable over time. The average rate of test-takers who pass is 27.7% for the assistant surveyor test and 9.7% for the surveyor test. The data shows that the examination for licensing surveyor is a national qualifying examination with a high level of difficulty in Japan.

Table 1 Results of national qualifying examinations for licensing surveyor and assistant surveyor

Class	Assistant surveyor			Surveyor		
Year	Number of examination -takers	Number of passing candidates	Passing rate (%)	Number of examination -takers	Number of passing candidates	Passing rate (%)
2007	11,052	2,654	24.0	2,398	274	11.4
2008	10,858	2,435	22.4	2,203	219	9.9
2009	10,520	2,704	25.7	2,170	181	8.3
2010	10,387	2,757	26.5	2,256	144	6.4
2011	10,233	2,192	21.4	2,162	258	11.9
2012	10,551	4,289	40.7	2,281	279	12.2
2013	10,596	2,248	21.2	2,457	127	5.2
2014	11,118	4,417	39.7	2,394	290	12.1
Average of passing rate			27.7	Average of passing rate		9.7

For the national qualifying examination for licensing surveyor and assistant surveyor, there are no academic requirements. For example, a high school student can take the examination. Students at industrial and agricultural high schools nationwide are encouraged and instructed to obtain the qualification. Every year, many high school students pass the national qualifying examination (Osaka city Miyakojima technical high school; 2014, Miyazaki Prefectural Miyakonojo Agricultural High School; 2014, Tokyo metropolitan Tanashi technical high school; 2014). Figure 1 shows the routes for one to obtain surveyor and assistant surveyor licenses by passing the national qualifying examination. From this figure, it is found that it is even possible for one to obtain the qualification of surveyor even if one does not have an assistant surveyor qualification.

Even a person with sufficient work experience has to pass the national qualifying examination to obtain the surveyor license if that person has not graduated from the relevant schools as illustrated in Fig. 2. However, if a person with an assistant surveyor license graduates from a technical school whose purpose is to educate surveyors, that person is able to obtain the surveyor license without passing the national qualifying examination. In Japan, there are two technical schools that fall into the above-described category (Geospatial Information Authority of Japan, 2014b). One of these two schools graduates more than 90% of its students every year. Generally, graduating from a relevant school is the shortest route for obtaining the surveyor license for adults and high school students who have obtained the assistant surveyor license.

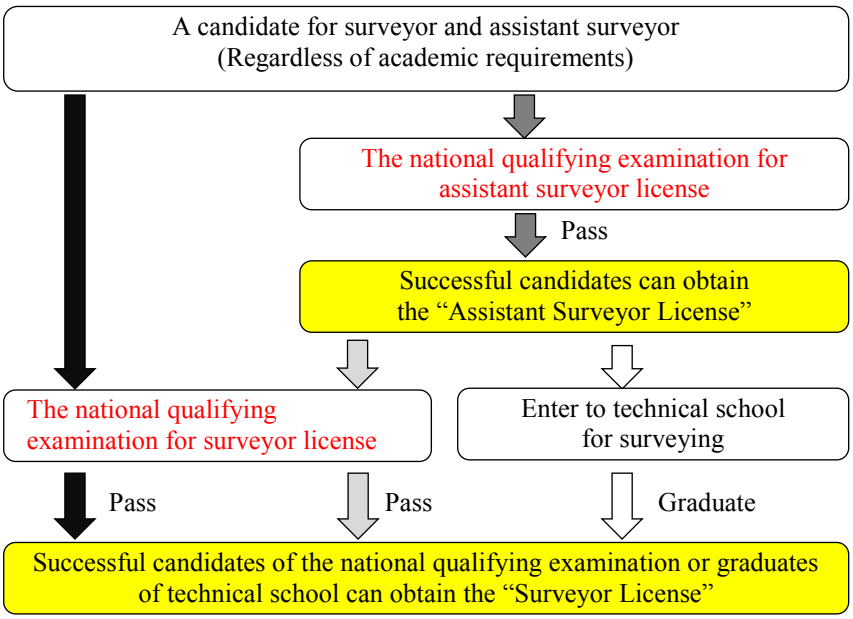
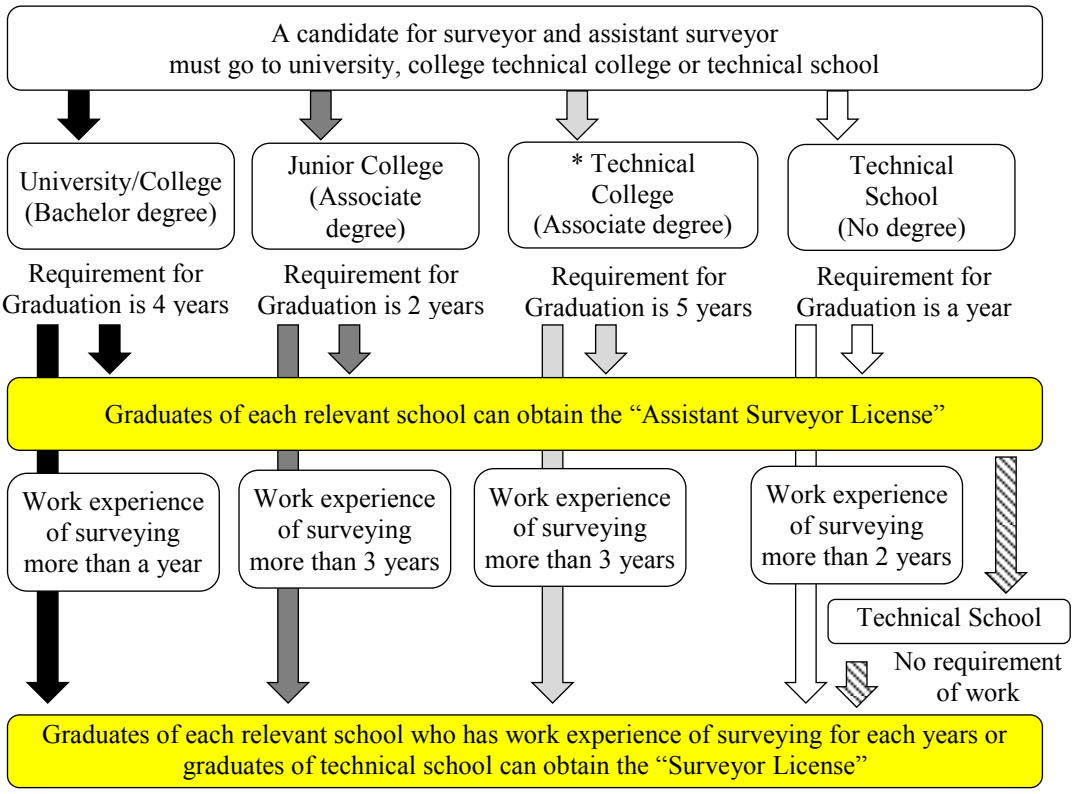


Fig. 1 Flow chart of acquisition of surveyor license via national qualifying examination

Acquiring Qualification of Surveyor / Assistant Surveyor at Relevant Schools

Figure 2 shows the routes for obtaining the qualifications of surveyor and assistant surveyor by graduating from the relevant schools. It is possible for the graduate of a relevant school who has earned required number of credits to register as an assistant surveyor with the Geospatial Information Authority of Japan. If a person who graduated from the relevant school has the required years of work experience in surveying, then that person is able to obtain the qualification of surveyor without passing the national qualifying examination, even the person does not have the qualification of assistant surveyor. The range of work related to surveying does not necessarily need to cover a range as wide as that of the national qualifying examination for licensing surveyors. The requirement in this case is simply surveying experience. Given that an average of only 9.7% of those who take the national qualifying examination for surveyors pass, it is advantageous for someone who wishes to acquire the qualification to graduate from a relevant school and to work for some years, rather than taking the national qualifying examination. A person who acquires the qualification of assistant surveyor and then graduates from a relevant school is able to obtain the qualification of surveyor without any work experience.

The surveyor licensing system is liable to create surveyors without balanced knowledge. Therefore, it is desirable for the relevant schools to educate their students by providing subjects that address domestic and international regulations, which are included in the questions of the national qualifying examination, and that address a wide range of items covered in the national qualifying examination, including traversing, GNSS and GIS.



**This is composed of high school education and junior college education*

Fig. 2 Flow chart of acquisition of surveyor license without national qualifying examination

Results of Ability Verification Test

Roughly, there are two routes for obtaining the assistant surveyor qualification; one is by passing the national qualifying examination and the other is by graduating from a relevant school. To assess the relative ability of assistant surveyors qualified through the two different routes, 10 students were given an ability verification test: five who had obtained their qualification by passing the national qualifying examination, and five who had obtained their qualification by graduating at a relevant school.

The results of the ability verification test are shown in Table 2. The average number of correct answers for the group of assistant surveyors who obtained their licenses by passing the national qualifying examination was 14.2, and that for the group of examinees who obtained their licenses by studying at a relevant school was 13.0. The number of correct answers of the former group was 1.2 higher than that of the latter group. The standard deviation for the former group was 4.0, and that for the latter group was 4.7. The scores for the former were more narrowly distributed than those of the latter. Therefore, the coefficient of variation for the former was 27.9%, and that for the latter was 36.1%. The variance of the scores of the former was smaller than that of the latter. Correct answers as a percent of all questions averaged 50.7% for the former and 46.4% for the latter was. The former is higher.

As a result, it can be said that the former student group performed better than the latter. The reason for the difference in test results is thought to be that the latter group of students had not been taught a wide range of subjects in surveying or, even if they had been taught the subjects, they had not learned sufficiently, and the sense of purpose in studying surveying of the students in the latter group was more diverse than that of the former.

Table 2 Results of ability verification test for surveying that practiced at a technical school (Chuo College of Technology)

(a) Students who obtained assistant surveyor license by passing the national qualifying examination			(b) Student who obtained assistant surveyor license by graduating at a relevant school		
Subjects (5 students)	Number of correct answers (28 questions)	Correct answer rate (%)	Subjects (5 students)	Number of correct answers (28 questions)	Correct answer rate (%)
A	15	53.6	F	17	60.7
B	9	32.1	G	11	39.3
C	14	50.0	H	9	32.1
D	13	46.4	I	19	67.9
E	20	71.4	J	9	32.1
Average	14.2	50.7	Average	13.0	46.4
S.D. *	4.0	-	S.D. *	4.7	-
C.V. ** (%)	27.9	-	C.V. ** (%)	36.1	-

** : standard deviation **: coefficient of variation*

Requiring New Materials for Teaching Surveying at the Relevant Schools

If the relevant schools are providing technical education that produces surveyors and assistant surveyors who have poor knowledge, then the situation is problematic. It is unfortunate for society and for surveyors who obtain licenses by graduating from relevant schools if their knowledge and techniques are insufficient. To solve this problem, it is necessary to further enhance the educational content qualitatively and quantitatively at the relevant schools. New educational materials need to be created by taking into consideration the latest technologies, which address the changes of the times, and the questions on the national qualifying examination, including previous questions. Licensing via school education has an advantage over licensing via national qualifying examination, in that the students are able to learn how to use surveying equipment in their practice training and how to produce documents, drawings and other materials after the training; they are also able to learn how to work as members of a team, as their training is done in groups. The development of new educational materials is required to take into consideration the above characteristic advantages of school education.

CONCLUSION

The circumstances of surveyor license acquisition system in japan were investigated from the Survey Act and the national qualifying examination. Further, in order to clarify the abilities of the surveyors who passed the national qualifying examination and of those who graduated from the relevant schools, the ability verification test of assistant surveyors was given. As the results, the following points are summarized.

(1) As the results of the investigation on Japan's national qualifying examination for surveyor and assistant surveyor licensing for seven years, it became clear that the characteristic of the national qualifying examination. Namely, new technologies and a wide range knowledge for survey has been setting in the national qualifying examination. The percentage of examination-takers who pass was 27.7% for the assistant survey examination and 9.7% for the surveyor examination. The surveyor has been required the new technologies and a wide range knowledge for survey.

(2) Given that an average of only 9.7% of those who take the national qualifying examination for surveyors pass, it is advantageous for someone who wishes to acquire the qualification to graduate from a relevant school and to work for some years, rather than taking the national qualifying examination.

(3) As the results of the ability verification test, the students who obtained the assistant surveyor qualification by graduating from passing the national qualifying examination were higher correct answer rate, lower standard deviation and coefficient of variation than the students who obtained that qualification by graduating from a relevant school. The differences in test results are following reasons. The latter group of students had not been taught a wide range of subjects in surveying. Even if they had been taught the subjects, they had not learned sufficiently. The sense of purpose in studying surveying of the students in the latter group was more diverse than that of the former.

(4) Licensing via school education has an advantage over licensing via national qualifying examination, in that the students can learn how to use surveying equipment in their practice training and how to produce documents, drawings and other materials after the training; they can also learn how to work as members of a team, as their training is done in groups. In order to enhance the educational content qualitatively and quantitatively at the relevant schools, the development of new educational materials is required to take into consideration the latest technologies, which address the changes of the times, and the questions on the national qualifying examination, including previous questions, while taking into consideration the above characteristic advantages of school education.

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REFERENCES

Dagtekin, E. 2012. Training of surveying course in Dicle University faculty of architecture. Procedia - Social and Behavioral Sciences, 47, 292-296.

Enemark, S. 2005. The digital cadastral database and the role of the private licensed surveyors in Denmark. Irish Institute of Surveyors, Dublin Institute of Technology, 23, 1-9.

Geospatial Information Authority of Japan. 2014a. (Website: http://www.gsi.go.jp/LAW/SHIKEN-siho-siken.html, accessed; 19 Nov. 2014).

Geospatial Information Authority of Japan. 2014b. (Website: http://www.gsi.go.jp/PCOMMENT/ SurveyAct030618_ shiteiichiran.htm, accessed; 19 Nov. 2014).

Japan Association of Surveyors. 2014. Statutes at large, Japan Association of Surveyors, p.20. (in Japanese).

Koshimizu, H., Fujimura, H. and Sakabe, S. 2008. Licensing system of surveyors in Japan and abroad. Journal of the Geospatial Information Authority of Japan, 116, 45-59. (in Japanese with abstract in English).

Masuyama, K. 2009. Effective use and problem in the future of the second class civil engineering works execution management technology authorization subject examination in engineering works system student. Journal of Japan Society of Civil Engineers. Series H (Engineering Education and Practice), 1, 105-110. (in Japanese with abstract in English).

Miyazaki Prefectural Miyakonojo Agricultural High School. 2014. (Website: http://www.miyazaki-c.ed.jp /miyakonojo-ah/pg454.html, accessed; 11 Nov. 2014).

Osaka city Miyakojima technical high school. 2014. (Website: http://www.ocec.ne.jp/hs/miyakojima /c/index.html, accessed; 11 Nov. 2014).

Tokyo metropolitan Tanashi technical high school. 2014. (Website; http://www.tanashikougyo-h.metro. tokyo.jp/cms/html/entry/ 37/5.html, accessed; 11 Nov. 2014).

Research article

Growth Performance and Feed Utilization of Common Lowland Frog (*Rana rugulosa* Wiegmann) Fed with Supplementation by Bromelain Extracted from Pineapple Feed

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Abstract This study aimed to determine the effect of bromelain extracted from the crown of pineapple supplemented in diet on growth performance and feed utilization of common lowland frog. Diets were isonitrogenous at 35% protein and 3,000 $KcalKg^{-1}$ supplemented at 0, 0.25, 0.5 and 1 mL bromelain extraction g^{-1} of feed. Frog with an initial weight of 0.25 ± 0.1 g were fed on feed trial in triplicate groups for 120 days. The results showed that the enzyme extracts did not effect growth performance but enhancement the survival rate with all levels ($P<0.05$) especially at 1 mL/g feed had the highest feed utilization and protein efficiency ratio (PER). The percentage of edible flesh of 0, 0.5 and 1 mL/g feed group were higher than the 0.25 mL/g feed group. These results demonstrated that bromelain extracted supplementation of all levels improved survival rate and feed utilization and PER especially at 1 mL/g feed.

Keywords common lowland frog, bromelain, pineapple, growth performance, feed utilization

INTRODUCTION

In 2011 the total area of pineapple cultivation in Thailand is around 104,571 hectare (646,000 rai). Prachuapkhirikhan has the largest share at 47% of the total pineapple cultivated areas of the country; other major growing provinces are Chonburi, Rayong, Trat, Chacheongsao, Kanchanaburi, Phetchaburi and Ratchaburi. Thailand is the world's number one exporter of canned pineapple. In 2011, Thailand exported canned pineapple totaling 641,167 tons (or 36,430 FCLs; 1 FCL = 17.6 tons), with the total value of 669.4 million dollars. Thailand's main export markets are United States, EU and Russia. The waste from pineapple (peel, core, stem and crown) generally is about for 50% of the whole fruit that causing a serious environmental problem (Ketnawa et al., 2012). The utilization of waste as feed additive in aquatic animal feed is the alternative way for handling the great deal of waste problem.

Bromelain is a mixture of proteolytic enzyme, belong to a group of protein digesting enzyme derived from the fruit or stem of pineapple (*Ananas comosus* L.) (Bhattacharyya, 2008; Bala et al., 2012). Bromelain is the most effectiveness in reduction of inflammatory and decreasing swelling as a natural anti – inflammatory enzyme. It's a mixture of different thiol endopeptidase and other components like phosphatase, peroxidases, glucosidases, glycoproteins, cellulose, carbohydratase and several protease inhibitors (Bhattacharyya, 2008). Bromelain is not very specific in action but preferentially cleaves glycol, anayl and leucyl bonds. The bromelain actions on protein predigestion, diarrhea, digestive aid, anti thrombotic, oedema treatment and osteoarthritis and promotes the absorption of antibiotic drug. (Corzo et al., 2012). It is contains, among other components, various closely related proteinases, anti - edematous, anti - inflammatory,

antithrombotic and fibrinolytic activities. Moreover, due to its safety and lack of undesired side effects, bromelain has earned growing acceptance and compliance among patients as a phytotherapeutical drug. The pharmacological properties depend on the proteolytic activity only. Bromelain contains several distinct cysteine proteinases that have similar but distinct amino acid sequences, as well as differences in proteolytic specificity and sensitivity to inactivation (Hale et al., 2005). From the mentioned properties, the bromelain from pineapple should be used as feed additive in frog feed. Because of the gastrointestinal tract of tadpole and juvenile frog are similar to fish larvae that required feed all the time that causes digestive aid and dead in final. In addition, at the disappearence of the tail stage the frog does not eat feed experiences mortality also. This problem is often found in aquatic animal larvae. The digestion depend on digestive enzyme such as protease, amylase and lipase especially protease because the frog is carnivorous and has the high protein requirement (Duellman and Trueb, 1994). From the properties of bromelain and the problem on digestion of frog, bromelain should be used as feed additive in frog feed for improving the digestion and depressing the digestive aid and the mortality.

OBJECTIVE

The purpose of this study was to investigated the ability of diet supplemented with bromelian extraction from pineapple on feed utilization, growth performance, percentage of edible flesh and survival rate of common lowland frog.

METHODOLOGY

Experimental Frogs

Frogs at 10 days old (initial mean weight 0.25 ± 0.10 g), produced in Petchaburi Rajabhat University aquaculture program were randomly stocked into 1 m^2 cement tank at a density of 30 frog per tank. Frogs were acclimated for 1 week with control feed (pellet feed without bromelain supplementation) before start the experiment.

Raw Material and Crude Extract Preparation

The pineapple (*Ananus comosus* L.) (“Batavia”) was collected from plantation in the Ratchaburi province, Thailand. The fruit was washed and air dried. The crown (Fig. 1) was separated and chopped to small pieces. This study used the crown because from the previous study it was found that the bromelain activity (from waste: peel and crown) was highest in crown. Small pieces of crown were blended with cold distilled water at a 1:1 ratio for 5 min and the blended liquid was filtered through a sieve (250 μm) and then centrifuged at 10,000 x g at 4 ^{o}C for 20 minnutes (Ketnawa et al., 2012). The supernatant (crude extract) will be collected to mix with feed.

Experimental Diets

Frogs were fed with floating pellet diet (35% protein, 3000 Kcalkg^{-1} energy). Proximate composition of the experimental diets is determined by analysis (Kjeldahl method for crude protein, Soxhlet method for lipid, Detergent method for crude fiber, Oven drying method for moisture and determination of ash by muffle furnace) (AOAC, 2000). Bromelain extraction was used at 0, 0.25, 0.5 and 1 mg^{-1} diet as a feed supplement. In the preparation of experimental diet, bromelain were mixed with a diet and control diet was also mixed with 1 mL water for 1 g feed. These pelleted diets were coated with fish oil at 1% and then incubated at 37 ^{o}C for 1 hour then dried in the hot air oven at 90 ^{o}C for 2 hours. The dry pellets were placed in covered plastic bag and stored at room temperature.

A B

Fig. 1 Pineapple whole fruit (A) and crown proportion (B)

Experimental Procedure

Each of the four experimental diets was randomly assigned to triplicate groups of frog and all the groups were fed with the prepared diet at 5% body weight twice daily for 120 days. Also, water was changed for every two days for 100% throughout the study.

Analytical Method

During experiment, the mortality was recorded daily and frog in each tank were monthly counted and weighed individually. Growth rate were monitored to determine the final weight, weighed gain, Specific Growth Rate (SGR), average daily gain, survival rate, feed intake, Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER) were calculated according to Castell and Tiews (1980). At the start of experiment, 50 frogs randomly were dried for the determination of body proximate composition. At the end of the feeding trial, 10 frogs from each group (n = 30 frogs/group) were analyzed for final whole body proximate composition. Proximate composition of body was analyzed following the AOAC (2000) method.

Statistical Analysis

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

RESULTS AND DISCUSSION

Growth Performance

The result of the growth trial showed that all groups were not significantly different ($P>0.05$) (Table 1). The mean final weight, weigh gain, ADG and SGR of different diets ranged between 84.94 – 98.62 g/f, 84.60 – 98.37 g/f, 0.91 – 1.11 g/f/day and 2.54 – 2.79 %, respectively. In the contrary, survival rate in all groups fed with supplemented bromelain feed showed significantly the highest survival rate ($P<0.05$). Bromelain is contains, among other components, various closely related anti - edematous, anti - inflammatory, antithrombotic and fibrinolytic activities that promote the great health effected on the high survival rate. The growth rate was similar with among group because frog is carnivorous which the density effected on the growth rate. The amount of frog after fed with supplement bromelain feed for 120 days has the high density proportion when compared with no supplement bromelain feed group so make the growth rate not outstanding.

Table1 Growth performance of frog fed with supplementation diet by bromelain extracted at 120 days

Growth performance	Bromelain supplementation (mL/g feed)			
	0	0.25	0.5	1
Initial weight (g/f)	0.24 ± 0.02	0.25 ± 0.01	0.25 ± 0.01	0.26 ± 0.00
Final weight (g/f)	98.62 ± 3.71	84.94 ± 2.55	89.92 ± 5.76	87.23 ± 6.75
Weight gain (g/f)	98.37 ± 3.73	84.70 ± 2.54	89.66 ± 5.76	86.79 ± 6.74
Average daily gain (g/f/day)	1.11 ± 0.13	1.11 ± 0.39	1.09 ± 0.25	0.91 ± 0.07
Specific growth rate (%/day)	2.79 ± 0.19	2.74 ± 0.03	2.72 ± 0.28	2.54 ± 0.08
Survival rate (%)	75.00 ± 2.36^{b}	85.55 ± 5.09^{a}	92.22 ± 1.92^{a}	91.11 ± 7.69^{a}

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

Feed Utilization

The result of feed utilization of frog fed with supplementation with bromelain at different level for 120 days showed that diet containing 0.25 – 1 mL of bromelain per 1 g feed were significantly higher (P<0.05) than controlled group especially at 1 mL of bromelain per 1 g feed group resulted in the highest feed utilization i.e. the best FCR, FCE and PER and the worst feed intake (Table 2). Bromelain is a mixture of proteolytic enzymes, belonging to a group of protein digesting enzyme (Bhattacharyya, 2008 and Bala et al., 2012). It's a mixture of different thiol endopeptidase and other components like phosphatase, peroxidases, glucosidases, glycoproteins, cellulose, carbohydratase and several protease inhibitors (Bhattacharyya, 2008 Maurer, 2001). On the other hand, the highest caseinolytic activity at a pH 5.5 - 8 (Ketnawa et al., 2012; Corzo et al., 2012 and Bala et al., 2012) these cause make it has high digestibility efficiency. In addition, bromelain has been successfully used as a digestive enzyme following pancreatectomy, in case of exocrine pancreas insufficiency and the advantage is it has activity in the stomach as well as the small intestine which also shown to be an adequate replacement of pepsin and trypsin in case of deficiency (Bhattacharyya, 2008).

Table 2 Feed utilization of frog fed with supplementation diet by bromelain extracted at 120 days

Feed utilization	Bromelain supplementation (mL/g feed)			
	0	0.25	0.5	1
Feed intake (g/f/day)	1.56 ± 0.02^{a}	1.05 ± 0.15^{bc}	1.17 ± 0.24^{ab}	0.65 ± 0.00^{c}
Feed conversion ratio	1.64 ± 0.52^{a}	1.18 ± 0.14^{b}	1.47 ± 0.43^{ab}	0.80 ± 0.09^{c}
Feed conversion efficiency (%)	74.43 ± 8.03^{b}	85.42 ± 9.81^{b}	81.59 ± 12.01^{b}	133.99 ± 0.21^{a}
Protein efficiency ratio	1.84 ± 0.51^{b}	1.73 ± 1.23^{b}	2.04 ± 0.55^{b}	3.60 ± 0.38^{a}

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

Carcass Composition

The effect of different bromelain supplementation level on carcass composition showed in Table 3. The results showed that there was no significant difference on percentage of bone and skin, viscera and fat and hepatosomatic index (HSI) (P>0.05) but it effected on percentage of edible flesh (P<0.05) that showed the highest on control group, 0.5 and 1 ml/g feed and has the lowest in 0.25 mL/g feed group. The composition of the amino acid (AA) mixture that was significantly influence the composition of the fish free amino acid (FAA) pool. However, when fish are fed a feed supplemented bromelain, a faster absorption of FAA may lead to transient AA imbalances and consequently to decreased protein utilization if crystalline AA are used to supplement dietary protein.

Table 3 Carcass composition of frog fed with supplementation diet by bromelain extracted at 120 days

Carcass composition (%)	Bromelain supplementation (mL/g feed)			
	0	0.25	0.5	1
Edible flesh	31.58 ± 1.34[a]	27.63 ± 1.69[b]	28.72 ± 0.54[ab]	30.21 ± 0.48[ab]
Bone and skin	41.71 ± 0.37	43.36 ± 1.46	44.30 ± 1.97	41.10 ± 2.07
Viscera and fat	28.84 ± 2.55	29.01 ± 1.81	28.77 ± 2.05	31.49 ± 0.14
Hepatosomatic index	6.04 ± 0.12	6.38 ± 0.10	5.59 ± 1.06	6.01 ± 0.82

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

CONCLUSION

Bromelain extracted from pineapple could be used as frog's survival rate promoter. The supplementation bromelain all levels improved survival rate, feed utilization and PER especially at 1 mL/g feed. It can be concluded that bromelain extracted from pineapple's crown is useful for aquaculture and environment to get rid of the waste from agriculture.

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REFERENCES

A.O.A.C. 2000. Official methods of analysis. Virginia Association of Official Analytical Chemist, Inc.

Bala, M., Ismail, N.A., Mel, M., Jami, M.S., Salleh, H.M. and Amid, A. 2012. Bromelain production: Current trends and perspective. Archives Des Sciences, 65, 369-399.

Bhattacharyya, B.K. 2008. Bromelain: An overview. Natural Production Radiance, 7, 359-363.

Castell, J.D. and Tiews, K. 1980. Report on the EIFAC, IUNS and ICES. Working group on the standardization of methodology in fish nutrition research, Hamburg, Federal Republic of Germany. 21-23 March, EIFAC Technical Paper, 26 p.

Corzo, C.A., Krzysztof, N.W. and Jorge, W.C. 2012. Pineapple fruit bromelain affinity to different protein substrates. Food Chemistry, 133, 631-635.

Duellman E. and L. Trueb. 1994. Biology of amphibians. The Johns Hopkins University press, London.

Hale, L.P., Paula, K.G., Chau, T.T. and Cindy, L.J. 2005. Proteinase activity and stability of natural bromelain preparations. International Immunophamacology, 5, 783-793.

Ketnawa, S., Phanuphong, C. and Saroat, R. 2012. Pineapple wastes: A potential source for bromelain extraction. Food and Bioproducts Processing, 90, 385-391.

Research article

Mangrove Rehabilitation Using *Rhizophora* sp. in Northeastern Bohol, Philippines

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Abstract National government issued an Executive Order 26, series of 2011 – declaring interdepartmental convergence initiative for national greening program. Bureau of Fisheries and Aquatic Resources commissioned the Bohol Island State University (BISU) Candijay Campus to facilitate the rehabilitation of degraded mangrove areas in coordination with local government units and in partnership of mangrove planters in Northeastern Bohol. Hence, the main objective of the study was to to document the progress and accomplishment of mangrove rehabilitation project in Northeastern Bohol, Philippines. Survived mangroves were counted manually. Principal branch of mangrove was measured to determine the growth performance in 12 months. Identified the sea shells for baseline information and interviewed the mangrove planters for determining the problems. In this study, a 48.36% survival rate was found out after one year of planting. The average growth (in height) was 6.097 cm per month. The Municipality of Candijay had the highest growth rate. *Terebralia* sp. (Dao-dao) and *Narita* sp. (Sihi) are the common sea shells found in the reforested areas. Proper selection of site is important before planting *Rhizophora* sp.

Keywords mangrove, reforestation, survival, sea shell, rehabilitation, propagule

INTRODUCTION

Mangrove is a type of forest growing along tidal mudflats and along shallow water coastal areas. Its ecosystem is primarily dominated by mangrove trees which is the primary producer. These trees interacts with associated aquatic fauna, and social and physical factors of the coastal environment (Melana et al., 2000a). Mangrove trees produces leaf litter and detrital matter, which are valuable sources of food for animals in estuaries and coastal waters. It is also use as firewood in coastal communities and most bakeries because of its heating value, but a greater volume is exported to Japan as a source of rayon (Melana et al., 2000b).

Philippines is endowed with lush coastal ecosystems including mangrove. Unfortunately, the huge area of mangrove forest in the country decreases into 120, 000 ha in the year 1981 from an estimated coverage of 450,000 ha in 1918. This has happened due to the rapid degradation during 1960's and 1970's when the government set a national policy that encourages expansion of the aquaculture. This reduces the forest into 117,700 hectares (DENR, 1995) that disturbed the whole coastal ecosystems.

In 2011, the national government with the leadership of President Benigno Simeon Aquino III issued the Executive Order No. 26, s. 2011 – declaring and interdepartmental convergence initiative for a national greening program. This order strengthened after the issuance of Executive Order No. 23, s. 2011 – mandated the DA-DAR-DENR convergence initiative to develop a national greening program in cooperation with the Department of Education, Commission on

Higher Education, Department of Social Welfare and Development and Department of Budget and Management, private sector and other concerned agencies and institutions.

The Bohol Island State University Candijay Campus was commissioned by the Bureau of Fisheries and Aquatic Resources to rehabilitate the degraded mangrove areas in Northeastern Bohol. Fifty three (53) hectares of intertidal zones were planted with *Rhizophora* sp. in year 2013 in collaboration with local communities and local government units in Northeastern Bohol.

OBJECTIVES

The general objective of this study was to document the progress and accomplishment of mangrove rehabilitation project in Northeastern Bohol, Philippines. Specifically, the study aims to:

1. determine the survival rate of *Rhizophora* planted after one year,
2. determine the growth rate after year of planting,
3. identify the sea shells for baseline information in the rehabilitated areas, and
4. identify the problems encountered in planting and management of *Rhizophora*.

METHODOLOGY

Location

Project sites are located in the four coastal municipalities of Northeastern Bohol, Philippines namely; Candijay, Mabini, Bien Unido and Talibon (Fig. 1). Coordinates for Talibon are 10˚09'55.55"N; 124˚20'57.25"E, then 10˚10'56.2"N; 124˚23'13.5"E for Bien Unido; 9˚55'20.04"N; 124˚32'32.23"E for Mabini and 9˚49'05.78"N; 124˚34'17.13"E for Candijay. These municipalities were chosen intentionally because these are the areas where the Bohol Island State University- Candijay Campus is working for mangrove rehabilitation using *Rhizophora* sp. with the coordination of the local government units and in partnership with mangrove planters.

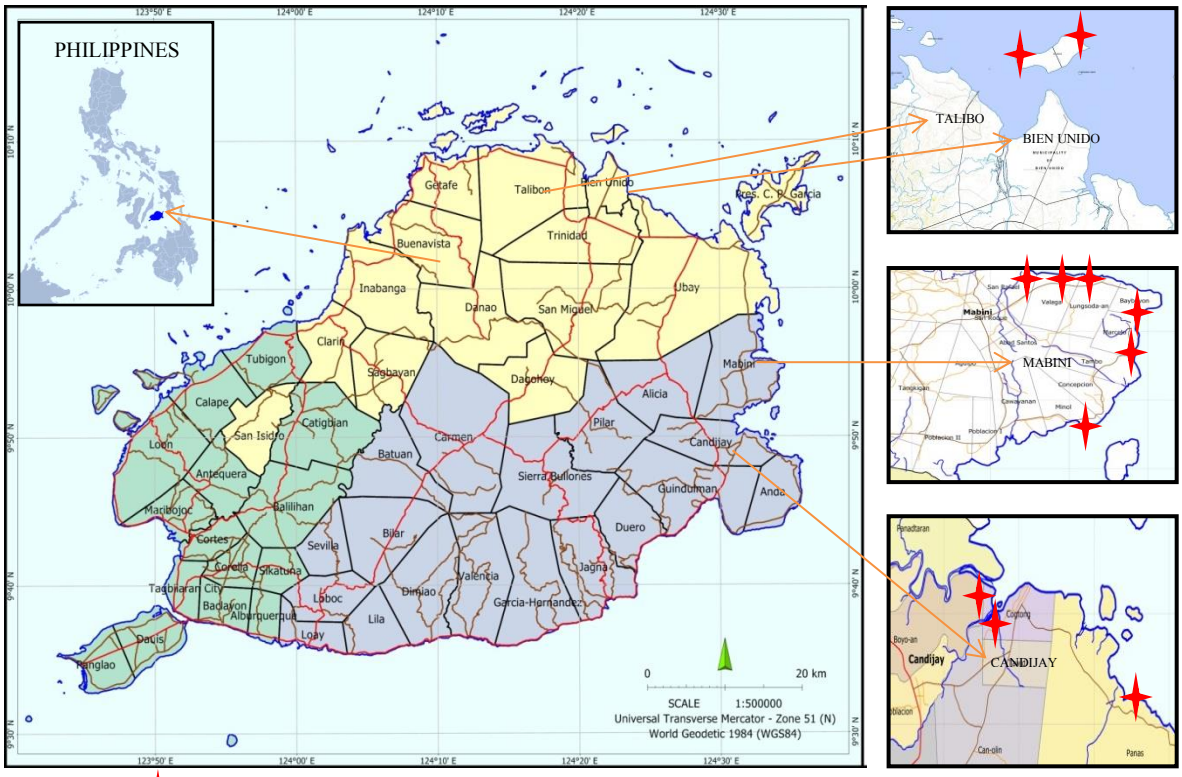
Procedures

General purpose of the study was presented to the local government officials of the four coastal municipalities in Northeastern Bohol for their information and guidance about the activity. Support from them was obtained. Data on the numbers of *Rhizophora* sp. planted in the four coastal municipalities in Northeastern Bohol were then gathered from the Extension Office of Bohol Island State University-Candijay Campus. The data were validated by the mangrove planters.

Census was applied in the counting of planted *Rhizophora* with participation of mangrove planters. Tally counters, slateboards and pencils were used for recording and counting of live *Rhizophora* sp. in four coastal municipalities in Northeastern Bohol. Sea shells were identified to establish baseline information in the reforested area. Assistance from mangrove planters were utilized especially on the naming locally of sea shells then after it was referred to the field guide published by FAO (1998) for right identification and naming scientifically.

Growth rate was measured inside the 6 ha mangrove plantation. This area is equivalent to 10% of 53 ha of planted *Rhizophora* sp. Eighteen plots were ramdomly established in 6 ha with 1 plot per hectare, and in every plot has 10 samples of mangrove trees. Samples were measured with tip measure with the aid of slateboard and pencil. The aimed was to determine the growth in height of planted mangroves.

Problems encountered in planting and management of *Rhizophora* sp. were gathered through an informal discussion with the 30 mangrove planters in four coastal municipalities in Northeastern Bohol. Problems were listed and collated and then it was presented to the other members of the communities for verification and validation of the data.



Legend: ✦ Study sites

Fig. 1 Map of Bohol

RESULTS AND DISCUSSION

Table 1 shows the four coastal municipalities of Northeastern Bohol that involved in mangrove planting using *Rhizophora* sp. The largest area planted with *Rhizophora* sp. is in the municipality of Mabini. It was planted in the lower intertidal zones near the river banks. The Municipality of Candijay has the second largest area where the species was planted in the middle and upper intertidal zones, followed by the municipality of Bien Unido and Talibon where the mangroves planted mostly in the lower intertidal zones of the island. All the mangroves were planted in 2013.

Table 1 Rehabilitated mangrove areas in Northeastern Bohol using *Rhizophora* sp.

Municipalities	Total area per municipality (Ha)
Candijay	19
Mabini	27
Bien Unido	4
Talibon	3
Total	**53**

Table 2 *Rhizophora* sp. that survived in the rehabilitated mangrove areas (53 ha)

Municipalities	Number of *Rhizophora* sp. planted	Numbers of survived *Rhizophora* sp.	Survival rate (%)
Candijay	63,327	46,463	73.37
Mabini	89,991	23,774	26.42
Bien Unido	13,332	8,901	66.76
Talibon	9,999	2,687	26.87
TOTAL	**176,649**	**81,825**	**48.36**

Table 2 presents the number of *Rhizophora* sp. that survived in four coastal municipalities in Northeastern Bohol after one year of planting. It was found out that Candijay has 73.37% survival rate followed by Bien Unido with 66.76% survival rate, Talibon with 26.8%, and Mabini with 26.42%. Overall, the average survival rate of *Rhizophora* sp. planted in Northeastern Bohol is 48.36%. It was observed that the mangroves planted in the midle and upper intertidal zones have good survival rate compared to those planted in the lower intertidal zones near the river banks.

Table 3 shows the identified sea shells in the rehabilitated mangrove areas in four coastal municipalities in Northeastern Bohol. Reason of identifying the sea shells in the rehabilitated areas was to establish baseline information. It was found out that there are eleven species of sea shells in the municipality of Mabini and Talibon, eight in Bien Unido and seven in Candijay, Bohol. The most dominant and common species in the four municipalities are *Terebralia* sp. (Dao-dao) and *Narita* sp. (Sihi). These species occurs widely in the mangrove system (Crowe, 1997).

Table 3 Sea shells identified in the rehabilitated area in northeastern Bohol

Municipality(s)	Sea shell species	
	Scientific name	**Local name**
Mabini, Bohol	*Terebralia* sp.	Dao-dao
	Apolymetis sp.	Toway
	Narita sp.	Sihi
	Bursidae sp.	Lubot-anay
	Telescopium sp.	Bagongon
	Crassostrea sp.	Tagnipis
	Donas sp.	Punaw
	Anadara sp.	Litob
	Solen sp.	Tudlo dato
	Protothaca sp.	Balisaha
	Perna sp.	Amahong
Bien Unido, Bohol	*Terebralia* sp.	Dao-dao
	Narita sp.	Sihi
	Bursidae sp.	Lubot-anay
	Anadara sp.	Litob
	Protothaca sp.	Balisaha
	Conidae sp.	Liswe
	Pinna sp.	Tab
	Morola sp.	Tandok-tandok
Talibon, Bohol	*Terebralia* sp.	Dao-dao
	Narita sp.	Sihi
	Anadara sp.	Litob
	Protothaca sp.	Balisaha
	Perna sp.	Amahong
	Conidae sp.	Liswe
	Pinna sp.	Tab
	Motorola sp.	Tandok-tandok
	Cuarium sp.	Aninikad
	Turbo sp.	Taktakon
	Unidentified sp.	Wasay-wasay
Candijay, Bohol	*Terebralia* sp.	Dao-dao
	Apolymetis sp.	Toway
	Bursidae sp.	Lubot-anay
	Telescopium sp.	Bagongon
	Crassostrea sp.	Tagnipis
	Morola sp.	Tandok-tandok
	Saccostrea sp.	Sihi

Fig. 2 presents the growth (in height) performance of mangrove planted. Kruskal Wallis Test was used in determining significant difference on the growth of the mangrove planted between sites. Tukey's post hoc test was then used afterwards. It was found out that the average mean of growth in height is 6.097 cm per month and that the growth of the mangrove planted in Mabini differs from Candijay, Bien Unido and Talibon. *Rhizophora* is best suited in the intertidal zone (Feller and Sitnik, 1996).

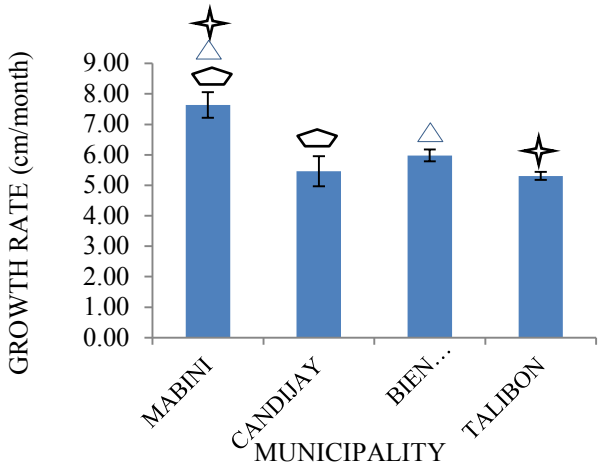


Fig. 2 Growth performance of *Rhizophora* sp. in terms of heights (in cm.)

Fig. 3 presents the problems encountered in planting and management of *Rhizophora* sp. From the data we could see that the barnacles gave greatest problem of the project and to the mangrove planters, followed the fishing inside the rehabilitated areas. Same problem met by the mangrove planters in Thailand who used *Rhizophora mucronata* (Erftemeijer and Lewis, 2000). This problem highly contributed to the low survival rate.

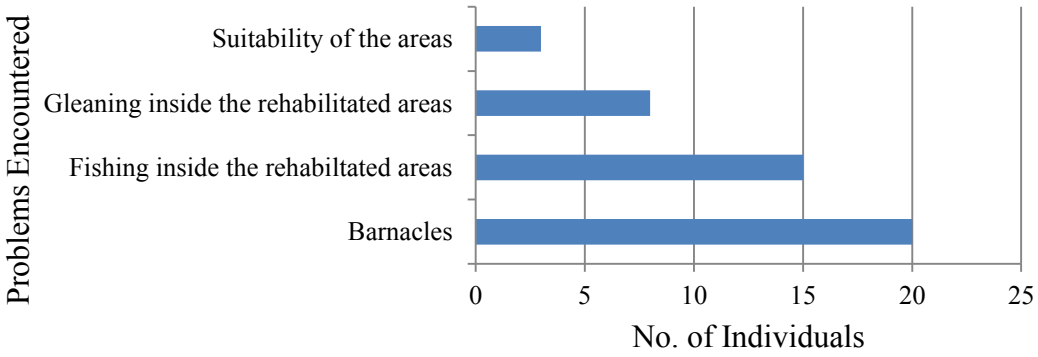


Fig. 3 Problems encountered in planting and management of *Rhizophora* sp. (n=30)

CONCLUSION

It is concluded that *Rhizophora* sp. planted in the middle and upper interterdal zones has higher survival rate compared to the mangrove planted in the lower intertidal zones near the river banks. The occurence was due to the infestation of barnacles in the mangroves planted. In terms of growth rate, the Municipality of Candijay had the highest since the mangrove was planted in the lower intertidal which suites them best. With regards to the sea shells, it was observed that *Terebralia* sp. and *Bursidae* sp. are common in all the rehabilitated areas.

REFERENCES

Crowe, T.P., 1997. The distribution of Terebralia palustris (Linne) with respect to microhabitat in mangrove forests of Darwin Harbour I: Description of patterns. In: Hanley, J.R., Caswell, G., Megirian, D. and Larson, H.K. (Eds.), Proceedings of the Sixth International Marine Biological Workshop. The Marine Flora and Fauna of Darwin Harbour, Northern Territory, Australia. Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association, 435-443.

DENR Statistics. 1995. Environmental and natural resources atlas of the Philippines. Environment Center of the Philippines Foundation. 1998. Manila, Philippines.

Erftemeijer, P.L.A. and Lewis, R.R. 2000. Planting mangroves on intertidal mudflats: Habitat restoration or habitat conversion?. Proceedings of the ECOTONE VIII Seminar Enhancing Coastal Ecosystems Restoration for the 21st Century, Bangkok: Royal Forest Department of Thailand. 156-165.

Feller, I.C. and Sitnik, M. 1996. Mangrove ecology: A manual for a field course. A Field Manual focused on the Biocomplexity on Mangrove Ecosystems. Smithsonian Institution, Washington.

FAO. 1998. Species identification guide for fishery purposes. The Living Marine Resources of the Western Central Pacific. Volume 1 Seaweeds, Corals, Bivalves and Gastropods. Edited by Carpenter, K.E. and Niem, V.H.

Melana D.M., Melana, E.E. and Mapalo, A.M. 2000a. Mangrove management and development in the Philippines. A paper presented during the meeting on "Mangrove and Aquaculture Management" held at Kasetsart University Campus, Bangkok, Thailand on February 14-16, 2000.

Melana D.M., Joseph Atchue III, Yao, C.E., Edwards, R., Melana, E.E. and Gonzales, H.I. 2000b. Mangrove management handbook. Department of Environment and Natural Resources, Manila, Philippines through the Coastal Resource Management Project, Cebu City, Philippines. 96 p.

Research article

The System of Rice Intensification (SRI): Assessment on SRI Farmers' Contribution to the Rice Markets

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Abstract One of the main reasons of food shortage in some areas of Cambodia is low productivity. Conventional farming practice is believed to cause the low yield. The System of Rice Intensification (SRI) proved to increase the yield has been introduced and practiced in Cambodia. Therefore, it is very interesting to research whether SRI farmers are able to share their contributions to the market since SRI can provide higher yields. This study aims to assess whether SRI farmers can contribute their products to the markets that are still immature and inaccessible. A households survey and field observations were conducted in three rain-fed villages in the southern part of Cambodia: two in Kampot Province and one in Kampon Speu Province. Findings revealed that besides the sufficiency of self-consumption, most of selected farmers are able to sell products to the markets and based on the expenditure on agricultural input and income analyses, farmer could earn profits although labor is the highest cost. It was also found that prices set by middlemen in the village are slightly cheaper than the one set on the market. However, farmers agree to sell to middle men because they would spend more on transportation and labor fee if they wanted to sell directly to the market. Importantly, collective sale in a large amount helps farmers to get higher prices compared to an individual sale. Results also indicate that practicing SRI positively increases the household's production and leads to the increase of village production, possibly also to national level production, therefore, the surplus can be contributed to the rice markets.

Keywords system of rice intensification (SRI), conventional practice, rice market, collective sale, farmers' contribution

INTRODUCTION

Cambodia is known as an agrarian country, which heavily depends on its agricultural sector as the core of economic growth. According to records, since 1995 Cambodia produced a rice surplus (Hang Chuon and Suzuki, 2005) and has been able to export paddy to other countries such as Thailand, and Vietnam. However, most of the exporting activities are conducted in informal ways. The middle men or brokers determine the price and demand for products since farmers do not have adequate access to market information (CDRI, 2014). Although Cambodia could produce a rice surplus, it did not refer that all rice producing farmers could make themselves at subsistence level. Farmers are still facing shortage of food resulting from low production. IFAD in Cambodia (n.d.) said that 1.6 million rural households face seasonal food shortages every year and conventional farming practice causes low yields. In 2009 about 110,530 Cambodian farmers with area of 59,785 ha were practicing a new method that can improve their rice yields (Chhay, 2010). This renewed system is called the System of Rice Intensification (SRI). This technique can increase yields up to 15 to 20 t/ha when farmers can apply the methods well and improve the soil (Uphoff, 2004).

OBJECTIVE

It is very interesting to know whether SRI farmers are able to share their contribution to the rice markets since SRI can increase the yields. Therefore, this study aims to assess whether SRI farmers can contribute their products to the markets that are still immature and inaccessible.

METHODOLOGY

The fieldwork was conducted during February and March, 2014 in Kampot and Kampong Speu provinces of Cambodia. Farmers including SRI and Non-SRI Farmers were selected from each village (A1-A3, B1-B3, and C1-C3) for the household interviews. Farmers were selected randomly among other farmers assigned by village chiefs upon the requests of the author.

Field observation and document review: Village resources, farming land and the status of agricultural practices in the village can be noticed in order to create real images for the research. Journals and reports on SRI practices and promotion were also reviewed in order to understand the current SRI practices in Cambodia.

Data analysis: It was done by using both qualitative and quantitative approaches. Data are condensed and critically discussed in order to respond to the above-mentioned objective.

RESULTS AND DISCUSSION

Village Based Information

In village A (Trapaing Russey), six farmers of total household farmers are practicing SRI; while in village B (Khnheay Khang Lech) there are 86 out of 198 and 42 out of 84 households in village C (Mohaleap). Data on land use is not available in village B, even the village chief has still availed any confirmation from the upper level. About 50% and 94% of total area in village A and C, respectively, are used for agricultural activities. Selected farmers got the SRI trainings from same local NGO. Farmers in Village A and B started to practice SRI in 2004 or 2005; while farmers in Village C in 2006.

Table 1 Village based information for 2013

Description	Village A	Village B	Village C
No. of Total Household	181	200	86
No. of Farmer Household	181	198	84
No. of SRI Household	6	86	42
Area (ha)	216.9	-	193.8
Agricultural Area (ha)	132.9	-	145
Available Jobs	Farmers, businessmen, factory and construction workers, NGO staff, etc.	Farmers, businessmen, factory and construction workers, NGO staff, etc.	Workers, farmers, tailors, handmade craft makers, etc.

Based on the field observation, there is a disparity between villages A and B and village C in terms of the location of residential houses. In villages A and B, houses are scattered far from one to another. There is a long distance between one house and another due to innumerable paddy fields in between. Farmers have their own personal small ponds. In village C, also a rain-fed area, residential houses are gathered in one place. Paddy fields are outside the residential areas. With few ponds in the village, rainfall is stored at the reservoir.

Information on Selected Farmers

Majority of selected farmers have more than one farming plots. Therefore, some farmers can grow rice twice per year. It is impossible for a farmer possessing one plot to grow rice twice on the same

plot since water is available only in the rainy season. Normally, the main source of water is rainfall. The average plot size is about one hectare, which included both conventional and SRI practices. The production difference between SRI and conventional practices are shown in Table 2. Majority of SRI farmers are able to increase their yields after practicing SRI although some still get the same amount. It is believed that poor water management might be one of main constraints causing SRI yield having no significant different from the conventional yield. Proper water management is difficult to be conducted in these rain-fed areas where rainfall is unstable and there is no irrigation system. Still, at least SRI can help farmers increase their yields with their own adaptive conditions.

Table 2 Information on selected farmers

Farmer	Area (ha)	Varieties	Practice	Conv. Production (t)	2013 SRI Production (t)	Increased Production by plot in %
A1	(a) 0.70	LRV (Korchor Chab)	Conv.	2.50	-	-
A2	(b) 0.15	LRV (Car51)	SRI	0.32	0.32	0%
	(c) 0.10	LRV (Korhorm)		0.30	0.30	0%
A3	(d) 0.60	LRV (Korchor Chab)	SRI	1.00	1.30	+30%
	(e) 0.48	LRV (Korhorm)		0.60	0.80	+33%
B1	(f) 1.00	LRV (Korhorm)	Conv.	1.30	-	0%
	(g) 1.00	ERV (Jasmine)	SRI	1.00	2.00	+100%
B2	(h) 1.00	ERV (Jasmine)	SRI	0.80	1.00	+25%
B3	(i) 2.00	LRV (Korhorm)		2.00	2.00	-
	(j) 0.06	LRV (Korchor Chab)	SRI	0.10	0.20	+100%
	(k) 0.40	ERV (Jasmine)		-	0.80*	-
C1	(l) 0.88	LRV (Chhmarprum)	SRI	1.50	1.75	+17%
	(m) 1.98	ERV (Jasmine)		2.00	3.00	+50%
C2	(n) 1.00	LRV (Chhmarprum)	SRI	1.20	1.62	+35%
C3	(o) 0.50	LRV (Riangchey)	SRI	0.70	1.00	+43%
	(p) 0.50	ERV (Jasmine)		0.80	1.00	+25%

Source: Ches and Yamaji, 2014
LRV: Late Ripening Varieties; ERV: Early Ripening Varieties; Conv.: Conventional
** No past data available because just started growing ERV in 2013*

Total Expenditure on Rice Growing in 2013

The main items of expenditure include seed, fertilizer, irrigation and hired labor. Seeds, local varieties exchanged among inside or outside villagers, have been stored from previous harvesting. Then, farmers do not spend on seeds. However, farmers spend more on hired labor; followed by chemical fertilizer and irrigation (Table 3). The cost of hired labor varies based on the working condition. The land preparation work costs about 20,000Riel to 30,000Riel and transplanting work costs from 10,000Riel to 15,000Riel per day per person. Harvesting work is paid based on the amount of the harvest. Farmers stated that the costs keep increasing due to less labor in the village. People leave the village for other non-farming jobs. The costs of hired labor can be negotiated. However, some farmers did not spend or spent less on hired labor cost because they could get help from neighbors or worked with their family members. Although water is important, most of the farmers did not spend money on it; they strongly depend on rainfall. The cost of irrigation was the expenditure on fuel for pumping machines. Water was pumped from small streams, reservoirs or from ponds nearby their farms or houses. In case of village C, acquiring water from the reservoir is limited because the same water source is also used for raising animals.

Most of the farmers spent a lot of money on chemical fertilizers to add up on amount of the organic ones. Normally, chemical fertilizers are used during the land and nursery preparation. Some farmers did not spend on them because they used only organic fertilizers; compost which they produced by themselves or some farmers just collected and applied the animal wastes and leaves to the field. However, farmers have tried to reduce or kept the same amount of chemical fertilizers. They understand the adverse impacts of chemical fertilizers on the soil quality and on their health.

Table 3 Total expenditures on rice growing in 2013

Farmer	Plot (ha)	Items (Riel)				Total Expenditure	
		Seed	Chemical Fertilizer	Irrigation	Hired Labor	Riel	USD (Calculation)
A1	(a) 0.70	0	90,000	10,000	438,000	538,000	134.50
A2	(b) 0.15	0	15,800	0	138,000	153,800	38.45
	(c) 0.10	0	19,400	0	138,000	157,400	39.35
A3	(d) 0.60	0	0	0	0	0	0
	(e) 0.48	0	70,000	0	0	70,000	17.50
B1	(f) 1.00	0	155,000	0	0	155,000	38.75
	(g) 1.00	0	0	0	0	0	0
B2	(h) 1.00	0	0	0	50,000	50,000	12.50
B3	(i) 2.00	0	495,000	0	459,000	954,000	238.50
	(j) 0.06	0	0	10,000	88,000	98,000	24.50
	(k) 0.40	0	80,000	0	0	80,000	20.00
C1	(l) 0.88	0	174,000	45,000	257,000	476,000	119.00
	(m) 1.98	0	240,000	45,000	370,000	655,000	163.75
C2	(n) 1.00	0	360,000	0	255,000	615,000	153.75
C3	(o) 0.50	0	10,000	0	75,000	85,000	21.25
	(p) 0.50	0	0	0	75,000	75,000	18.75

Source: Household Interview; 1USD=4,000Riel (basic estimation)

Table 4 Details of paddy price and sold amount

Farmer	Plot (ha)	Varieties	2013 Production (t)	Sold Amount (Kg)	Price (Riel/Kg)	Total Income	
						Riel	USD (Calculation)
A1	(a) 0.70	LRV	2.50		*Self-Consumption*		
A2	(b) 0.15	LRV	0.32	300	1,200	360,000	90.00
	(c) 0.10	LRV	0.30		*Self-Consumption*		
A3	(d) 0.60	LRV	1.30	1000	1,000	1,000,000	250.00
	(e) 0.48	LRV	0.80		*Self-Consumption*		
B1	(f) 1.00	LRV	1.30	1000	1,000	1,000,000	250.00
	(g) 1.00	ERV	2.00	1000	1,350	1,350,000	337.50
B2	(h) 1.00	ERV	1.00	500	1,350	675,000	168.75
B3	(i) 2.00	LRV	2.00	1700	1,000	1,700,000	425.00
	(j) 0.06	LRV	0.20		*Self-Consumption*		
	(k) 0.40	ERV	0.80	800	1,600	1,280,000	320.00
C1	(l) 0.88	LRV	1.75		*Self-Consumption*		
	(m) 1.98	ERV	3.00	2400	1,200	2,880,000	720.00
C2	(n) 1.00	LRV	1.62	1000	930	930,000	232.50
C3	(o) 0.50	LRV	1.00		*Self-Consumption*		
	(p) 0.50	ERV	1.00	1000	1,400	1,400,000	350.00

Incomes and Profits for Each Household

All selected farmers grow Jasmine variety for early growing season due to its popularity. Even farmers possessing single plot are able to sell some to the market such as Farmer B2. Farmers prefer to sell total amount of Jasmine paddy to the markets and keep the LRV paddy for consumption. Middlemen buy paddy directly from the farmers. Price set by middlemen is cheaper than the price set at the markets. However, farmers agree to sell; otherwise, they will spend more on transportation and labor costs if they were to sell directly at the market. Importantly, collective sale (some farmers put their products together in order to get a bigger amount of products) help farmers to get higher prices compared to an individual or one-time sale. Moreover, collective sale helps middlemen to save the time to buy the large amount of paddy. That is why; middlemen can set the higher price for farmers. For example, Jasmine variety (ERV) sells for 1,600R/kg if farmers can collect a big amount and sell. Otherwise, the price is only 1,350Riel to 1,400Riel per kg for single sale. The collective sale could happen due to two possible reasons: (1) the short distance between each household's house or plot where farmers easily gather their products and (2) good

relationship with the neighboring household. According to household interviews, farmers stated that their harvests for a year are enough for their family consumption and were able to sell the surplus to middlemen. This means that farmers could earn some profits from their farming activities. Total expenditure and incomes of each selected farmer are referred to Table 3 and Table 4 respectively. The Fig. 1 clearly illustrates that besides the sufficiency for self-consumption, farmers also could earn the profit by selling their surplus. The negative income as shown in Fig. 1 is the value of the paddy amount for self-consumption.

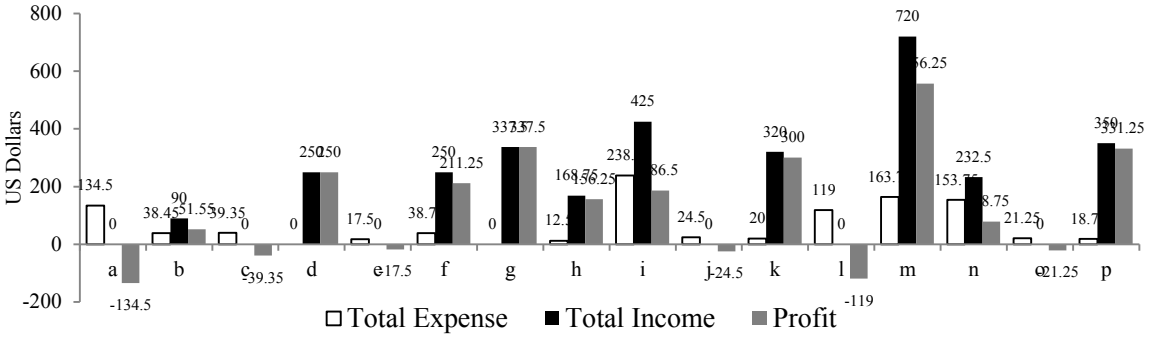

Fig. 1 Expenditure, incomes and profits for each household

Table 5 Surplus produced by SRI farmers in each village

Farmer	Increased Production by Family	Ratio of Increased Production	Average No. of SRI Household	Surplus Produced by SRI Farmers
A1	-			
A2	0%	+22.5%	3%	+0.68%
A3	+31%			
B1	+100%			
B2	+25%	+33.3%	43%	+14.3%
B3	+4.8%			
C1	+36%			
C2	+35%	+35.0%	50%	+17.5%
C3	+33%			

Contribution to the Rice Markets

Increased production in percentage for each family was the average of all plots that each farmer has. The ratio of increased production, derived from the increase of total production of selected families, in village A, B, and C is 22.5%, 33.3% and 35.0% respectively. As shown in Table 2, most of the selected farmers are practicing SRI and it led to increase in their conventional yield. It can be deduced from the study that SRI farmers contributed to increase in production in each village.

With the average number of total SRI household in each village, total surplus produced by SRI farmers in village A, B, and C is 0.68%, 14.3% and 17.5% respectively (Table 5). It can be concluded that practicing SRI positively increases the household's production and leads to the increase of village production as a whole. Thus it can be explained that a village has more production to share to rice markets besides the sufficiency of self-consumption of each household in the village. Finally increase in the number of SRI farmers in each village will increase the village production. Possibly, increase the number of SRI also leads to the increase of national paddy production in Cambodia. Average of SRI yield in Cambodia was recorded as 3.48 t/ha (ranging from 2.7 to 4.2 t/ha) with SRI applied area of 59,785 ha in 2009 (Chhay, 2010). However, according to data from Ministry of Agriculture, Forestry and Fisheries (MAFF) the average national yields were 2.84 and 3.17 t/ha in 2009 and 2011 respectively. With these data, at least within the rice growing area of 59,785 ha, only in 2009 SRI could increase the rice production about 22.5%. Therefore, it can be concluded that increase the number of SRI as well the SRI

applied areas will increase not only the household production but also the country production. This will lead to the increase the paddy supply in the rice markets.

CONCLUSION

As explained and discussed so far, most of the selected farmers can share their products to the rice market although selling and buying processes are happening indirectly via the middlemen. However, collective sales can help farmers to get better prices. Since the national paddy production is still low, increase in the number of SRI farmers as well as SRI applied areas can increase the household and village production as well as possibly lead to the increase of the country production and the surplus can be contributed to the rice market.

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REFERENCES

Chhay, N. 2010. Overview of SRI application and adaptation in Cambodia. Ministry of Agriculture, Forestry and Fisheries. (Retrieved from http://www.slideshare.net/SRI.CORNELL/overview-of-sri-application-and-adoption-in-cambodia, Accesed on 10th April, 2015.)

Ches, S. and Yamaji, E. 2014. Impacts of the system of rice intensification (SRI): Labor requirement analyses in Cambodia. Oral presentation by Power Point File for Paddy and Water Environment Engineering [PAWEES] Conference. 30-31 October, 204 in Kaoshiung, Taiwan.

Cambodia Development Resource Institute [CDRI]. 2014. Annual development review 2013-14. Phnom Penh, Cambodia.

Hang Chuon, C. and Suzuki, N. 2005. Characteristics of the rice marketing system in Cambodia. Faculty of Agriculture, Kyushu University, Japan, 50 (2), 693-714.

International Fund for Agricultural Development [IFAD]. (n.d.). Rural Poverty in Cambodia. (Retrieved from http://www.ruralpovertyportal.org/country/home/tags/cambodia, Accesed on 25th April, 2015.)

Uphoff, N. 2004. System of rice intensification responds to 21st century needs. (Retrieved from http://archieves.dailynews.lk/2004/08/03/bus15.html, Accesed on 27th April, 2015.)

Research article

Evaluation of River Water Quality in Agricultural Watershed with the Environmental Standards

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Abstract Japan has general environmental standards for organic matter in its public water bodies. However, there are no environmental standards for nutrient salts such as phosphorus (P) and nitrogen (N) in river water. In this study, the water quality of rivers at normal water level was evaluated in agricultural watersheds by focusing on water quality standards. The investigated sites are in the Tokachi area (24 watersheds; upland and dairy farming) and the Nemuro area (11 watersheds; large-scale dairy farming), which are in Eastern Hokkaido. The investigations were carried out in the two agricultural areas in 2005, 2006 and 2012. Electrical conductivity (EC) and water temperature were measured at the same time as river water samples were collected in the two areas. Water quality was analyzed for potential of hydrogen (pH), biochemical oxygen demand (BOD), suspended solids (SS), total phosphorus (T-P), total nitrogen (T-N) and other values. Most of the values associated with organic matter, such as pH, BOD and SS, in river water were within the thresholds for the standards of The Environmental Standards Concerning the Conservation of the Living Environment (Rivers). In contrast, some values of nutrient salts (N and P) exceeded the thresholds (T-P≦0.1 mg/L, T-N≦1.0 mg/L). Many of the watersheds in the Tokachi area had T-N concentration in excess of 1.0 mg/L. This suggests that the concentrations of nutrient salts (P and N) increase with increases in agricultural land development in a watershed. For the evaluation of river water quality in agricultural watersheds, it was found to be necessary to measure both organic matter and nutrient salts as indices of water quality. And it was found that controlling the runoff of P and N from agricultural land is essential for water quality conservation in public water bodies.

Keywords organic matter, nutrient salts, agricultural watershed, environmental standard

INTRODUCTION

In countries around the world, the river water quality is seriously worsening. As is well known, agriculture has been pointed out as a cause.

The authors have long been researching the concentration of nitrogen in river water at normal water levels by targeting two areas with different agricultural land use (Yamazaki et al., 2013; Muneoka et al., 2013; Yamazaki et al., 2014; Muneoka et al., 2014). This research has been under way in Eastern Hokkaido, which has precious regional characteristics in the Asian monsoon region,

with consideration of study results pertaining to the concentration of nitrate nitrogen in river water from the study performed by Tabuchi et al. (1995). Based on the accumulation of these basic data, it is expected that study and research will make further progress toward measures for controlling the runoff of nitrogen into rivers in agricultural and forest watersheds.

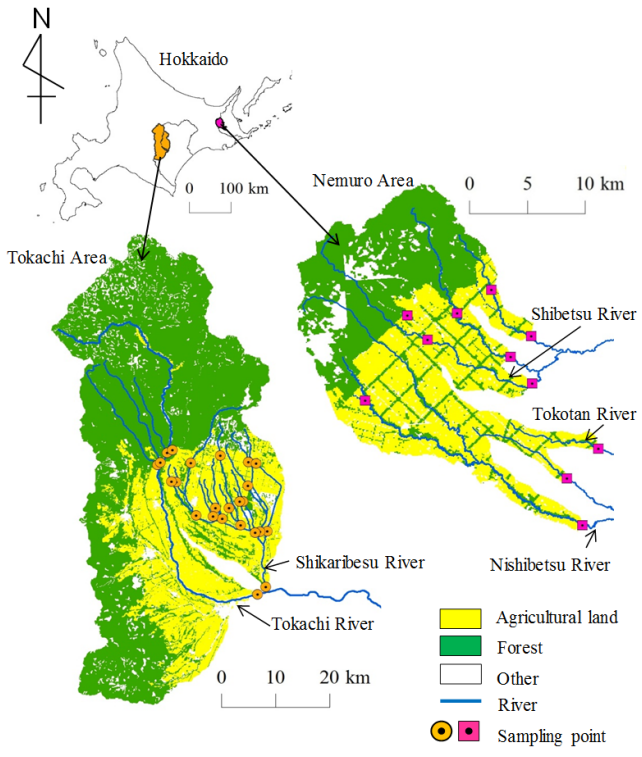
Japan sets general environmental standards for organic matter in its public rivers. However, there are no environmental standards for nutrient salts such as phosphorus (P) and nitrogen (N) in river water. Therefore, while the evaluation of land use in agricultural and forest watersheds that use nitrogen concentration in river water as an index has progressed, there are few cases that use other nutrient salts (e.g., P) as well as organic matter as indices for evaluating the water quality of rivers.

In this report, the present condition of river water quality at normal water levels in Eastern Hokkaido was evaluated within agricultural watersheds, with reference to water quality standards.

METHODOLOGY

General Description about the Studied Watershed and the Study on River Water Quality

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



Sampling Point	River name	Bridge name	Area (km²)	Land use (%)	
				Agricultural land	Forest
Tokachi area					
1	Tokachi	Oojika	632	1	94
2	Penkenai	Pennai	23	0	98
3	Penkenikorbetsu	Penkenikorobetsu	48	2	96
4	Penkenikoro	Minamiiwamatsu	72	2	97
5	Tokachi	Nakajima	1798	21	70
6	Shikaribetsu	Urimaku	217	4	91
7	Sikanosawa	Kikuchi	5	83	13
8	Kamihoronai	Kamihoronai	3	88	12
9	Shikaribetsu	Momiji	256	13	81
10	Minami1sen	Nakashikakann2gou	13	72	17
11	Iketo	Minamisawa	9	95	2
12	Pankebibaushi	Kousui	27	90	7
13	Urimaku	(no bridge)	9	13	66
14	Poronai	(no bridge)	3	90	7
15	Urimaku	Mutsu	49	58	32
16	Penkeutorei	Honnmaki	3	88	11
17	Pankeutorei	(no name)	5	93	6
18	Pankeutorei	Komadome	17	65	25
19	Penkechin	Okuyama	26	22	49
20	Ponchin	Kamimaki	13	75	18
21	Penkechin	Isami	63	46	33
22	Pankechin	Sinnei	10	52	32
23	Pankechin	Taneuma	72	72	15
24	Shikaribetu	Kunimi	667	48	45
Nemuro area					
A	Kanjiushi	Yourouushi	11	4	71
B	Keneka	Minori	41	7	81
C	Keneka	Hakuyou	82	32	57
D	Shibetsu	Nagori	54	3	91
E	Shibetsu	Kamisibetu	82	22	72
F	Masu	Masukawa	10	32	64
G	Masu	Kenebetsu	28	49	46
H	Tokotan	Houtoku	12	81	14
I	Nishibetsu	Kousai	19	10	60
J	Nishibetsu	Nishisyunnbetsu	149	54	32
K	Pononnebetsu	Akashi	19	73	21

Fig. 1 Outline of the Tokachi and Nemuro areas

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

The investigation of the river water quality was conducted at the normal water level at 35 sampling points. Electrical Conductivity (EC) and water temperature were measured at sampling points. And discharge was also measured on the rivers in small watersheds (varied between 22 and 25 by year). Items analyzed to determine water quality varied with each year. This study used potential of hydrogen (pH), biochemical oxygen demand (BOD), suspended solids (SS), total phosphorus (T-P) and total nitrogen (T-N) and other values as indices of water quality. The investigations were carried out during late August to early September in 2005, 2006 and 2012.

Environmental Standards for River Water in Japan

Water quality in Japan is regulated by the Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Rivers), which uses organic matter as indices (Table 1). The standard values are divided into 6 stages (Type-AA to Type-E) according to the suitable use of the water, with each acceptable range specified as follows: pH (always between 6.5 and 8.5), BOD (between 1 mg/L and 10 mg/L) and SS (between 25 mg/L and 100 mg/L).

Table 1 The Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Rivers (Extract))

	Standard values		
Type	pH	BOD	SS
AA	between 6.5 and 8.5	1 mg/L or lower	25 mg/L or lower
A	between 6.5 and 8.5	2 mg/L or lower	25 mg/L or lower
B	between 6.5 and 8.5	3 mg/L or lower	25 mg/L or lower
C	between 6.5 and 8.5	5 mg/L or lower	50 mg/L or lower
D	between 6.5 and 8.5	8 mg/L or lower	100 mg/L or lower
E	between 6.5 and 8.5	10 mg/L or lower	※

※ No floating matter on the surface of the water

Table 2 Some water quality standards on the nutrient salts (N and P)

(a) The Environmental Quality Standards
Concerning the Protection of the Human Health (Extract)

Combined concentration of NO_3-N and NO_2-N	10 mg/L or lower

(b) The Environmental Quality Standards
Concerning the Coservation of the Living Environment

		Standard values	
	Type	T-N	T-P
Lakes	I	0.1 mg/L or lower	0.005 mg/L or lower
(Appendix 2)	II	0.2 mg/L or lower	0.01 mg/L or lower
	III	0.4 mg/L or lower	0.03 mg/L or lower
	IV	0.6 mg/L or lower	0.05 mg/L or lower
	V	1.0 mg/L or lower	0.10 mg/L or lower
Seas	I	0.2 mg/L or lower	0.02 mg/L or lower
(Appendix 2)	II	0.3 mg/L or lower	0.03 mg/L or lower
	III	0.6 mg/L or lower	0.05 mg/L or lower
	IV	1.0 mg/L or lower	0.09 mg/L or lower

In Japan, there are two major water quality standards that use nitrogen, and nutrient salts, as indices. The Environmental Quality Standards Concerning the Protection of Human Health specifies the highest acceptable combined concentration of nitrate nitrogen (NO_3-N) and nitrite nitrogen (NO_2-N) as 10 mg/L (Table 2(a)).

As shown in Type-V in Table 2(b) of Appendix 2 of the Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Lakes) and Type-IV in Table 2(b) of Appendix 2 of the Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Seas), acceptable concentration of total nitrogen (T-N) is regulated at 1 mg/L or lower.

Further, in Type-V in Table 2(b) of Appendix 2 of Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Lakes), which is the water quality standard that uses phosphorus as an index, the acceptable concentration of total phosphoru s (T-P) is regulated at 0.1 mg/L or lower, and in Type-IV in Table 2(b) of Appendix 2 of said standards (Seas), the acceptable concentration of total phosphorus (T-P) is regulated at 0.09 mg/L or lower.

However, there are no environmental standards for nutrient salts in river water of public water bodies. In this report, by referring to the water quality standards mentioned above, "threshold levels" that use nutrient salts (N and P) as indices were established by specifying T-P as 0.1 mg/L or lower and T-N as 1.0 mg/L or lower to evaluate water quality.

RESULTS AND DISCUSSION

Evaluation of Water Quality using Organic Matter as an Index

In Table 3, the pH of river water was within the range of 7.1 to 8.0 for the Tokachi area and 7.3 to 7.7 for the Nemuro area, both of which satisfied the standard values in Type-AA (betwee 6.5 and 8.5). BOD was within the range of <0.5 to 3.1 mg/L in the Tokachi area, which exceeded the standard values of Type-B (3 mg/L or lower) at only 1 spot. BOD was within the range of <0.5 to 1.2 mg/L in the Nemuro area, which satisfied the standard values of Type-A (2 mg/L or lower). SS was within the range of <1 to 39 mg/L in the Tokachi area, and <1 to 13 mg/L in the Nemuro area, which exceeded the standard values of Type-AA to B (25 mg/L or lower) at only 1 spot.

Therefore, the indices of organic matter for river water at normal water levels in agricultural watersheds in Eastern Hokkaido were mostly within the standard values in every year when the study was carried out, regardless of differences in size of watershed area or the area of upland and pasture as a share of the watershed.

Evaluation of Water Quality using Nutrient Salts as Indices

The T-P concentration in river water was within the range of 0.024 to 0.39 mg/L in the Tokachi area, which exceeded the threshold level at 9 spots, and 0.060 to 0.23 mg/L in the Nemuro area, which exceeded the threshold level at 5 spots (Table 4).

Next, T-N concentration was within the range of 0.25 to 10 mg/L in the Tokachi area, which exceeded the threshold level at 17 spots. In the Nemuro area, it was within the range of 0.19 to 3.2 mg/L, which exceeded the threshold level at 6 points (Table 4).

Therefore, the spots where the values exceeded the "threshold level" of nutritional salts saw a relatively high share of upland field and pasture in watersheds (22 to 95%), and runoff had high concentrations of T-N.

The authors consider that it is necessary to measure both organic matter and nutrient salts as indices to evaluate river water quality in agricultural watersheds. In addition, it was found that controlling the runoff of P and N from agricultural land is essential for water quality conservation in public water bodies. To accomplish these, systematic watershed management is required that gives consideration to both agricultural land use and farming.

Table 3 Water quality using organic matter as an index (2005, 2006 and 2012)

Investigate area (Sampling spots)	Measuring values		
	pH	BOD (mg/L)	SS (mg/L)
Tokachi Area (24 spots)	7.1 ～ 8.0	<0.5 ～ 3.1※	<1 ～ 39※
Nemuro Area (11 spots)	7.3 ～ 7.7	<0.5 ～ 1.2	<1 ～ 13

※ exceeded the standard value of Type-B at only 1 spot

Table 4 Water quality using nutrient salts an index (2005, 2006 and 2012)

Investigate area (Sampling spots)	Measuring values	
	T-P (mg/L)	T-N (mg/L)
Tokachi Area (24 spots)	0.024 ～ 0.39※ (9 spots)	0.15 ～10※ (17 spots)
Nemuro Area (11 spots)	0.060 ～ 0.23※ (5 spots)	0.19 ～ 3.0※ (6 spots)

※ the number which exceeded the threshold level
(T-P >0.10mg/L; T-N >1.0mg/L)

CONCLUSION

Evaluations of river water quality using the environmental standards in Japan show that organic matter at normal water levels in agricultural regions in Eastern Hokkaido are within the standard values. In contrast, it was confirmed that nutrient salts constantly run off at high concentrations. In order to consider measures for controlling the runoff of nutrient salts (especially nitrogen) with both sustainable agriculture and environment conservation in mind, constructing comprehensive watershed management is an urgent issue. In the future, we would like to contribute to measures for the evaluation of land and water conservation in wide water catchment areas with Asian monsoon climate by applying the environmental standards in Japan for the evaluation of river water quality in other agricultural regions.

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REFERENCES

Muneoka, T., Yamazaki, Y., Wakou, S., Shimura, M., Yoshino, K., Tsuji, O. and Tabuchi, T. 2013. The nitrogen runoff characteristics in agricultural watersheds after enforcement of animal waste regulation. IJERD, 4 (2), 56-61.

Muneoka, T., Yamazaki, Y., Wakou, S., Kimura, M. and Tsuji, O. 2014. Evaluation of Nitrate Pollution in River Water at Agricultural Watershed. IJERD, 5 (2), 51-55.

Tabuchi, T., Yoshino, K., Shimura, M., Kuroda, S., Ishikawa, M. and Yamaji, E. 1995. Relation between land use and nitrate concentration of outflow water from watersheds of agricultural and forest area, Japan. Trans. of JSIDRE, 178, 129-135 (in Japanese with English abstract).

Yamazaki, Y., Muneoka, T., Wakou, S., Shimura, M., Yoshino, K., Tsuji, O. and Tabuchi, T. 2013. The difference of agricultural land use in watersheds and long term fluctuation on the river water quality. IJERD, 4 (1),152-157.

Yamazaki, Y., Muneoka, T., Wakou, S., Kimura, M. and Tsuji, O. 2014. Evaluation of the ion components for the estimation of total nitrogen concentration in river water based on electrical conductivity. IJERD, 5 (1), 160-164.

Research article

Characteristics of Ion Components in River Water with Multivaraite Analysis and Piper Diagram in Agricultural Area

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Abstract The Tokachi and Nemuro areas are large-scale agricultural land, and are located in Eastern Hokkaido. Increases in nitrogen concentrations in the river water caused by the outflow of excess nitrogen from an agricultural land in the Tokachi and Nemuro area have been reported. Here we considered the characteristics of the origin of river water quality with multivariate analysis and piper diagram in the Tokachi and Nemuro areas with different agricultural land use. The main agricultural land uses in the Tokachi area are upland and dairy farming. It is an area mainly of dairy farming in the Nemuro area. The investigation was carried out in late August 2005. We analyzed the following ion parameters: Cl^-, NO_3^-, NO_2^-, SO_4^{2-}, HCO_3^-, CO_3^-, PO_4^{3-}, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+} by liquid chromatography. NO_3^- and SO_4^{2-} were higher in the Tokachi area; the values of NO_3^- and SO_4^{2-} were 0.71-31 mg/L and 1.9-39 mg/L in the Tokachi area and 0.44-9.7 mg/L and 2.0-19 mg/L respectively. On the other hand, HCO_3^- and Na^+ were higher in the Nemuro area; 6.4-31 mg/L and 3.3-9.9 mg/L in the Tokachi area and 13- 42 mg/L and 5.8-15 mg/L in the Nemuro area respectively. The plot in piper diagram showed that most of the river water samples in the Tokachi area fall in the field of mixed Ca-Mg-Cl type of water. Some samples are also representing Ca-Cl and Ca-HCO_3 types. The most of the samples in the Nemuro area fall in the field of Ca-HCO_3 types, and some samples also representing Na-Cl types. This result suggests that the outflow of excess nitrogen from the agricultural land affected river water quality in the Tokachi area while the mixing of seawater and geological component affected river water quality in the Nemuro area.

Keywords agricultural area, river water quality, ion components, multivariate analysis, piper diagram

INTRODUCTION

Large-scale agriculture is practised under harsh climatic conditions in Eastern Hokkaido, Japan, and nitrate pollution of river water and ground water in this region has been reported (Tabuchi et al., 1995; Matsumoto and Tou, 2006). Studies on several watersheds have shown that nitrogen concentrations in the river water are strongly correlated with the proportion of upland areas

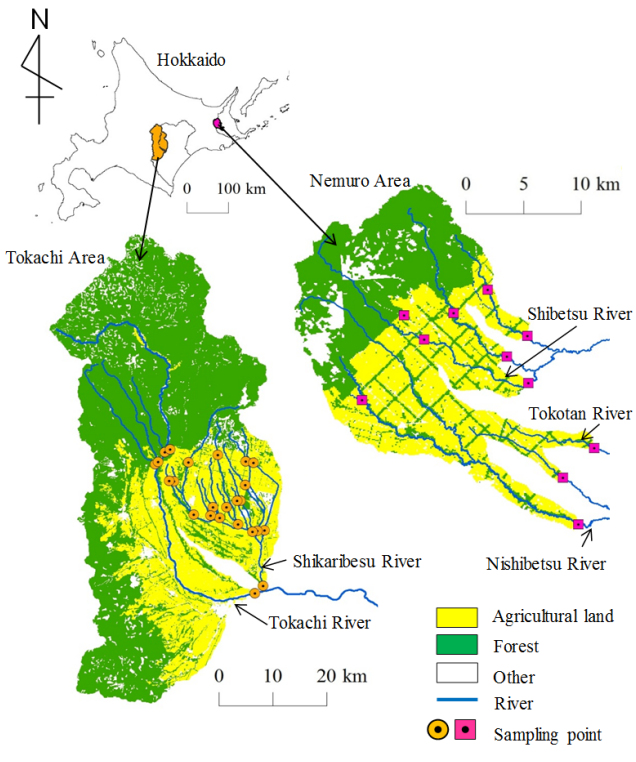
(Tabuchi et al. 1995; Nagumo and Hatano 2000; Woli et al. 2004).

We had previously investigated the long-term river water quality in the Tokachi and Nemuro areas, where the agricultural land use is mutually different (Yamazaki et al., 2013, 2014; Muneoka et al., 2013). It was shown that the nitrate-nitrogen concentration in the river water was higher in the Tokachi area and the electrical conductivity was higher in the Nemuro area, when the proportion of agricultural land was in the same range in each sampling point (Yamazaki et al., 2013). It was inferred that, apart from the nutrients run off from agricultural land, regional differences was the reason for such differences. The percentages of ionic components were also different in the Tokachi and Nemuro area (Yamazaki et al., 2014). It is necessary to elucidate not only the water quality but also the origin of the river water to reduce water pollution in the agricultural area.

In this study, we examined the characteristics of river water quality by multivariate analysis and piper diagram to analyse in detail the differences in ionic components within the river water in the Tokachi and Nemuro areas.

METHODOLOGY

The study sites are outlined in Fig. 1. The Tokachi area, which consists of a total of 24 watersheds in the Tokachi river system and in the Shikaribetsu river system (No. *1* to *24*), is in the north-western part within the jurisdiction of Tokachi General Sub-prefectural Bureau. It is an area of upland and dairy farming. The Nemuro area, which consists of a total of 11 watersheds in the Shibetsu, the Tokotan, and the Nishibetsu river systems (*A* to *K*), is located in the western part within the jurisdiction of Nemuro Sub-prefectural Bureau. It is mainly an area of dairy farming. In both these areas, large-scale farming has been pursued, and there have been no substantial changes in agricultural land use in either area since 1985.



Sampling Point	River name	Bridge name	Area (km²)	Land use (%) Agricultural land	Forest
Tokachi area					
1	Tokachi	Oojika	632	1	94
2	Penkenai	Pennai	23	0	98
3	Penkenikorbetsu	Penkenikorobetsu	48	2	96
4	Penkenikoro	Minamiiwamatsu	72	2	97
5	Tokachi	Nakajima	1798	21	70
6	Shikaribetsu	Urimaku	217	4	91
7	Sikanosawa	Kikuchi	5	83	13
8	Kamihoronai	Kamihoronai	3	88	12
9	Shikaribetsu	Momiji	256	13	81
10	Minami1sen	Nakashikakann2gou	13	72	17
11	Iketo	Minamisawa	9	95	2
12	Pankebibaushi	Kousui	27	90	7
13	Urimaku	(no bridge)	9	13	66
14	Poronai	(no bridge)	3	90	7
15	Urimaku	Mutsu	49	58	32
16	Penkeutorei	Honnmaki	3	88	11
17	Pankeutorei	(no name)	5	93	6
18	Pankeutorei	Komadome	17	65	25
19	Penkechin	Okuyama	26	22	49
20	Ponchin	Kamimaki	13	75	18
21	Penkechin	Isami	63	46	33
22	Pankechin	Sinnei	10	52	32
23	Pankechin	Taneuma	72	72	15
24	Shikaribetu	Kunimi	667	48	45
Nemuro area					
A	Kanjiushi	Yourouushi	11	4	71
B	Keneka	Minori	41	7	81
C	Keneka	Hakuyou	82	32	57
D	Shibetsu	Nagori	54	3	91
E	Shibetsu	Kamisibetu	82	22	72
F	Masu	Masukawa	10	32	64
G	Masu	Kenebetsu	28	49	46
H	Tokotan	Houtoku	12	81	14
I	Nishibetsu	Kousai	19	10	60
J	Nishibetsu	Nishisyunnbetsu	149	54	32
K	Pononnebetsu	Akashi	19	73	21

Fig. 1 Outline of the Tokachi and Nemuro areas

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

The investigation of the river water quality was conducted at the normal water level at 35 sampling points. The investigations were carried out in late August 2005. We analysed the concentrations of following ions as parameters: Cl^-, NO_3^-, NO_2^-, SO_4^{2-}, HCO_3^-, CO_3^-, PO_4^{3-}, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+} by liquid chromatography.

We used the cluster analysis and the piper diagram to classify the trend of ionic components in the river water. A cluster analysis is a group of multivariate techniques. It is often used to analyse water quality characteristics. We used the R package and Ward's method for cluster analysis. A piper diagram is a method for water quality classification by graphical representation. It is used for an observation of ground water and river water quality. A piper diagram shows the characteristics of water by the location of the plot in the key diagram from the proportion of equivalent concentration of cations and anions. In this study, we used the Cl^-, NO_3^-, SO_4^{2-}, HCO_3^-, Na^+, K^+, Ca^{2+} and Mg^{2+} for the piper diagram. The results are classified into five types: Cl-SO_4-NO_3 type, Ca-HCO_3 type, Na-HCO_3 type, Na-Cl type, and mixed type.

RESULTS AND DISCUSSION

Ion Concentrations in the Tokachi and Nemuro Areas

Table 1 shows the concentration of ionic components in the Tokachi and Nemuro areas. Ca_2^+ and HCO_3^- were the main ionic components in both areas. However, the trend of ionic components differed between the two areas. The concentrations of NO_3^- and SO_4^{2-} were 0.71–31 mg/L and 1.9–39 mg/L, respectively, in the Tokachi area and 0.44–9.7 mg/L and 2.0–19 mg/L, respectively, in the Nemuro area. The average concentrations of these components were found to be higher in the Tokachi area. On the other hand, concentrations of HCO_3^- and Na^+ were 6.4–31 mg/L and 3.3–9.9 mg/L, respectively, in the Tokachi area and 13.5–42.1 mg/L and 5.8–15 mg/L, respectively, in the Nemuro area. The average concentrations of these components were found to be higher in the Nemuro area.

Cluster Analysis

Cluster analysis was conducted to classify the tendency of ionic components in the river water. Figure 2 shows the results of cluster analysis for each sampling point in the Tokachi area (nos. *1–24*) and the Nemuro area (*A–K*) in a dendrogram. NH_4^+, NO_2^- and PO_4^{2-} were excluded from the cluster analysis because their values were too small. The dendrogram shows four major clusters. The sampling points in the Tokachi area were classified into clusters 1, 3 and 4. The sampling points in the Nemuro area were classified into clusters 1 and 2. The cluster 1 and 2 tended to include the sampling points that had high concentration of cationic components and the proportion of agricultural land use was less than 50%. Meanwhile, the cluster 3 and 4 tended to include the sampling points that had high concentration of anionic components and the proportion of agricultural land use was more than 50%. The river water quality was different between both areas except few sampling points from the cluster analysis. We verified the difference of the river water quality in the Tokachi and Nemuro areas by the piper diagram.

Piper Diagram

Figure 2 (a, b) shows the piper diagram of the ionic components in the two areas. The piper diagram was classified by the cluster 1–4 (a) and the proportion of agricultural land (b). Many sampling points in the Tokachi area belonged to the mixed type. In addition, the cluster 4 belonged to the Na-SO_4-NO_3 type, and it was confirmed that the proportion of (SO_4 + NO_3) and (Ca_2 + Mg)

increased due to the agricultural activities in the cluster 4. In the Nemuro area, many sampling points belonged to the mixed type and to the Ca-HCO_3 type. Only *D* in cluster 2 belonged to the Na-Cl type, because of the commingling of the sea water or hot spring water into the ground water. Furthermore, as shown in Fig 2(b), which shows if the proportion of agricultural land use was less than or more than 50%, the sampling points in the Tokachi area, which had high proportion of the agricultural land, were located at upper part of the key diagram. On the other hand, it was not confirmed whether the clear difference of ionic components in the Nemuro area was due to the small or large proportion of agricultural land. From these results, the river water quality was found to be very different in the Tokachi and Nemuro areas. In addition, the ionic components of the river water in the Tokachi area were influenced by agriculture, whereas the ones in the Nemuro area were influenced by other geological features.

Table 1 Ion concentrations in the Tokachi and Nemuro areas

Sampling point	Ion concentration (mg/L)											
	Na^+	K^+	NH_4^+	Ca^{2+}	Mg^{2+}	Cl^-	NO_3^-	NO_2^-	HCO_3^-	SO_4^{2-}	PO_4^{3-}	Total
Tokachi area												
1	5.5	1.3	0.018	6.9	1.5	3.3	0.71	< 0.05	13.5	9.2	<0.001	41.9
2	3.3	1.4	< 0.01	3.3	0.9	1.6	0.75	< 0.05	9.3	4.0	<0.001	24.6
3	3.8	1.9	< 0.01	3.1	0.8	1.7	0.84	< 0.05	9.6	3.4	<0.001	25.2
4	3.7	1.7	< 0.01	3.2	0.9	1.8	0.89	< 0.05	6.4	3.2	<0.001	21.8
5	5.0	1.6	0.039	6.5	1.6	3.9	2.5	< 0.05	12.9	8.0	<0.001	42.0
6	8.7	1.6	< 0.01	7.6	1.8	6.1	2.1	< 0.05	29.2	7.0	<0.001	64.1
7	5.4	2.8	< 0.01	9.1	2.9	5.2	15.0	< 0.05	13.0	6.8	0.01	60.2
8	5.4	3.7	< 0.01	9.6	3.1	5.5	15.0	< 0.05	15.5	6.5	0.005	64.3
9	7.5	2.3	< 0.01	8.1	2.0	5.1	3.9	< 0.05	17.6	6.7	0.003	53.2
10	9.9	3.6	< 0.01	28.0	8.7	8.0	27.0	0.095	31.1	39.0	0.10	155.5
11	9.1	5.8	< 0.01	18.0	6.0	9.1	20.0	< 0.05	25.9	18.0	0.25	112.2
12	8.5	4.9	< 0.01	17.0	5.3	7.9	19.0	< 0.05	22.4	18.0	0.18	103.2
13	3.7	1.5	< 0.01	5.7	1.2	1.5	1.1	< 0.05	14.3	2.0	0.08	31.1
14	8.2	2.4	< 0.01	20.0	6.5	6.6	30.0	< 0.05	13.4	36.0	0.05	123.2
15	6.6	2.7	< 0.01	13.0	3.7	5.0	12.0	< 0.05	19.5	10.0	0.18	72.7
16	9.4	3.6	< 0.01	21.0	7.3	12.0	22.0	0.099	17.7	35.0	0.01	128.1
17	8.7	3.8	< 0.01	24.0	7.0	9.7	31.0	0.079	21.2	30.0	0.12	135.6
18	7.0	4.1	< 0.01	15.0	4.8	6.7	13.0	< 0.05	16.4	23.0	0.07	90.1
19	3.8	1.7	0.003	6.5	1.2	1.3	0.66	< 0.05	15.7	1.9	0.06	32.8
20	5.8	2.1	< 0.01	13.0	3.0	4.1	12.0	< 0.05	17.4	10.0	0.03	67.4
21	5.1	2.2	< 0.01	11.0	3.0	3.5	6.6	< 0.05	18.9	8.1	0.02	58.4
22	6.3	3.6	< 0.01	22.0	4.1	5.8	15.0	< 0.05	31.1	11.0	0.07	99.0
23	8.6	4.1	< 0.01	27.0	8.7	7.0	16.0	< 0.05	30.8	36.0	0.10	138.3
24	8.4	3.6	< 0.01	16.0	4.6	6.8	11.0	< 0.05	22.1	17.0	0.02	89.5
Average	6.6	2.8	0.020	13.1	3.8	5.4	11.6	0.091	18.5	14.6	0.08	76.4
Nemuro area												
A	5.8	0.6	< 0.01	4.3	1.3	2.3	0.44	< 0.05	13.5	2.0	0.05	30.3
B	7.1	0.9	< 0.01	5.4	1.3	3.4	1.0	< 0.05	15.3	2.5	0.11	37.0
C	8.9	1.7	< 0.01	11.0	2.5	5.6	4.2	< 0.05	23.8	3.6	0.09	61.4
D	13.0	0.9	< 0.01	6.6	1.3	9.6	< 0.05	< 0.05	12.6	11.0	0.07	55.1
E	13.0	1.2	< 0.01	9.3	2.1	8.6	1.8	< 0.05	17.9	8.8	0.04	62.7
F	8.6	1.3	< 0.01	6.1	1.9	3.7	2.2	< 0.05	17.5	2.5	0.11	43.9
G	9.9	2.2	< 0.01	13.0	3.5	6.4	5.3	< 0.05	28.2	2.4	0.08	71.0
H	12.0	2.4	< 0.01	23.0	6.0	11.0	9.7	< 0.05	42.1	5.4	0.03	111.6
I	15.0	1.6	< 0.01	9.9	3.1	5.7	0.58	< 0.05	20.5	19.0	0.22	75.6
J	13.0	1.9	< 0.01	13.0	3.3	6.6	3.7	< 0.05	24.7	13.0	0.19	79.4
K	12.0	3.6	< 0.01	20.0	4.7	11.0	8.9	< 0.05	34.0	6.3	0.08	100.6
Average	10.8	1.7	< 0.01	11.1	2.8	6.7	3.8	< 0.05	22.7	7.0	0.10	66.2

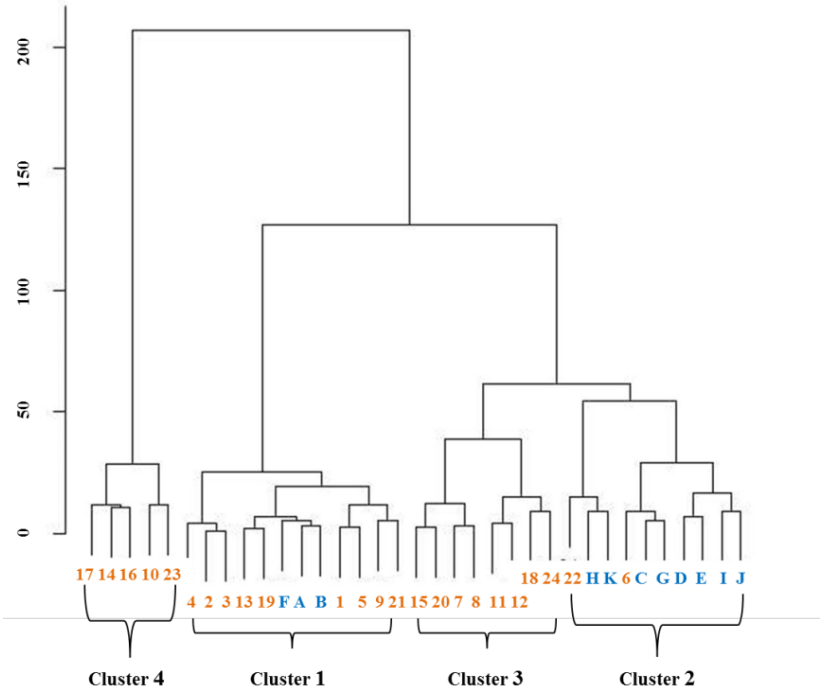


Fig. 2 Dendrogram from cluster analysis

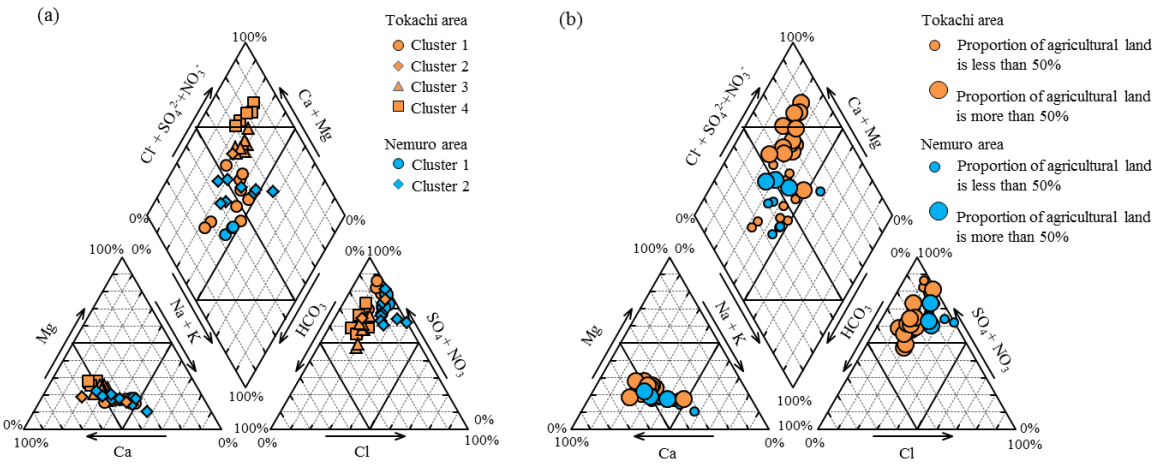


Fig. 3 Piper diagram of the ionic components in the Tokachi and Nemuro areas

Correlation Matrix of Ion Concentrations

Table 2 shows the correlation matrix of ion concentrations within the Tokachi and Nemuro areas. NO_3^- and SO_4^{2-} showed a strong correlation in the Tokachi area. It was recognized that the NO_3^- and SO_4^{2-} in the river water was derived from chemical fertilizer because an ammonium sulfate was mainly used for a nitrogen fertilizer in the Tokachi area. In the Nemuro area, Na^+ had a strong correlation with SO_4^{2-}. There is a hot spring in the upper part of the Nemuro area. The spring quality is sodium-sulfate spring. It was inferred that the proportion of Na^+ in the river water was increased due to the hot spring water mixed into the ground water. Especially, *D*, *E*, and *I* in the Nemuro area which was classified into cluster 2 (Fig. 2) and belonged to near Na-Cl type in the piper diagram (Fig. 3), showed high proportion of (SO_4+Na). Ca^{2+} and Mg^{2+} had a strong correlation with NO_3^- within the two areas, it was considered that these ionic components eluted easily due to use of fertilizer and soil acidification in the agricultural area.

Table 2 Correlation matrix of ion concentrations in the Tokachi and Nemuro areas

	Tokachi area								Nemuro area							
	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	NO_3^-
Na^+	1.00								1.00							
K^+	0.68	1.00							0.37	1.00						
Ca^{2+}	0.81	0.72	1.00						0.43	0.89	1.00					
Mg^{2+}	0.84	0.75	0.96	1.00					0.43	0.86	0.98	1.00				
Cl^-	0.91	0.77	0.80	0.85	1.00				0.69	0.64	0.76	0.67	1.00			
SO_4^{2-}	0.80	0.57	0.89	0.95	0.79	1.00			0.86	0.04	0.07	0.11	0.29	1.00		
HCO_3^-	0.73	0.57	0.74	0.64	0.58	0.48	1.00		0.29	0.86	0.98	0.98	0.63	-0.06	1.00	
NO_3^-	0.74	0.70	0.87	0.89	0.82	0.84	0.45	1.00	0.16	0.89	0.95	0.92	0.63	-0.23	0.97	1.00

CONCLUSION

Based on our results, the proportion of (SO_4 + NO_3) and (Ca + Mg) increased due to chemical fertilizer in the Tokachi area. In contrast, many sampling points in the Nemuro area belonged to the Ca-HCO_3 type and to the mixed type, and it was not confirmed whether the difference in ionic components was due to a small or large proportion of agricultural land. Our results revealed that the river water quality in the Tokachi area was affected by the agricultural activity, whereas the river water quality in the Nemuro area reflected the impact not only of agricultural activity but also of other geological features and regional nature.

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REFERENCES

Matsumoto, T. and Tou, S. 2006. Risk assessment of nitrate pollution in groundwater based on the environmental nitrogen-assimilation capacity of agricultural lands in Hokkaido. Jpn. J. Soil Sci. Plant Nutr, 77, 17-24 (in Japanese with English abstract).

Muneoka, T., Yamazaki, Y., Wakou, S,. Shimura, M., Yoshino, K., Tsuji, O. and Tabuchi, T. 2013. The nitrogen runoff characteristics in agricultural watersheds after enforcement of animal waste regulation. IJERD, 4 (2), 56-61.

Nagumo T and Hatano, R. 2000. Impact of nitrogen cycling associated with production and consumption of food on nitrogen pollution of stream water. Soil Sci Plant Nutr, 46 (2), 325-342

Tabuchi, T., Yoshino, K., Shimura, M., Kuroda, S., Ishikawa, M. and Yamaji, E. 1995. Relation between land use and nitrate concentration of outflow water from watersheds of agricultural and forest area, Japan. Trans. of JSIDRE, 178, 129-135 (in Japanese with English abstract).

Woli KP, Nagumo T, Kuramochi K and Hatano R. 2004. Evaluating river water quality through land use analysis and N budget approaches in livestock farming areas. Sci Total Environ, 329 (1-3), 61-74

Yamazaki, Y., Muneoka, T., Wakou, S., Shimura, M., Yoshino, K., Tsuji, O. and Tabuchi, T. 2013. The difference of agricultural land use in watersheds and long term fluctuation on the river water quality. IJERD, 4 (1),152-157.

Yamazaki, Y., Muneoka, T., Wakou, S,. Kimura, M., and Tsuji, O. 2014. Characteristics of ion components in river water with multivariate analysis and piper diagram in agricultural area. IJERD, 5 (1), 160-164.

Research article

Mitigating Splash Erosion with Applying *Bacillus subtilis* Natto

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Abstract Soil erosion from upland fields affects not only soil productivity but also water environment. From the viewpoints of soil and water conservation, many strategies for mitigation of soil erosion were discussed. Especially, conservation strategy for mitigating splash erosion which is the first process of soil erosion should be considered. Moreover, biological crust mixing with microorganisms has been focused as one of the treatments for splash erosion. Therefore, two objectives were determined in this study. The first is to evaluate the effect of *Bacillus subtilis* Natto adding on mitigating splash erosion, and the second is to investigate the kinetic energy of raindrop to break the binding force of soil particles with hyphae of *Bacillus subtilis* Natto. Raindrop experiment was carried out with stainless cans and Mariotte bottle of splash erosion apparatus. Stainless cans were filled with soil, and then *Bacillus subtilis* Natto was applied. In addition, raindrop energy was changed through controlling the height of Mariotte bottle. Based on the experimental results, there was a tendency that soil loss from the cans applied *Bacillus subtilis* Natto was significantly lower than controlled cans. In addition, it was observed that *Bacillus subtilis* Natto mitigated splash erosion until kinetic energy of raindrop at 4.86×10^{-5} J/drop. Therefore, it was concluded that *Bacillus subtilis* Natto is applicable for mitigation of splash erosion.

Keywords splash erosion, *Bacillus subtilis* Natto, biological crust

INTRODUCTION

Large amounts of soils were released from upland fields by rainfall and surface runoff. Soil erosion is a cause of decreasing soil productivity. Moreover, soil erosion causes water pollution such as eutrophication in watersheds. Therefore, some conservation strategies for soil erosion such as buffer strips installation (Kawai et al., 2007; Gopal and Mihara, 2008; Siriwattananon et al., 2009, Torillo and Mihara, 2011, 2014) have been discussed.

On the other hand, conservation strategies for mitigating splash erosion which is the first process of soil erosion should been considered. In this connection, making soil crust has been considered as a proper treatment for mitigating splash erosion. Soil crust formation was affected by microorganism activity, root growing, soil animal activity or mineral interaction (Six et al., 2002). Therefore, microorganism growing is important for mitigating soil loss. There was a report by Shimomura et al. (2007) that growing microorganisms in soil is able to reduce soil loss. However, it was not discussed about specific species of microorganism for mitigate raindrop erosion.

So, this study focused on *Bacillus subtilis* Natto which is a kind of Gram-positive bacteria. *Bacillus subtilis* Natto can make spore which has tolerance for acid, ultraviolet or heat (Hosoi, 2003). In addition, *Bacillus subtilis* Natto creates hyphae which contain viscous material as γ-poly-glutamic acid (Hara, 1990).

In this study, two objectives were determined. One is to evaluate the effect of *Bacillus subtilis* Natto adding on mitigating splash erosion and the other is to investigate the kinetic energy of raindrop to break the binding force of soil particles with hyphae of *Bacillus subtilis* Natto.

METHODOLOGY

In this study two experiments were conducted, the evaluation of *Bacillus subtilis* Natto addition on mitigating splash erosion, and the investigation of the kinetic energy of raindrop to break the binding force of soil particles with hyphae of *Bacillus subtilis* Natto.

Evaluation of *Bacillus subtilis* Natto Addition on Mitigating Splash Erosion

Bacillus subtilis Natto used in this experiment was laboratory made (Fig. 1). It consists of a dry powder which contained 1.08×10^7 colonies formed units per gram (cfu/g) of *Bacillus subtilis* Natto.

Soil properties are shown in Table 1. Stainless cans of 1.1 cm diameter and 1.0 cm deep were filled up with Andosol soil. Then *Bacillus subtilis* Natto powder at 1 g/cm^2 was applied to soil. After applying *Bacillus subtilis* Natto, stainless cans were put in incubator set at 37 ºC for 2 weeks. Every day, physiological saline solution at 0.8 ml was applied to each can.

Fig. 1 *Bacillus subtilis* Natto powder

Fig. 2 Stainless can

Table 1 Characteristics of the soil (volcanic ash soil)

Specific gravity	Particle size distribution %					Soil texture	pH	EC µS/cm
	Gravel	Coarse sand	Fine sand	Silt	Clay			
2.63	1.97	12.3	27.8	0	39.3	CL	5.74	155

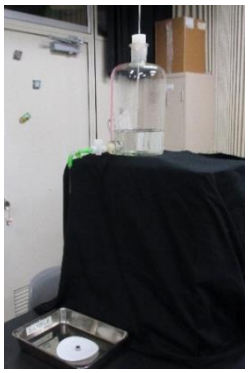

Fig. 3 Apparatus for raindrop experiment

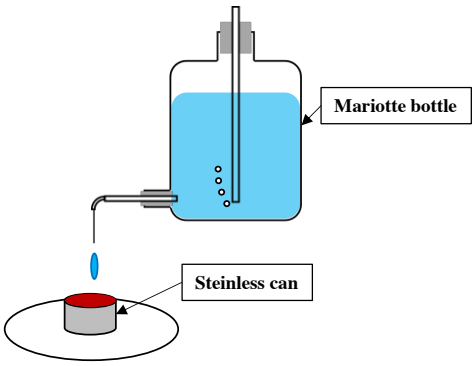

Fig. 4 Outline of raindrop experiment

Raindrop experiments were carried out with a Mariotte bottle as shown in Figs. 3-4. A needle of DIK-6000 artificial rainfall simulator was attached with Mariotte bottle. Water was dripped from

a height of 18.0 cm. Based on the observation and calculation, kinetic energy of raindrops was 2.36×10^{-5} J. For an experiment, 50 raindrops were applied to soil sample of each can.

Kinetic Energy of Raindrop to Break Binding Force of Soil Particles with Hyphae

Bacillus subtilis Natto powder and soil sample used in this experiment were the same as the first experiment. *Bacillus subtilis* Natto at 1.01×10^{7} colonies were observed in the powder.

Raindrop experiments were conducted employing Mariotte bottle as well as the first experiment. Raindrop was applied at the heights of 20, 40, 60 and 80 cm. Kinetic energies of raindrop in each height were observed and calculated based on the Eq. (1). Raindrop mass was measured with dried filter paper and raindrop velocities of each height was measured by photographs shuttered at 1/100 second. The results of observed and calculated kinetic energy of raindrops are indicated in Table 2.

$$\text{Kinetic energies of raindrop, Ek (J)} = \frac{1}{2}\times M \times v^2 \quad (1)$$

Where M is raindrop mass (kg), v is raindrop velocities of each height measured by photographs at 1/100 second (m/s).

Table 2 Raindrop energies in each height

Height of raindrop cm	Kinetic energy $\times10^{-5}$ J
20	3.26
40	4.86
60	9.66
80	13.8

Analysis of Soil Loss

After raindrop experiments, the mass of soil particles splashed out from the samples was measured. Then soil loss rate was calculated with Eq. (2).

$$\text{Soil loss rate (\%)} = \left(1 - \frac{\text{Remained soil mass in the stainless can (g)}}{\text{Initial soil mass in the stainless can (g)}}\right)\times 100 \quad (2)$$

RESULTS AND DISCUSSION

***Bacillus subtilis* Natto Addition on Mitigating Splash Erosion**

Fig. 5 shows the rate of soil loss in stainless cans. In control cans, about 20% of soil was released from cans. On the other hand, in case of stainless cans with *Bacillus subtilis* Natto, the rate of soil loss was reduced to 13%. Moreover, based on the results of statistical analysis, significant difference at $p \leqq 0.01$ was observed between the rate of soil loss of control and that of *Bacillus subtilis* Natto added.

In addition, as a result of microscope observation, hyphae of *Bacillus subtilis* Natto was observed in soil applied with *Bacillus subtilis* Natto as shown in Fig. 6. So, it was considered that *Bacillus subtilis* Natto formed biological crust with hyphae growing.

Therefore, it was considered that *Bacillus subtilis* Natto is applicable to mitigate splash erosion.

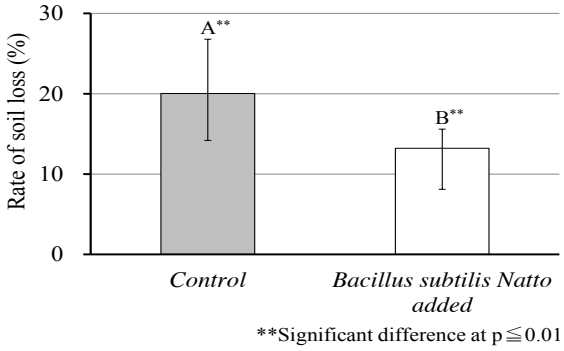

Fig. 5 Rate of soil loss

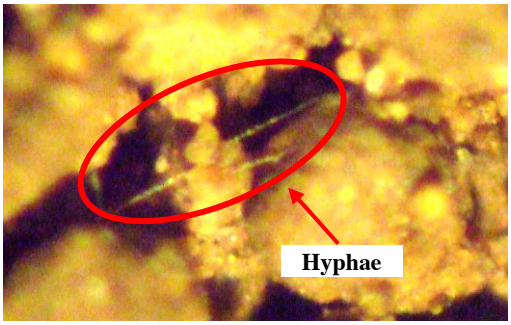

Fig. 6 Hyphae in soil

Kinetic Energy of Raindrop to Break Binding Force of Soil Particles with Hyphae

Figure 7 shows the relationship between the rate of soil loss and the kinetic energy of raindrop. According to the results, the rate of soil loss increased with the kinetic energy of raindrop in both cans of control and *Bacillus subtilis* Natto added. As a result of statistical analysis, confidence interval at 99% was observed for both regression lines of the rate of soil loss of control and that of *Bacillus subtilis* Natto added.

The changes in soil loss rate were shown in Fig. 8. *Bacillus subtilis* Natto reduced the soil loss rate at kinetic energy of raindrop from 3.46 to 4.86×10^{-5} J. In addition, significant difference was observed between the rate of soil loss of control and *Bacillus subtilis* Natto added. However, when the kinetic energy of raindrop was larger than 9.66×10^{-5} J, significant difference was not observed.

Therefore, it was considered that biological crust formed by *Bacillus subtilis* Natto was not broken by splash erosion until 4.86×10^{-5} J of kinetic energy.

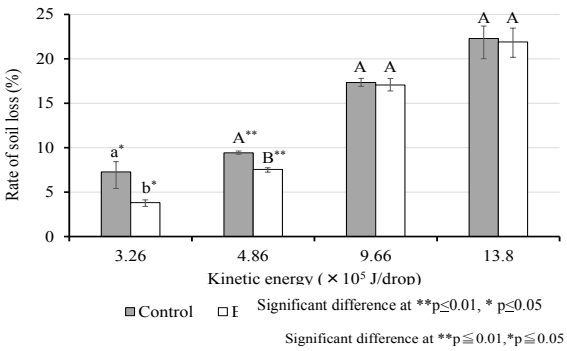

Fig. 7 Relationship between rate of soil loss and kinetic energy of raindrop

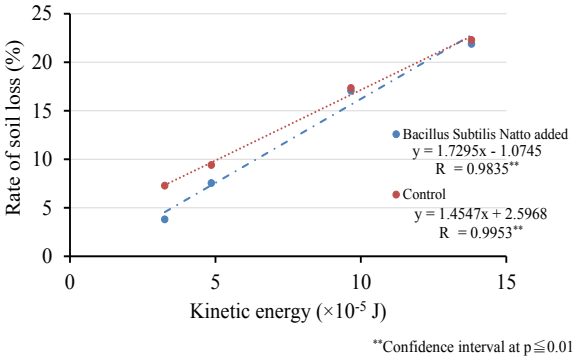

Fig. 8 Changes in soil loss rate

CONCLUSION

In this study, two experiments were carried out to investigate the effect of *Bacillus subtilis* Natto addition for mitigating splash erosion. Based on the experimental results, the rate of soil loss was decreased by *Bacillus subtilis* Natto addition. Moreover, hyphae of *Bacillus subtilis* Natto were observed in the soil which *Bacillus subtilis* Natto was applied. So, it was considered that *Bacillus subtilis Natto* is able to form biological crust with growing hyphae.

In addition, there was a tendency that *Bacillus subtilis* Natto mitigated splash erosion until kinetic energy of raindrop at 4.86×10^{-5} J/drop.

Therefore, it was concluded that *Bacillus subtilis* Natto is applicable to mitigate splash erosion. In addition, it was found out that biological crust formed with *Bacillus subtilis* Natto started

to break at kinetic energy of raindrop 4.86×10^{-5} J/drop.

The results of this study showed that microorganisms which create viscid hyphae such as *Bacillus* sp. may be applicable to mitigate splash erosion.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the members of Lab. of Land and Water Use Engineering in Tokyo University of Agriculture, Japan for the meaningful discussion.

REFERENCES

Gopal, T. and Mihara, M. 2008. Palm shell filter strips as a conservation strategy in mitigating soil and nutrient losses. Eco-Engineering, 20 (2), 59-65.

Hara, T. 1990. Root of Natto. Chemical and Biology, 28 (10), 676-681, (in Japanese).

Hosoi, T. 2003. Probiotic effects of *Bacillus subtilis* (*Natto*). Journal of the Brewing Society of Japan, 98 (12), 830-839.

Kawai, T., Kawamura, S. and Mihara, M. 2007. Effect of width in grass buffer strips on trapping characteristics of soil and nutrient components using *Ophiopogon japonics* Ker-Gawl. Paper on Environmental Information Science, 21, 591-594, (in Japanese).

Shimomura, S., Tomisaka, M., Shimada, M., Kobayashi, M., Fujisawa, H., Kurihara, J., Sakurai, J., Tagata, S., Ozawa, K., Nagumo, F., Hoshikawa, A. and Nakano, T. 2007. Experimental studies on the effectiveness of natural microorganisms on the ground surface at controlling erosion. Kouei Forum, 15, 21-29, (in Japanese).

Siriwattananon, L., Kawai, T. and Mihara, M. 2009. Effect of grass buffer strips using *Ophiopogon japonicus* on reducing soil and nitrogen losses under different fertilization. Journal of Environmental Information Science, 37 (5), 61-66.

Six, J., Feller, C., Denef, D., Ogle, S.M., de Moraes Sa, J.C. and Albrecht, A. 2002. Soil organic matter, biota and aggregation in temperate and tropical soils - Effects of no-tillage. Agronomie, 22, 755-775.

Torillo, J. Jr. and Mihara, M. 2011. Soil erosion control by coconut husk buffer strip in Bohol island of Philippines. International Journal for Environmental and Rural Development, 2 (1), 25-30.

Torillo, J. Jr. and Mihara, M. 2014. Effects of retting treatment on coconut husk buffer strips for eliminating nutrient losses. International Journal for Environmental and Rural Development, 4 (2), 185-190.

Research article

An Approach for Monitoring the Reforestation and Conservation Efforts by Local Communities

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Abstract Considering Philippines's well defined commitment toward social forestry system since 1970s, we examined its purpose of contribution, motivation and achievement toward reforestation and forest conservation through interviews with related stakeholders, as well as decadal forest cover changes by analyzing the forest type classification map of two different period of time which were prepared based on Earth Observation Satellite (EOS) image data and field sampling. EOS based forest cover change analysis, coupled with field sampling and stakeholder consultation, resulted into definitive facts and figures, which can be used for reforestation and forest conservation decision making process.

Keywords community people, forest restoration, forest land-use plan, satellite image

INTRODUCTION

The Philippines has been carrying out Social Forest Program (SFP) since 1970s in order to preserve the forest properly excluding government owned forest land. In the SFP, indigenous people and local communities have effectively used and managed remaining forest in their territories, and the government took the initiative in developing community based monitoring and information system. Under such circumstance, reforestation through National Greening Program (NGP) and forest plantation with the participation of local communities has been extended throughout the country. This Study has been conducted in Mangatarem area of Pangasinan province where local communities have been dedicating to the forest restoration. Their effort is actively supported by local government, NGO and DENR (Department of Environment and Natural Resources).

The main focus of this study is to analyze change of its spatial distribution in forest coverage in their land by using ASTER satellite images, which is one of the widely used EOS for such purpose.

OBJECTIVE

The forest land cover is concentrated in the hilly area of Mangatarem town. The area has been well managed for restoration of the forest land through series of creation of forestland and conservation

activities by local communities. The area therefore was selected as a study site to examine the effect of those efforts by local communities' participatory forest conservation activities. The location of the study site is illustrated in Fig. 1.

Fig. 1 Location of the study area

METHODOLOGY

In order to analyze decadal forest cover changes, forest land cover types and its distribution has been mapped by using EOS images acquired at two different period of time. Changes of the forest cover were examined in association with the forest land use plan and participatory forest management where local people had been involved in forest restorations.

RESULTS AND DISCUSSION

Current Status of Forest Conservation and Management in Mangatarem LGU

In the mountain of the study site, high endemic species of plants and animals (terrestrial vertebrate species) are found, which has been confirmed by the recent surveys. Municipal Local Government Unit (MLGU) of Mangatarem and DENR, in partnership with Haribon Foundation, have worked together to further educate the Mangatarem community on forest restoration and conservation with the support of donation from Japanese companies for planting trees (Municipality of Mangatarem, 2013). The Forest Land Use Plan (FLUP) was developed for the conservation of the biodiversity of the area. The location of the targeted activities is illustrated in Fig. 2, which form the part of this study site.

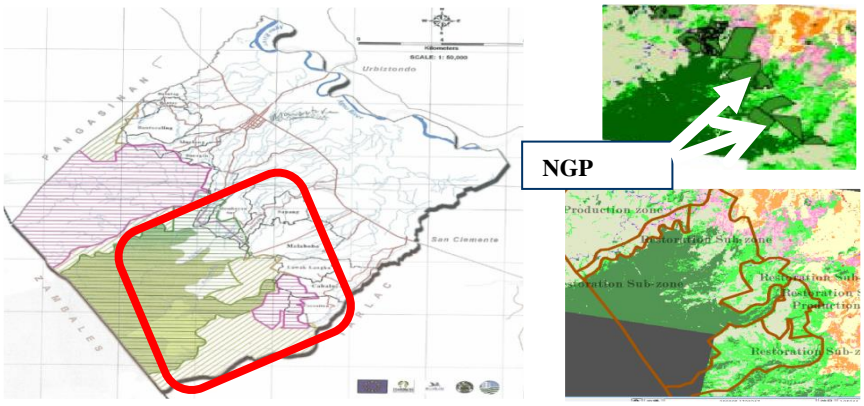


Fig. 2 Forest Land Use Plan (DENR, *LGU (~2040)*) over the study area and reforestation areas (above) by NGP (DENR)

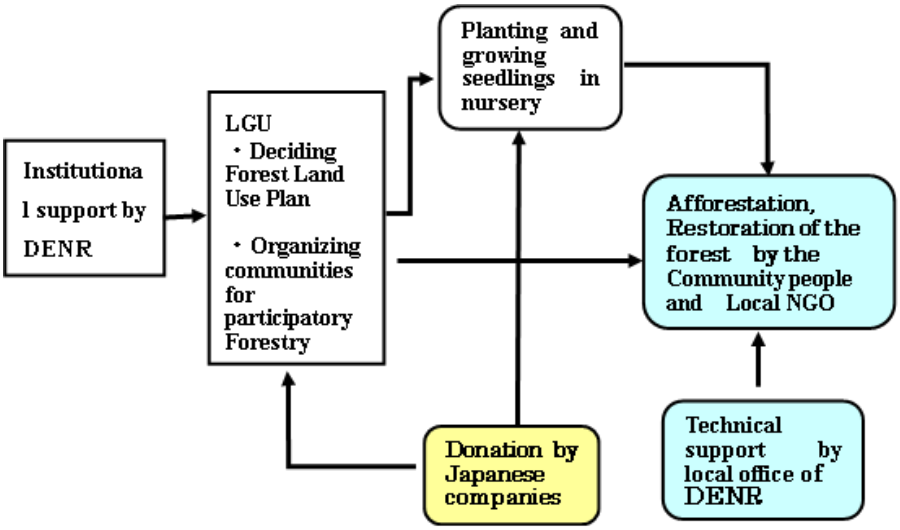


Fig. 3 Schematic diagram of forest restoration by the community

Villagers of the communities, participating in the activity of restoration and conservation, are dedicating themselves to planting trees, growing seedlings and taking care of the forest under the FLUP. And the work is coordinated by MLGU with the technical and financial support from Haribon Foundation; a local NGO; and Japanese companies respectively. For Japanese companies, it is part of their CSR activities, while for Haribon Foundation, it is non-profit social contribution. The concept is shown in Fig. 3. The generous contribution from all collaborating institutions, mentioned above, resulted into the formulation of a Forest Land Use Plan (FLUP) (Borlagdan et al., 1990).

Land use in the forest land is restricted not to log without permission in accordance with the FLUP (Fig. 2) and preserved strictly in some area. In parallel with the FLUP, afforestation has been conducted since 2013 under the National Greening Program of DENR.

Social-Economic Factors of the Communities Surrounding the Forest Land

As discussed in previous section, effort of the local communities and LGU toward the participatory forest conservation and restoration in the area is significant. Considering this fact, the study was conducted through interviews to the stakeholder consisting of villagers in order to grasp the purpose of contribution, dependence on the forest, livelihood and motivation to get involved in the Community-based Forest Management (CBFM). We therefore examined Mangatarem villagers' considerations and activities toward the Forest Management & Conservation using outcome of the interviews. As a result, following facts were found.

a. Profile of the community: Local government of Mangatarem consists of 82 barangays. Most of the community people are engaging in farming rice and vegetables. Out of 82 barangays, 9 get involved in CBFM. Furthermore, 10 barangays are participating in restoration of the forest under NGP.

Table 1 Involvement in the forest restoration and conservation

Type	No. of Barangays	Remarks
CBFM	9	
NGP	10	
Total No. of Barangays	82	Including CBFM and NGP

b. Interviewee and findings: We interviewed 27 villagers in the barangays whose average age was 44.6 years old. Among them, the oldest interviewee was 78 years old and the youngest was 24 years old. In the interviews to the villagers, from relevant community, the main questions were (1)

motivation to participate in the forest management and conservation, (2) main method of contribution to the forest management and conservation activities, (3) expectation from their involvement in the forest management and conservation, and (4) measure to improve livelihood. The obtained replies have been listed as shown in Table 3.

Table 2 Profile of interviewee

Type	Age
Average age	44.6 years old
Youngest	24 years old
Eldest	78 years old
Number of Interviewee	27 Villagers

Table 3 Mangatarem villagers' considerations and activities toward the forest conservation and restoration

Factors noted	Outstanding Answer
Motivation	・Improve livelihood (80% of villagers interviewed) ・Yield and gain the co-benefits from the forest (80%) ・Preserve the forest for sustainable environment (88%)
Main Method of Contribution	・Nursery of seedling (80%) ・Plant seedlings (92%) ・Preserve forest for sustainable environment (81%) ・Grow and take care of planted trees (62%)
Expectation from their activities	・Increase income and by-product (50%) ・Restoration of natural environment and biodiversity (95%) ・Mitigation of disasters (90%) ・Better landscape for people inhabiting (62%)
Measure to improve livelihood with forest management	・Plant valuable trees (75%) ・Enhance natural resources for Ecotourism (75%)

Degradation and Restoration of the Forest in the Area

To know what have happened in the areas where the people of the communities involved in restoration and preservation of the forest under the FLUP, decadal forest cover changes has been analyzed using the forest type classification map of two different period of time.

a. Land use and forest type classification: Land use including forest types, which is useful input for forest management practice, were classified using ASTER satellite image. There are four different types of forest cover in the study area (Fig. 4). The definition of each category of forest types is given below.

Closed forest: A type of forest with canopy cover over 70%

Degraded forest: A type of forest which possess uneven sizes of crown with some noticeable open land

Open forest: A type of forest with vegetation cover almost below 50% and grass land with scattered trees

Agro forest: A type of forest categorized as man-made plantation

Degraded forest is mostly found in hilly land adjacent to Zambales Mountains, whereas the closed forest on relatively steep slopes of the mountain. And the open forest is embedded among them.

b. Forest Cover Change in FLUP Forest Land: The change in area of forest land during 10 years (2001-2010) was estimated to verify the significant change between the forest relatively close to the communities involved in reforestation and conservation and the other forest land areas. The summary of the result is shown in Table 4.

As shown in Fig. 5, forest area in the "Strict Restoration-Zone "decreased while the forest in Restoration Zone-1 even increased slightly.

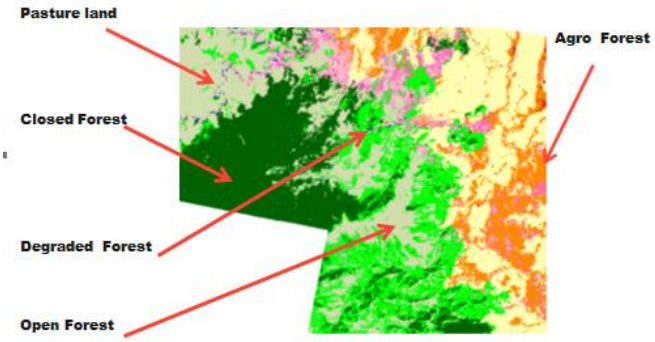
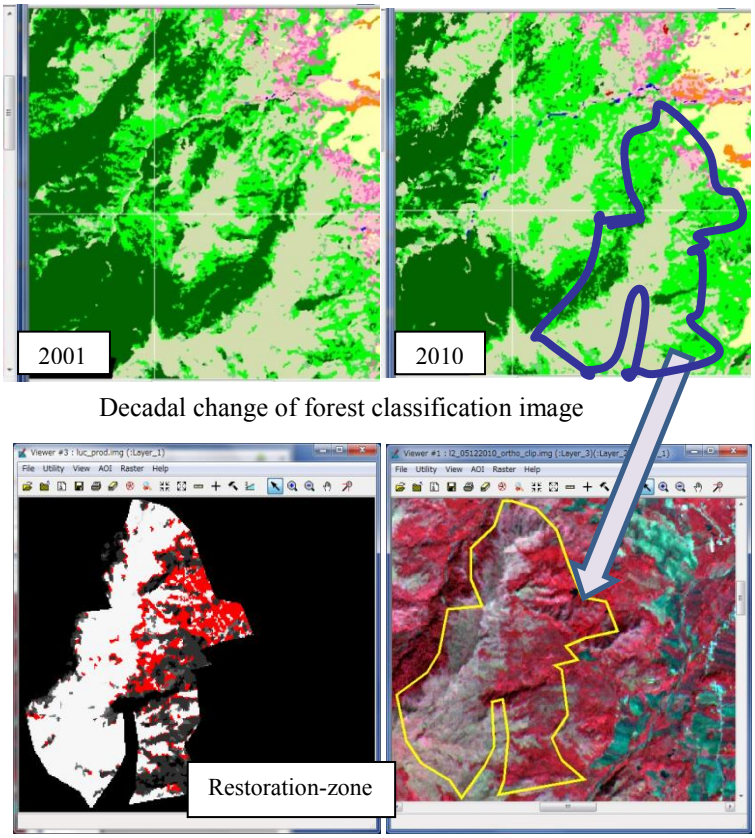


Fig. 4 Land use and forest type classification

It should be noted that the area falling on the restoration-zone 1 is situated in the vicinity of communities and villagers that have positively contributed to afforestation and planting trees.

Table 4 Decadal change of each forest type accommodating FLUP

Zone	2001 Area in (Ha)				2010 Area in (Ha)			
	Closed Forest	Degraded Forest	Open Forest	Total	Closed Forest	Degraded Forest	Open Forest	Total
Strict Restoration Zor	*3,498.0*	*658.9*	*88.7*	**4,245.5**	*3,152.4*	*705.0*	*38.4*	**3,895.8**
Restoration Zone1	*365.0*	*473.2*	*176.4*	**1,014.7**	*212.5*	*758.7*	*108.2*	**1,079.3**
Restoration Zone2	*117.9*	*189.6*	*27.3*	**334.8**	*19.7*	*272.9*	*16.4*	**309.0**
Production Zone	*46.5*	*128.8*	*26.3*	**201.6**	*34.7*	*237.8*	*10.9*	**283.4**
	4,027.4	**1,450.5**	**318.6**	**5,796.5**	**3,419.2**	**1,974.4**	**173.9**	**5,567.4**



Decadal change of forest classification image

Fig. 5 Comparison of decadal change of the forest area

(*Features in red color on the left picture in below line depict the recovery of young forest*)

Focusing on the change in each zone of the FLUP, the Closed Forest inside "Strict Restoration-zone" has been preserved relatively well, say 90% of existing forest remain unchanged, while the forest area decreased accounting for 48% in other restoration zones. On the other hand, restoration of forest has been found in Restoration-zone resulting in increase of the forest cover by 48% overall, however they fall in degraded forest (secondary forest in this case).

These facts infer the seedlings or shrub in the grassland in the study area have grown high and bigger after nearly 10 years as seen in Fig. 6.

Since Mangatarem LGU have been dedicating to encouraging the villagers to participate in the restoration of forest, where each barangay shall establish at least 10 hectares of woodlots within the production zone identified under FLUP. Their effort seems to bring significant effects in the forest restoration.

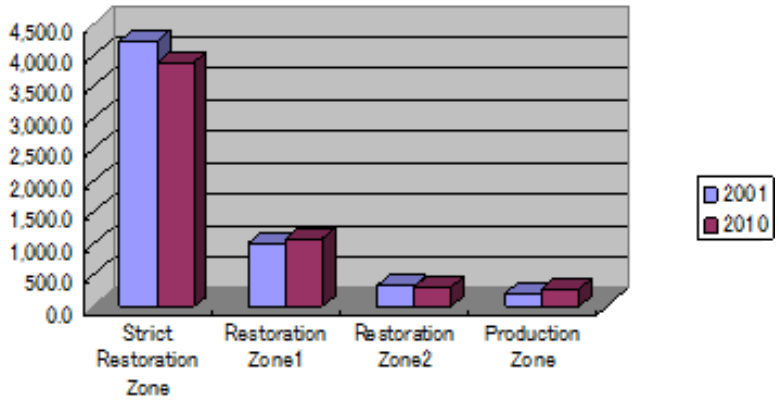


Fig. 6 Restoration of the grass land with shrub after 10 years

CONCLUSION

Monitoring of the forest change in the forest land where local people of the communities are involving in restoration of the forest was examined and proved to be effective to certain extent in order to verify their efforts. To make it more conclusive that the forest conservation can be sustainably continued, method to evaluate the effect brought from participatory restoration of the forest seems to be more important. It is because of the stakeholders can be encouraged to sustain their incentives for participating in forest conservation activities since increase of the biomass will be valued as a credit under the scheme such as REDD+ mechanism.

ACKNOWLEDGEMENTS

It is noted that great contribution of other organizations such as Japan Space Systems (JSS) and Department of Environment and Natural Resource (DENR) remained vital to complete this study. JSS provided ASTER satellite data and DENR played a courteous role of collecting the related data. Deep appreciation is given to DENR local staff as well as staff of Mangatarem LGU who assisted in the field work and helped in conducting interviews with villagers, especially to Engr. Tomas Vergata and staff of Haribon Foundation, Ms. Maria Belinda de la Paz and Mr. Noel A. Resurrecion.

REFERECNCE

Borlagdan, S.B., Alegado, E.M., Carillo, I.M. and Alcaria, J.F.A. 1990. Social forestry network, The Cebu Integrated Social Forestry Project, Network Paper No. 10c. Cebu, Philippines.

Municipality of Mangatarem. 2013. Critical Habitat Management Plan, 2014-2018. Pangasinan, Philippines.

Research article

Cultural Ecosystem Service Assessment in a Semi-Mountainous Area of Japan: Case in Toyota City

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Abstract One of the categories included in the Millennium Ecosystem Assessment (MA) developed in 2005 is cultural ecosystem services (CESs), which includes a variety of factors such as aesthetic values, recreation and ecotourism. In order to assess the CESs, a simple questionnaire survey was conducted in a semi-mountainous rural town in Japan. The town of Inabu in Toyota City, Aichi Prefecture, was selected for the case study. The face-to-face (FTF) survey was conducted from October to November 2012 and prioritized forest-related sites in the town. According to the results, aesthetic values received the highest score among the CESs, followed by recreation and ecotourism, while each forest-related site had a different combination of CES values. By using cluster analysis, three clusters were identified: aesthetic values, recreation and ecotourism, and 'others'. In some sites, the CES scores differed between residents and visitors such that residents recognized a wider variety of CES than visitors did.

Keywords cultural service, biodiversity, ecosystem service, forest, Japan

INTRODUCTION

Cultural ecosystem service (CES) is one of the ecosystem service (ES) categories in the Millennium Ecosystem Assessment (MA) developed in 2005 (MA, 2005). The CES category includes ten benefits, such as spiritual and religious values, aesthetic values, recreation and ecotourism, cultural heritage values, educational values, and several others (MA, 2005). There have been several studies on ES assessment (MA, 2005; Costanza et al., 1997; Milcu et al., 2013). While most of these studies focused on ESs (such as provisioning and regulating), the studies on CESs were limited (Brancalion et al., 2013). However, in the field of environmental economics, numerous studies have evaluated part of the CES, such as recreation or aesthetic value (TEEB, 2010). These studies endeavoured to place a monetary value on the cultural aspects of nature; in some cases, it was difficult to divide the values of each separate aspect from the whole. Recently, the number of studies focusing on CES assessment has increased (Daniel et al., 2012; Brancalion, et al., 2013; López-Santiago et al., 2014; Garcia-Nieto et al., 2013; Ota et al., 2013; Weyland and Laterra, 2014). Some of these utilized questionnaire surveys in an attempt to capture the people's perception of CESs. For example, Brancalion et al. (2013) studied aesthetic values, recreation and tourism values, religious and psychological values, educational values, knowledge generation, etc. in the Brazilian forest restoration project. López-Santiago et al. (2014) studied 16 ESs including tranquillity and relaxation, tourism, cultural identity, hunting, and aesthetic value in the case of transhumance in Spain. Ota et al. (2013) conducted a subjective assessment study on 36 ESs including 11 CES-related items. However, these studies did not focus on the identification and prioritization of forest-related sites in small scale areas. Also they did not capture the ES

characteristics of the sites which would be needed for spatially large scale assessment.

OBJECTIVE

The purpose of this study was to identify major forest-related sites in a semi-mountainous area and the characteristics of their CESs by employing a simple survey method. The town of Inabu in Toyota City, Japan, was selected for the case study.

METHODOLOGY

Study Area

Toyota City is located in Aichi Prefecture (Fig. 1). Inabu (the city branch office of which is at 35.216N, 137.509E) is located in the northeast part of the city, where about 87% of the area is forested (Toyota City, 2014a). The Japan Meteorological Agency (JMA) states that the average annual temperature for this area in 2013 was 11.9 °C and the average precipitation was 1785.0 mm (JMA, http://www.jma.go.jp/jma/index.html). The area of the town is approximately 99 km^2. The town has about 2,600 residents (Toyota City, 2014b) and is located 50–60 km east of Nagoya City, which is the third largest metropolitan area in Japan. The town is a typical example of a Japanese semi-mountainous area.

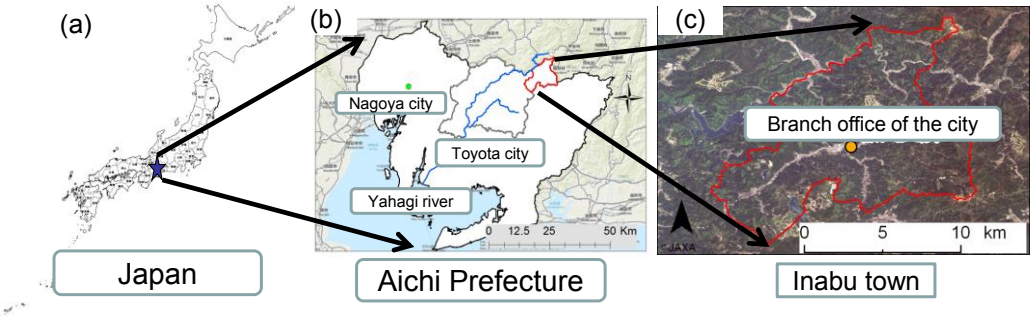

Fig. 1 Maps of the study area: (a) Japan with the Aichi Prefecture in the star symbol, (b) Aichi Prefecture outlined in black, Toyota City outlined in grey, rives in blue, (c) Inabu outlined in red

Source: (a) and (b) made by ArcGIS10.1 and (c) satellite image ©JAXA/ Distribution RESTEC

Methods

First, a document survey focusing on CESs was conducted in order to identify forest-related sites in Inabu. Second, a simple open-ended questionnaire was developed to ascertain respondents' opinions of 11 sites (Table 1); they could choose sites and also add others freely. The survey also contained questions on basic individual attributes including age, gender, municipality of residence, visiting frequency, etc. The reason for employing an open-ended format was to capture the people's direct opinions of a site. Third, a face-to-face (FTF) survey was conducted from October to November 2012 by the authors, research staff, and students in the author's lab with residents and visitors at local sites. Among the 11 sites, three (namely, Ooidaira Park, Donguri-no-sato (adjacent to Donguri Hot Spring and the Inabu Cultural Exchange Facility), and Mennoki Primary Forest) were selected as locations for the FTF survey as well as Inabu branch city office at a local event because the other sites received too few visitors during that season. Also during this period, interview surveys were conducted with an Inabu branch city officer, the city tourist office, a local museum, local knowledgeable people, and several other persons. Fourth, after collecting the answer sheets, two of the authors divided the responses for each site among the CESs based on the classifications of the MA (2005). If there was at least one explanation of a CES of a site, score 'one' was assigned to that CES for the site; if not, score 'zero' was assigned. Then, scores for each

CES were summed up both by site and overall. In cases where an answer sheet included several comments on a number of sites, each comment was treated as an individual comment for the site.

Table 1 Eleven forest-related sites in Inabu, Toyota City

Site name	General description
Donguri Hot Spring	Hot spring located near National Road 153 with some restaurants and shops
Ooidaira Park	Memorial park for a great man in this area and now is famous for autumn leaves
Mennoki Primary Forest	Primary forest of *Fagus crenata* and designated as a quasi-national park
Big Weeping Cherry Trees	370 year old tree in Zuiryuuji Temple and designated as a prefectural natural treasure
Others	Takadoya Wetland (famous for autumn leaves), Big Japanese Judas Trees (prefectural natural treasure), Oshikawa Waterfall, Big Ginkgo Tree (city natural treasure), Natsuyakejyou Mountain (hiking spot, famous for *Lycoris sanguinea var. kiushiana*), Inabu Cultural Exchange Facility, Wariyama (historical shared mountain forest system)

Source: Inabu Tourist Office (2014) amended by the authors

After collecting the data, a statistical analysis was conducted. First, as a basic study, a frequency distribution was developed for each CES in order to examine the cultural aspects of the Inabu forest sites as a whole. Second, the number of comments was totalled by site in order to gain an understanding of how the people prioritized the different areas. For this calculation, comments for a site were excluded if they were obtained through an onsite survey. For example, if an onsite survey was conducted in Ooidaira Park, comments on the park from that survey were excluded in the site totals. This exclusion was only applied to the calculation of site totals, and every effective answer sheet was used in the other analyses. Third, a cluster analysis on the total number of comments by site was conducted to categorize the CESs. Fourth, specific characteristics were examined by site and by residence. Fifth a logistic regression analysis was conducted focusing on cultural heritage values. The statistical analysis was conducted using SPSS statistics ver.22 (IBM).

RESULTS AND DISCUSSION

Table 2 shows the data collected in the FTF surveys. A total of 92 valid answer sheets were collected (95 were collected in all). In these valid answer sheets, there were 271 comments discussing all 11 sites.

Fig. 2(a) shows the percentage of responses that each cultural service received. Aesthetic values ranked highest among the CESs, followed by recreation and ecotourism. In order to compare the FTF survey results, the following data was developed: first, the explanations given by the Inabu Tourist Office website (Inabu Tourist Office, 2014) of the sites' various cultural resources were analysed and divided among the CESs. If there was an explanation of a cultural aspect, score 'one' was assigned to the CES in question. If not, 'zero' was assigned. Second, the total scores for each CES were calculated. When the FTF survey results were compared with the Inabu Tourist Office data, it was found that the two highest scoring subcategories were the same: aesthetic values and recreation and ecotourism. One significant difference was that cultural heritage values were mentioned far more frequently on the Inabu Tourist Office website than in the FTF results.

Fig. 2(b) shows the number of comments that each site received with Ooidaira Park earning the most, followed by Donguri Hot Spring, Big Weeping Cherry Trees, and Mennoki Primary Forest (listed in descending order). There was very little data available on forest site tourism. Aichi Prefecture (2013) statistics reported that in that year, Donguri-no-sato received the most visitors, followed by Donguri Hot Spring and Ooidaira Park. The other forest sites were not listed in the statistics.

Next, a cluster analysis (using average linkage between groups and squared Euclidean distance) revealed that the CESs provided by the Inabu forests were categorized into three clusters: aesthetic values, recreation and ecotourism, and 'others' (Fig. 3).

Specific characteristics were examined by site and by residence. High scoring CESs differed among the sites (Fig. 4(a)). For example, Ooidaira Park scored highest, nearly 80%, in aesthetic values. However, Donguri Hot Spring scored highest, over 90%, in recreation and ecotourism.

Furthermore, in some sites the CES scores differed between residents and visitors. Fig. 4(b) shows that the Mennoki Primary Forest received high scores in aesthetic values, cultural heritage values, and recreation and ecotourism (in descending order) from residents. Visitors, on the other hand, ranked aesthetic values and recreation and ecotourism highly while rarely mentioning cultural heritage values. Fig. 4(c) shows the sum of all the scores for all sites for both residents and visitors. Visitors had more focused values than residents did, as their scores were concentrated on aesthetic value and recreation and ecotourism. Additionally, residents placed a higher priority on cultural heritage values. The total scores by residents were larger than visitors' even though they completed fewer answer sheets (Table 2). Thus, it may be concluded that residents recognized a wider variety of CESs and better understood each site.

Fig. 5 shows the spatial characteristics of aesthetic values and cultural heritage values for Ooidaira Park and Mennoki Primary Forest (by ArcGIS 10.1, ESRI). For both sites, the spatial range of visitors for aesthetic values (Figs. 5(a) and (c)) was wider than that for cultural heritage values (Figs. 5(b) and (d)).

Table 2 Basic data from the collected answer sheets and comments in Inabu

Number of answer sheets collected		N	%	Number of comments received		N	%
Answer sheets	All collected	95		Age	Under 20 year old	20	7.4
	Valid collected	92	100.0		20–39 years old	62	22.9
Gender	Male answer sheets	38	41.3		40–59 years old	71	26.2
	Female answer sheets	48	52.2		Over 60 year old	110	40.6
	No data for gender	6	6.5		No data for age	8	3.0
Residence	Inabu residents	38	41.3	Residence	Inabu residents	141	52.0
	Visitors to Inabu	54	58.7		Visitors to Inabu	130	48.0
				Total comments received		271	100.0

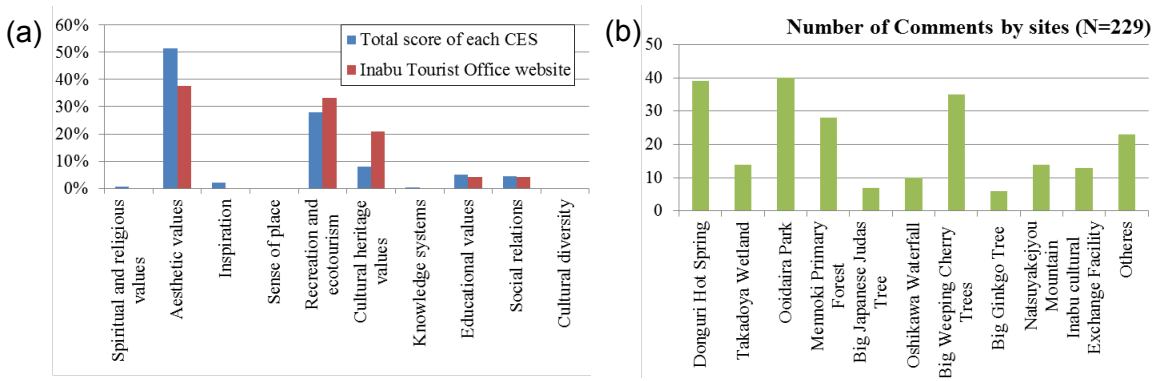

Fig. 2 Percentage of scores of each CES and the number of explanations on the Inabu Tourist Office website(%) (a) and number of comments by forest sites (N=229)⁺ (b)

Note: N=229 means that 42 comments (which were collected in on site surveys) were excluded from the total number of comments (N=271)

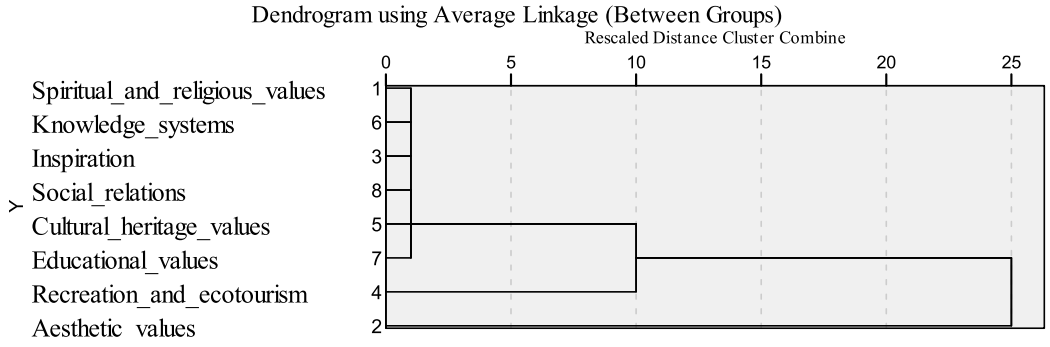

Fig. 3 Cluster analysis for forest sites by CES in Inabu (using average linkage between groups and squared Euclidean distance)

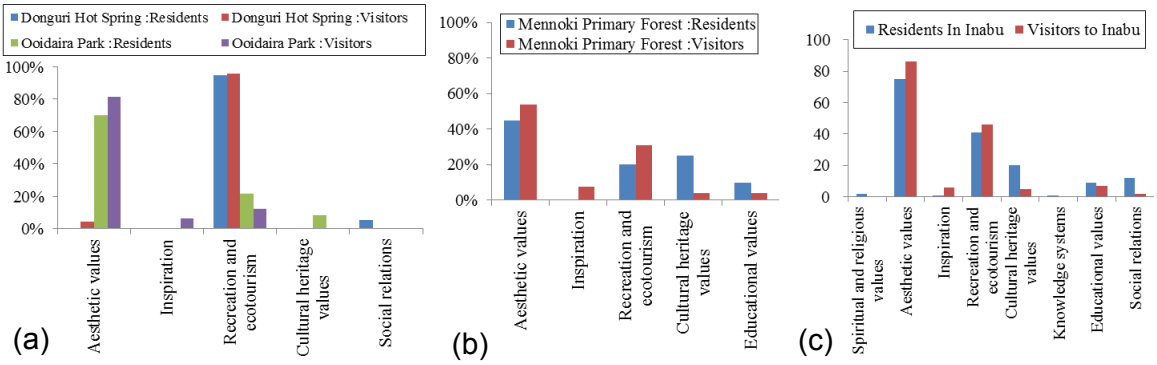

Fig. 4 Percentage of CES scores for Donguri Hot Spring[+] and Ooidaira Park[++] (a), percentage of CES scores for Mennoki Primary Forest[+++] (b), total CES scores for all sites[++++] (c)

Note: [+]total scores N=44, [++]total scores N=86, [+++]total scores N=46, [++++]total score N=313

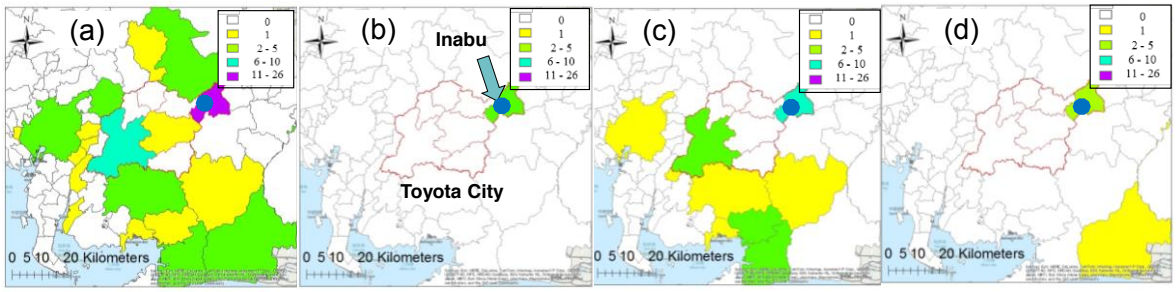

Fig. 5 Total Ooidaira scores by municipality for aesthetic values (a) and cultural heritage values (b), and Mennoki Primary Forest scores for aesthetic values (c) and cultural heritage values (d) by visitors' municipality of residence, blue symbol means Inabu branch office

Table 3 Logistic regression analysis of cultural heritage values in Mennoki Primary Forest (Method = backward stepwise (Wald, P-value in 0.1 and out 0.1))

Basic data		Variables in the Equation					
		B	S.E.	Wald	df	Sig	Exp(B)
Number of comments	Model 1						
Included in analysis (N=35)	Visiting frequency	-.928	.442	4.409	1	.036	.395
Dependent variable	Age range	.766	.399	3.698	1	.054	2.152
Cultural heritage values (1: yes, 0: no)	Gender	3.681	1.755	4.401	1	.036	39.705
Independent variables	Constant	-5.166	2.501	4.266	1	.039	.006
Gender: 1: male, 0: female	Model 2						
Age range: 1:<20, 3:20–39, 5:40–59,7: 60<	Residence	2.157	1.225	3.102	1	.078	8.642
Visiting frequency: 1: several/y- 5:everyday+	Gender	2.288	1.220	3.519	1	.061	9.856
Residence: 1: residents in Inabu, 0: visitors	Constant	-4.383	1.490	8.649	1	.003	.012

Model Summary:	Hosmer and Lemshow test			Cox and Snell	Nagelkerke R
	Chi-square	df	Sig.	R square	square
Model 1	1.112	6	.981	.301	.502
Model 2	.171	2	.918	.213	.355

+: converted to values by 3/year, 4.5/half year, 2.25/month, 1.56/week and 2/3/day, and calculated log

To clarify the factors of cultural heritage values, logistic regression analysis was conducted on Mennoki Primary Forest with cultural heritage values set as the dependent variable. Table 3 shows the basic data and the results of two selected models. First, nonparametric correlations among the variables were checked. Residence and visiting frequency had a rather high correlation of –.570**; thus, two types of variable selection were tested. Model 1 included all of the variables and Model 2 used 'residence' instead of 'visiting frequency'. Both results showed that residence-related factors, namely visiting frequency and residence, were one of the effective variables along with gender.

CONCLUSION

In the study, a simple method was used to assess CESs. According to the results, aesthetic values scored highest among CESs, followed by recreation and ecotourism. Furthermore, each forest site had a different combination of CES values. By using cluster analysis, three clusters were identified: aesthetic values, recreation and ecotourism, and 'others'. In some sites, the CES scoring differed between residents and visitors, indicating that residents recognized a wider variety of CES values than visitors did, such as cultural heritage values. Future studies should include a variety of respondent attributes, such as economic condition and education. By utilizing the results, further studies on detailed and comprehensive assessments of CESs could be conducted. In the future, by upgrading the study method, the beneficiaries, and the burden of cost for biodiversity or ES provisions could be identified. This identification may be useful in the development of better policies such as payment for ecosystem service (PES) and biodiversity offset policies.

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REFERENCES

Aichi Prefecture. 2013. Aichi tourist recreation user statistics. Aichi Prefecture, Japan. (in Japanese)

Brancalion, P.H.S., Cardozo, I.V., Camatta, A., Aronson, J. and Rodrigues, R.R. 2013. Cultural ecosystem services and popular perceptions of the benefits of an ecological restoration project in the Brazilian Atlantic forest. Restor. Ecol., 22 (1), 65-71.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. Nature, 387, 253-260.

Daniel, T.C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J.W., Chan, K.M.A., Costanza, R., Elmqvist, T., Flint, C.G., Gobster, P.H., Grêt-Regamey, A., Lave, R., Muhar, S., Penker, M., Ribe, R.G., Schauppenlehner, T., Sikor, T., Soloviy, I., Spierenburg, M., Taczanowska, K., Tam, J. and Von der Dunk, A. 2012. Contributions of cultural services to the ecosystem services agenda. Proceedings of the National Academy of Sciences of the United States of America, 109 (23), 8812-8819.

Garcia-Nieto, A.P., Garcia-Llorente, M., Iniesta-Arandia, I., and Martin-Lopez, B. 2013. Mapping forest ecosystem services: from providing units to beneficiaries. Ecosyst. Serv., 4, 126-138.

Inabu Tourist Office. 2014. Inabu tourist office web site, Japan. http://inabu-kankou.com/ (in Japanese)

López-Santiago, C.A., Oteros-Rozas, E., Martín-López, B., Plieninger, T., González Martín, E., and González, J.A. 2014. Using visual stimuli to explore the social perceptions of ecosystem services in cultural landscapes: the case of transhumance in Mediterranean Spain. Ecol. Soc., 19 (2), 27. (available from; http://dx.doi.org/10.5751/ES-06401-190227)

MA (Millennium Ecosystem Assessment). 2005. Ecosystems and human well-being: synthesis. Island Press, Washington, D.C., USA.

Milcu, A.I., Hanspach, J., Abson, D. and Fischer, J. 2013. Cultural ecosystem services: a literature review and prospects for future research. Ecol. Soc., 18 (3), 44. (available from; http://dx.doi.org/10.5751/ES-05790-180344)

Ota, T., Hayashi, K., Ito, H. and Ooba, M. 2013. Exploratory data analysis of subjective importance to ecosystem services provided by a restored ecosystem: a case of forest in Toyota City, Aichi. J. Hum. Env. Symbiosis, 22, 38-50. (in Japanese)

TEEB. 2010. The Economics of ecosystems and biodiversity: ecological and economic foundations. ed Kumar P, Earthscan, Oxford, UK.

Toyota City. 2014a. Toyota forest white paper of 2012. Toyota City, Japan. (in Japanese)

Toyota City. 2014b. Population in Toyota city. Toyota City, Japan. (in Japanese)

Weyland, F., Laterra, P. 2014. Recreation potential assessment at large spatial scales: A method based in the ecosystem services approach and landscape metrics. Ecol. Indic., 39, 34-43.

Research article

Nutrient Value and Palatability for Cattle on Corn Stover Silage

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Abstract As cultivated areas in Cambodia have increased, feed resources for feeding and grazing cattle have decreased significantly. Plantings of yellow corn, however, have increased substantially, in particular, in the north-west of Cambodia; consequently, a huge amount of corn residue is being produced but remains unused, despite offering potential as a cattle feed, particularly after ensiling. The aim of this study was to identify nutritive value and palatability of corn stover silage for cattle feeding. Corn stover was chopped at approximate 4 to 6 cm in length and ensilaged with different treatments as follows: 15% water (CSN), 3% salt+15% water (CSSa), 3% sugar palm+15% water (CSSu), and 10% rice bran+15% water (CSRB). Cattle were adapted over a 5 day periods and 1 kg of each silage was offered to each animal. The result shown that crude protein content in silage increased on average from 6.41 to 9.7%. Within the treatments the chemical composition of dry matter, crude protein, organic matter, ash and crude fiber were similar. However, the intake of silage was significantly different. Cattle consumed more CSSu (177.88 gDM) than the other types of silages and ate about 100 gDM or less. CSSa was the lowest intake. In conclusion, sugar (palm sugar) should be added to reach carbohydrate requirement in order to help the silage fermentation process as the stover was mature with high DM% and needed additional flavour added to the silage.

Keywords cattle, corn stover silage, flavour, palatability, silage

INTRODUCTION

Cattle play an important role in Cambodian farming systems and contribute to the household income. The estimated cattle population in 2011 was about 3,406,972 heads (DAHP, 2012).

The total estimated quantity of corn produced in 2012 was 780,774 tons, 83.9% of red corn and 16.1% of white corn, that was mostly grown in Battambang (106, 789.00 ha), Pailin (27,347.00 ha), and Kandal (18,805.00 ha) and 4,028,404 tons of fresh corn residue (leave, stem, bushes and cob) was produced in 2010 (FAO, 2012).

Cambodian cattle farmers depend mainly on the use of natural feed resources (Mob et al., 2014), and feed availability is the most significant constraint on cattle production in Cambodia (Pen et al., 2009; Mob et al., 2014). Martin (2013) recommended that some corn stover should be

left in the field to conserve the soil, improve crop water-use efficiency, and feeding cattle. However, the remaining should be used for other purposes, although, currently, few cattle farmers utilize the residue for feeding (Mob et al., 2014). Feeding or grazing cattle in cropland after harvesting only provides feed to cattle for short while. Moreover, during the harvesting period, other natural feed resources are in abundance, leading to less use of fresh crop residues. Limin (2001) suggested that storing maize as silage can be an outstanding way to store maize crop residues, but to maximize quality, it has to be ensiled using proper methods to create an anaerobic environment.

The fibrous increasing in the plants can lead to undesirable results of silage as a rapid development of mould from difficult of removing oxygen (Randy et al., 1999) and inefficient fermentation (Clark et al., 2009). Moreover, the more mature the plants the less digestible the diets since there are a loss of nitrogen and carbohydrate (Randy et al., 1999). These studies attempted to improve the quality of silage by adding extra carbohydrates during the silage making process. Silage can be fed any time and is very palatable to livestock (Anon, 2013) and increases productivity of beef and dairy cattle (Chin, 2002). The large amount of corn residues produced in Cambodia can be stored and fed to cattle via hay making and silage making (Martin, 2013). However, feed intake becomes a constraint for cattle production (Mob et al., 2014). By improving the palatability of silage by using additives, intakes can be improved.

OBJECTIVE

This study was conducted to identify chemical contents of corn stover silage mixed with different additives, and to investigate their effects on palatability.

METHODOLOGY

Silage Preparation and Experimental Animals

At harvesting time 105 day-old, sweet corn stover was obtained from farmers in Lerkdek district, Kandal province, Cambodia and cut into 5 cm lengths above the cob. Then, the stover was immediately transported to Royal University of Agriculture (RUA) and chopped into approximately 4 to 6 cm lengths using a cutter machine. The chopped stover was fermented for 75 days with different ensilaging treatments: 15% water (CSN), 3% salt+15% water (CSSa), 3% sugar palm+15% water (CSSu), or 10% rice bran+15% water (CSRB) and transferred into plastic bags with each bag weighing 2kg and hand compress.

Four crossbred Haryana beef cattle, 2 bulls (2.5 year-old) and 2 cows (3 year-old), were assigned to study on the palatability of corn stover silage. Prior to the experiment, all cattle were adapted at least 5 days with corn stover fermented with 15% water. After that four trays containing 1 kg each of the four kinds of silage were offered to each animal at 8 am. At first, animals were allowed to smell the silage for about 2 minutes and then they were allowed to select and eat for about 10 minutes. The residues were collected and recorded then sub-sampled for chemical analysis.

Data Collection and Analysis

After 75 days of ensilaging, samples of each silage were collected and analysed for dry matter (DM), organic matter (OM), crude protein (CP), crude ash (Ash) according to AOAC (1955) and crude fibre (CF) (Van Soest et al., 1991) at graduate school laboratory, Royal University of Agriculture. Prior the experiment, the silages (200 g) were taken for chemical analysis and also after the experiment.

Data Analysis

All data obtained from the present study were subjected to One-way ANOVA of variance using SPSS 16.0 for analyze of the average of chemical composition of silage and feed intake. Significant differences between the variables were identified using LSD multiple range test.

RESULTS AND DISCUSSION

Preservation of crop residues can be challenging to some producers as it needs proper methods and procedures to ensure the silage is in good condition. Harvesting plants for making silage must consider the stage of maturity of the plant. Moisture content in plant is very important if the plant is too young or too old; it can affect the quality of silage. In this study, we tried to use the mature crop residue that is produced in large quantities in local areas.

Before ensiling, the stover had 6.41% crude protein and the dry matter was 45% (Table 1). However, after preservation, the crude protein increased to about 9.7%. There were no differences between treatments in crude protein content, with an observed range from 9.15 to 10.45% (Table 2). This finding agreed with those of Kilmer and Hoyer (2012) that ensiling can produce high feed quality for ruminants.

Table 1 Chemical composition of samples

Samples	DM (%)	CP (%)	OM (%)	Ash (%)	CF (%)
Corn stover	45.00	6.41	85.12	0.35	22.30
Rice bran	93.05	11.53	84.18	0.41	11.56

Table 2 Chemical composition of corn stover silages

Type of corn stover silages	DM (%)	CP (%)	OM (%)	Ash (%)	CF (%)
	Mean	Mean	Mean	Mean	Mean
CSN	40.09	9.32	88.83	0.31	25.22
CSSa	35.74	9.87	80.80	0.50	23.75
CSSu	40.21	9.15	84.14	0.44	24.14
CSRB	42.63	10.45	86.40	0.39	22.61
SEM	1.41	0.22	1.23	0.02	0.56
P	0.399	0.153	0.103	0.116	0.456

(CSN: Corn stover + no additives, CSSa: Corn stover + added salt, CSSu: Corn stover + added sugar palm, CSRB: Corn stover + added rice bran, SE: Standard Error Mean, P: Probability)

There were significant differences between the treatments (P=0.000) in the amount of silage eaten by cattle (Table 3). In ten minutes eating, cattle showed a strong preference for CSSu (177.88 g). Consumption of other types of silage was about 100 g or less. CSSa (57.21 g) had the lowest intake.

As the corn stover was collected to ensile at harvesting stage that cause to the lack of carbohydrate and moisture (45% DM, Table 1). Sugar palm and rice bran (grade 3) were used to encourage the silage fermentation in which the acetic bacteria play a vital role in silage fermentation process. This agree with Yokota and Ohshima (1997) that used raw or/and defatted rice bran to better additive on the fermentation quality of the silage. The less intake of CSRB in the study may come from the long term preservation (75 days). According to Limin (2001), adding true carbohydrate such as molasses could encourage the fermentation process and Limin (2014) also indicated that silage additive with molasses effects on lactic fermentation, reducing silage pH, discouraging a clostridia fermentation and proteolysis, and generally decreasing organic matter losses that it agreed with those of Keady (1996) that used molasses as silage additive improve silage preservation and silage DM intake, but did not show the silage digestibility or animal

performance. From our results, adding palm sugar to silage not only improved silage fermentation but also increased palatability for cattle in comparison to non-additive silage and it provided include a good odour, colour, flavour, and texture. Jerry (2013) claimed that some research attempted to prove adding salt to forage material at the time of ensiling can improve silage fermentation, and with his result not only adding 40 g of salt/1 kg of fresh sorghum did show positive effect, but it did also with the combination of lactic bacteria. However, it is argued by the study of Shockey and Borger (1991) that adding salt (4 g of salt/1 kg fresh alfalfa) would inhibit growth of Clostridium and lactic acid bacteria result the silage was not well-preserved. With our result, adding salt 3% made less intake and short-preservation. Adding 15% water could increase artificial moisture and can aid in dissolving sugar and salt. According Jerry (2013) found that no additive sorghum silage contained 13.1 and 5 g/kg dry matter of butyric and propionic acid respectively result from fermentation by clostridia bacteria that lead to less energy value and reduced palatability.

Table 3 Silage intake of corn stover silages (gDM)

Type of corn stover silages	Mean	SEM	P
CSN	105.13[b]	10.29	0.000
CSSa	57.21[c]		
CSSu	177.88[a]		
CSRB	81.34[bc]		

(CSN: Corn stover + no additives, CSSa: Corn stover + added salt, CSSu: Corn stover + added sugar palm, CSRB: Corn stover + added rice bran, SE: Standard Error Mean, P: Probability, significant different: a>b>c)

CONCLUSION

The study shows that ensiling corn stover increases its crude protein content by 3.29%. Corn stover ensiled with added sugar is more palatable for cattle than the corn stover silage without additives, or with added salt or rice bran.

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REFERENCES

Anon, 2013. Silage making for small scale farmers. FAO/USAID. (available from; http://pdf.usaid. gov/pdf_docs/PNADQ897.pdf)

AOAC., 1995. Official method of analysis, 16th ed. Animal Feeds: Association of Official Analytical Chemists, VA, USA.

Chin, F.Y. 2002. Ensilaging of tropical forages with particular reference to South East Asian systems, Department of Veterinary Seriveces, 50630 Kuala Lumpur, Malaysia. Paper presented at the 13th International Silage Conference, 11-13th September, 2002. (available from: http://www.fao.org/ag/agp /AGPC/doc/pasture/spectopics/chinpaper.htm)

Clark I., James B., Mike P., Linden G., and Jody G. 2009. Harvesting corn silage by plant moisture. AG/Farmland/2009-03pr. (available from; extension.usu.edu/htm/publications/file=10450)

DAHP, 2012. Summarize report of animal production and health tasks in 2011 and proposed in 2012 (Khmer Version). Department of Animal Production and Health, Phnom Penh, Cambodia.

FAO, 2012. National assessment of Cambodia's main crop and fodder resources (draft final report), Centre for Livestock and Agricultural Development, Phnom Penh, Cambodia. 7-9, 25-26.

Keady, T.W.J. 1996. A review of the effects of molasses treatment of unwilted grass at ensiling on silage fermentation, digestibility and intake, and on animal performance. Irish Journal of Agricultural and Food Research, 35, 141.

Kilmer, L. and Hoyer, S 2012. Making quality corn silage. (Retrieved March 25, 2014. From; http://www.extension.iastate.edu/dairyteam/)

Jerry W.S. 2013. Salt may improve corn and sorghum silage fermentation. (Retrieved May 19, 2015. From: www.saltinstitute.org/wp.../First-Quarter-2013-Sorghum.pdf)

Limin, K.J. 2001. Silage fermentation and additives. (Retrieved January 09, 2014, from: http://www1.foragebeef.ca/$Foragebeef/frgebeef.nsf/all/frg69/$FILE/silagefermentationadditives.pdf)

Limin, K.J. 2014. A review on silage additives and enzymes. (Retrieved May 19, 2015, form: http://ag.udel.edu/anfs/faculty/kung/articles/a_review_on_silage_additiv)

MAFF, 2013. Annual report for agriculture forestry and fisheries 2012-2013. Phnom Penh: MAFF.

Martin, R. 2013. Crop residues as a potential cattle feed in north-west Cambodia. ACIAR project ASEM/2010/049 (Crops+Cows=Cash): discussion paper, September 2013.

Mob, S., Seng, M., Theng, K., and Chea, B. 2014. Cattle production systems in NW Cambodia. Livestock Research for Rural Development. Volume 26, Article #42. (Retrieved April 3, 2014, from http://www.lrrd.org/lrrd26/3/sere26042.htm)

Pen, M., Savage, D., Stür, W. and Seng, M. 2009. Constraint to cattle production of small-scale farmers in Kampong Cham Province, Cambodia. In: Proc. of the Tropentag 2009 Conference on International Research on Food Security, Natural Resource Management and Rural Development. (Retrieved July 09, 2013, from: http://www.tropentag.de/2009/abstracts/full/528.pdf.)

Randy, S., Joe, L. and Kevin, S. 1999. Here are some tips on corn silage harvest management. *A version of this article appeared in July, 1999 issue of Hoard's Dairyman. (Retrieved March 14, 2014, from: http://www.uwex.edu/ces/dairynutrition/documents/csharv99.pdf.)

Shockey, W.L. and Borger, D.C. 1991. Effect of salt on fermentation of alfalfa. 2. Treatment with sodium chloride, Clostridium butyricum, and lactic acid bacteria. J. Dairy Sci. 74:160-166

Van Soest, P.J., Robertson, J.B. and Lewis, B.A., 1991. Methods for dietary fiber neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science, 74, 3583-3597.

Yokota, H. and M. Ohshima. 1997. Silage quality of napier grass (*Pennisetum pupureum* Schum.) ensiled with rice bran. Anim. Sci. Technol. 68, 305-309.

Research article

Growth Rate of *Acropora nobilis* Attached to Table Type Framework

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Abstract The Municipality of Panglao has been experiencing constant pressures caused by human and natural factor that affect the resources within the municipality particularly the reefs. Reefs are underwater structures created by the growth of corals. It has the highest gross of primary productivity in marine systems. However, sustainable practices to maintain the state and well-being of reefs have been largely ignored. Transplanting coral fragments or ramets is one way of restoring damaged portion of reefs. Hence, this study aims to determine the survival and growth rates of ramets in a table type framework deployed at 5, 10, and 20 m depth in three months. Coral fragments found scattered on the reef bottoms were cut into smaller fragments (ramets). There were 16 ramets attached in a single coral nursery unit. One hundred forty three representing three levels of depths and three replicates per depth. Monitoring was conducted monthly. The survivorship of *Acropora nobilis was* found out to be at 88.7%. Ramets had overgrown the plastic cable ties as well as steel bars indicating three dimensional growths. The growth rate of the ramets were high but there was no significant difference found with depth (p=0.066). The highest growth rate was found out to be at 20 m, with a mean growth rate of 0.81 cm mo^{-} . The high survival and growth rate of *A. nobilis* proves that it is a good species for coral reef restoration in Panglao, Bohol.

Keywords coral, growth rate, framework, branching coral, survivorship

INTRODUCTION

Coral reefs have been in existence for many decades, an evident result of the complex constructive process. Among the five major marine ecosystems, coral reefs have the highest levels of marine biodiversity on earth, and play a big role in the highly tangible environment. In the Southeast Asia, a nearly 100,000 km of coral reef (34% of the world's total) can be seen. The species that are primarily abundant around the area are the branching corals, the same species that can be found in the coral reef ecosystem of Panglao, Bohol (USC, 2012).

Branching corals have been slowly declining due to illegal fishing practices, tourism, overfishing, global warming and pollution from land populated areas. A small change in the environmental parameters caused by the aforementioned activities can significantly affect up to 50% of the growth rate of this species (Crabbe and Smith, 2005; Jimenez and Cortes, 2003; Macdonald and Perry, 2003; Kaandorp, 1999). Hence, many have tried developing a technology that could conserve the coral reef ecosystem and mitigate the negative impacts (Lee et al., 2009:

Shaish et al., 2008; Raymundo et al., 2007; Rinkevich, 1995). Recently, researchers in the Philippines also started developing such technology, and pilot tested it at the different parts of the Philippines through the Coral Reef Rehabilitation Project. In this project, the itinerary is usually focused on the coral reef restoration and no studies have been done yet on the growth rate of ramets attached to nurseries deployed at different depths. It is in this context that this study will find its merits.

OBJECTIVES

This study aims to measure the growth rate of *Acropora nobilis* in 3 different water depth layers (i.e., 5, 10, 20 meters during the lowest low tide) in Alona Beach, Panglao Island, Bohol, Philippines.

Specifically, this study aims to

1. determine the survivorship of the ramets attached to the units, and
2. compare the growth rate of the *A. nobilis* in the 3 different water depth layers

METHODOLOGY

Site Description

This study was conducted in Alona Beach, Tawala, Panglao, Bohol (Fig. 1) from April-August, 2013. Alona beach is located at the south part of the island. It has fringing reef that experiences northeast monsoon from November to March and southwest monsoon from June to October, a shallow reef flats that are mostly composed of fine sediments, sands, seagrasses, seaweeds, and algae, and a fore reefs that extend up to several meters with coral cover of approximately 10 percent. Alona beach has been subjected to both natural and human induced destruction such as the typhoon Bupha or locally known as Pablo, improper anchorage, and poor buoyancy control of the divers.

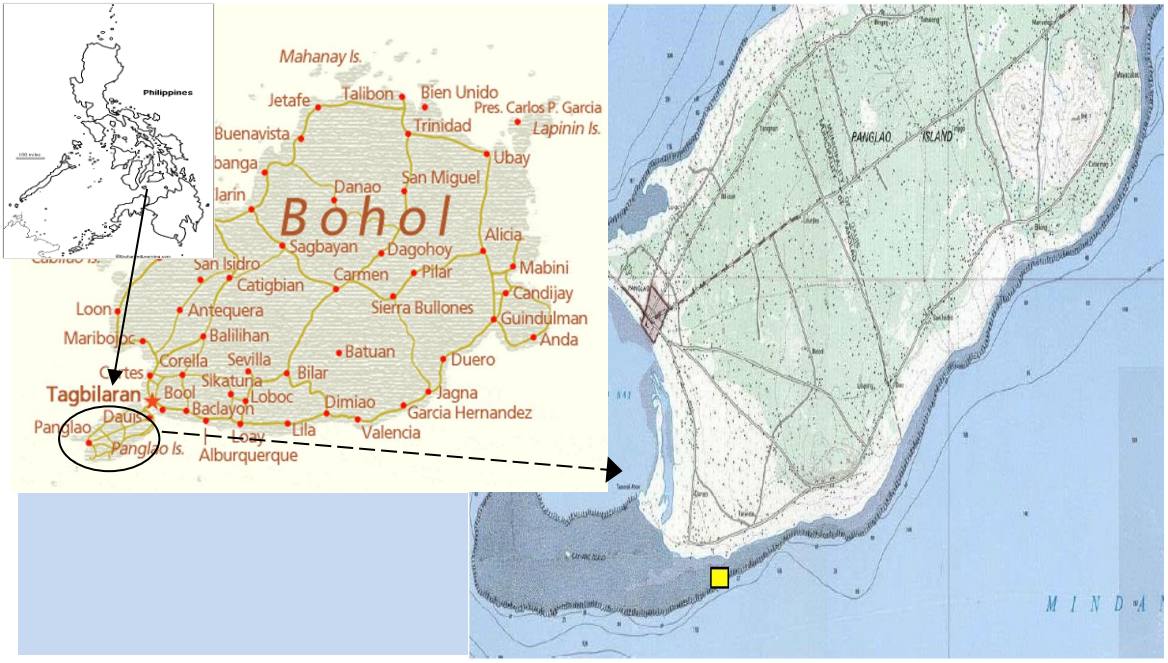

Fig. 1 Map of the study site in Panglao

Coral Nursery Construction

The coral nursery units, Table type were constructed from March 28-April 3, 2013 at Tawala, Panglao, Bohol. The nurseries were made up of 9 mm round bar materials, measuring 50 cm length by 50 cm width, and 40 cm depth with four fixed series of 9 mm round bars running the whole length with 10 cm gap in between and another four fixed series of 9 mm round bars running the whole width with the same gap in between. Additionally, a steel plate was connected to each of the nursery's foot so that it can be fixed on the bottom minimizing movement due to waves and currents. Each nursery was tagged randomly.

Collecting Fragments and Transplanting in Nursery

Fragments of *Acropora nobilis* were collected along the Alona strips. These were placed in red or yellow crates and were brought to waist level seawater. The fragments were cut into 5 cm (SD±0.05) smaller fragments (ramets) using hack saw. A plastic caliper was used to measure the maximum height of the ramets for growth rate determination. Tagging of ramets using dymo tags were done. All ramets were tied firmly with plastic cable ties for anchorage and will be attached to the coral nursery unit in a complete randomize manner. There were 16 ramets in a single coral nursery unit. Overall, there were 144 ramets representing three levels of depths, and three replicates per depth.

Deployment of the Framework Units

A pumpboat was rented when the framework units were deployed. Three framework units were deployed everyday for three consecutive days. The frameworks were attached to PVC rafts that were tied to the outriggers of the pumpboat so that the ramets will remain submerged in the seawater. The units at (20, 10, and 5 m) were placed perpendicular to the shoreline.

Survival and Growth Rate Determination

Survival was monitored every month for three months by recording the status of each ramet as dead, partially dead, bleaching, live, or missing.

After one week of deployment of the units, ramets were photographed with underwater camera. Growth measurement was done using a plastic caliper for calibration. Growth rate was calculated by using Eq. (1):

$$DGR = (Lf - Li) / t_2 - t_1 \quad (1)$$

where: Lf = final length, Li = initial length, t_2 = days terminated, and t_1 = start of study. The same procedures were done after three months.

Maintenance

A monthly dive was done to remove fouling organism (algae, sponges, etc), predators (crown of thorns, sea stars, corallivore snails, etc.), and other debris.

Data Analysis

Statistical analysis was performed using Systat 12. In lieu of one-way analysis of variance (one way-ANOVA) for the growth rate, a non-parametric analysis, Kruskall-Wallis test was used since the data failed to meet the assumptions even after transformation.

RESULTS AND DISCUSSION

Survivorship of the Ramets

Fig. 2 shows that the nurseries deployed in five meters had the highest number of live ramets while the nurseries at ten meters depth had the highest number of partially dead and dead ramets. Survival of all ramets was 88.7% for *Acropora nobilis* which is lower compared to the 94.8-95.8% of the Andaman Sea (Putchim et al., 2007) but is more or less equivalent to the 87% survivorship of the transplanted corals in the outfall of North Florida, USA (Thornton et al., 2000). The cutting and attachment process did not apparently affect their survival. One of the principal concerns about coral transplantation is the effect of relocation. Many have moved corals to different environments and experienced difficulties due to many changes in its habitat (Thornton et al., 2000). The high survival rate of the ramets in this study could be due to the lack of relocation effects.

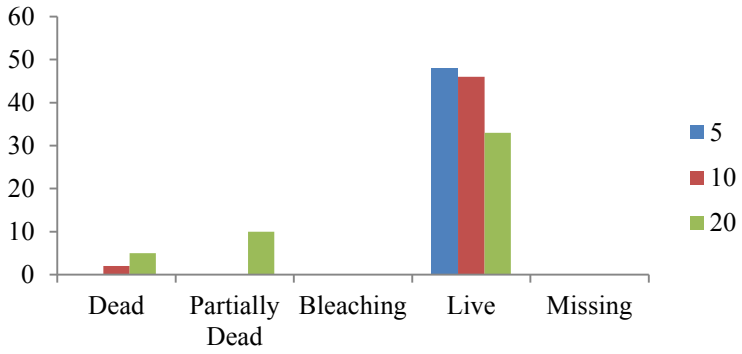

Fig. 2 Survivorship of the ramets at 20, 10, 5 meter depth

Growth Rate

First month after deployment, the ramets started to form new branches (Fig. 3). After three months, the ramets had overgrown the plastic cable ties as well as steel bars (Fig. 4).These indicates that the ramets deployed in three different depths have actually grown three-dimensionally. But, these growth rate showed no significant difference (p=0.066) with depth (Fig. 5). The mean growth rate at 20 m is 0.081 cm/d^{-} (SD ± 0.005) while, 10 m has a mean growth rate of 0.078 cm/d^{-} with (SD ± 0.009) and 5 m depth has a mean growth rate of 0.052 cm/d^{-} with (SD ±0.008). If computed monthly, 20 m has a mean growth rate of 0.81 cm mo^{-} while, 10 m has a mean growth rate of 0.78 cm/mo^{-} and 5 m depth has a mean growth rate of 0.52 cm/mo^{-} which is higher compared the 0.41 cm/m^{-} of the *A. grandis* and 0.23 cm/m^{-} of the *A. muricata* deployed at 8-10 m of the Andaman Sea (Putchim et al., 2007).

Fig. 3 Ramets forming new branches

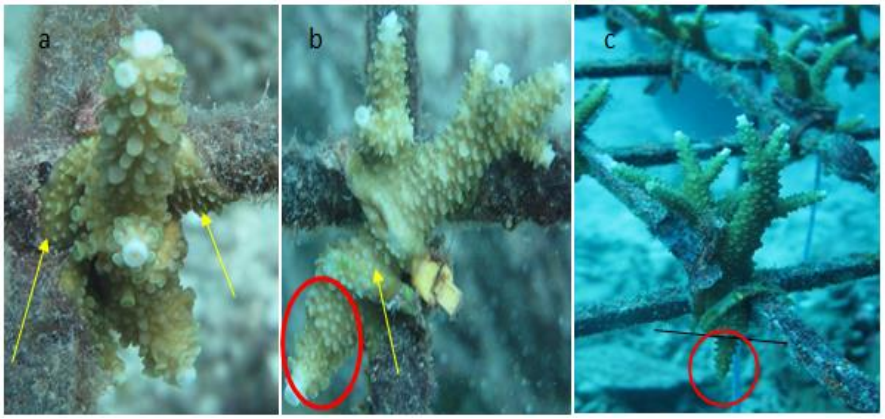

Fig. 4 Ramets overgrowing the steel bar and cable ties

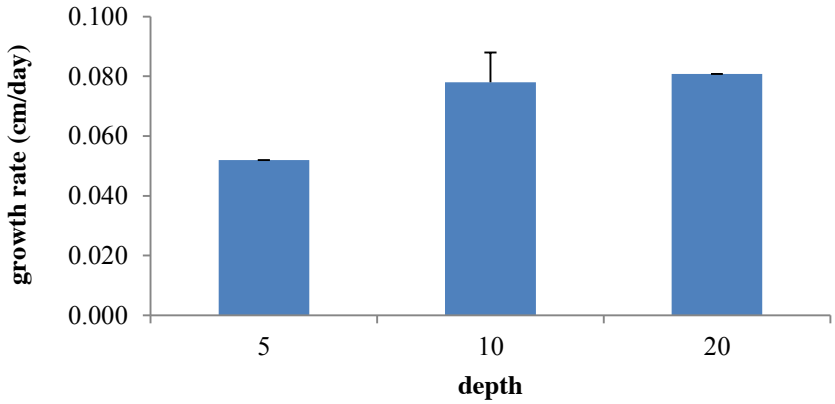

Fig. 5 Growth rate at 20, 10, 5 meter depth

CONCLUSION

In view of the results and discussion, the following generalizations are drawn:

1. Fix-to-bottom framework type is an ideal technique in doing coral reef restoration as it can eliminate the natural predators (e.g., crown of thorns, corralivore snails) from eating the corals that causes mortality to the nurseries. Secondly, it requires lesser maintenance compared to other types of nurseries.
2. Broken live fragments that measures 5 cm (SD±0.05) used as initial growth can give an assurance that the transferred ramets can survived and healed when attached to the nurseries.
3. Ten meter depth is so far the most ideal in doing coral reef restoration using *Acropora nobilis* due to its fast growth rate and less mortality rate.

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REFERENCES

Crabbe, M.J.C. and Smith, D.J. 2005. Sediment impacts on growth rates of *Acropora* and *Porites* corals from fringing reefs of Sulawesi, Indonesia. Coral Reefs, 24, 437-441.

Jimenez, C. and Cortes, J. 2003. Growth of seven species of scleractinian corals in an upwelling environment of the eastern Pacific (Golfode Papagayo, Costa Rica). Bulletin of Marine Science, 72, 187-198.

Kaandorp, J.A. 1999. Morphological analysis of growth forms of branching marine sessile organisms along environmental gradients. Marine Biology, 134, 295-306.

Lee, C.S., Walford, J. and Goh, B.P.L. 2009. Adding coral rubble to substrata enhances settlement of Pocillopora damicornis larvae. Coral Reefs, 28, 529-533.

Macdonald, I.A. and Perry, C.T. 2003. Biological degradation of coral framework in a turbid lagoon environment, Discovery Bay, North Jamaica. Coral Reefs, 22, 523-535.

Meesters, E.H., Bak, R.P.M., Westmacott, S., Ridgley, M. and Dollar, S. 1998. A fuzzy logic model to predict coral reef development under nutrient and sediment stress. Conservation Biology, 12, 957-965.

Raymundo, L.J., Maypa, A.P., Gomez, E.D. and Cadiz, P.L. 2007. Can dynamite-blasted reefs recover? A novel, low-tech approach to stimulating natural recovery in fish and coral populations. Marine Pollution Bulletin, 54, 1009-1019.

Rinkevich, B. 1995. Restoration strategies for coral reefs damaged by recreational activities: the use of sexual and asexual recruits. Restoration Ecology, 3, 241-251.

Putchim, L., Thongtham, N., Hewett, A. and Chansang, H. 2007. Survival and growth of Acropora spp. in mid-water nursery and after transplantation at Phi Phi Islands, Andaman Sea, Thailand. Proceeding of the 11th international Coral reef symposium, Ft. Lauderdale, Florida.

Shaish, L., Levy, G., Gomez, E., and Rinkevich, B. 2008. Fixed and suspended coral nurseries in the Philippines: Establishing the first step in the "gardening concept" of reef restoration. Journal of Experimental Marine Biology and Ecology, 73, 86-97.

Thornton, S.L., Dodge, R.E., Gilliam, D.S., DeVictor, R. and Cooke, P. 2000. Success and growth of corals transplanted to cement armor mat tiles in southeast Florida: implications for reef restoration.

Research article

Determinants of Learners' Intention to Continue Using the E-learning Program of the Agricultural Training Institute (ATI)

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Abstract The study investigated the influence of the learners' attitude, perceived satisfaction and perceived e-Learning effectiveness, on their intention to continue using the ATI's e-Learning program for agriculture and fishery in the Philippines. This study was conducted in the 16 regions of the Philippines where the ATI Network of Regional Training Centers were located. The respondents included 960 adult-learners, consisting of e-Learning enrollees and e-Learning graduates from 2009 to 2012. More than half, (58.9%) of the respondents were females, and nearly two-thirds (66.1%) were married. Their age level ranged from 16 to 63 years old with a mean age of 36 years old. More than half (56%) of the respondents were college graduates. More than two-thirds (67.9%) were agricultural extension workers and had a fair experience with e-Learning. They believed that the ATI's e-learning System is well-established, secure and stable. In its entirety, the respondents were satisfied with the course lab used by ATI. They preferred that a multi-media instruction would be used and recognized that the e-Learning system quality and the interactive learning activities of the program are important. The respondents pointed out that operating e-Learning boosted their self-efficacy/confidence and that the e-learning system is effective because it facilitated their learning efficiency, performance and motivation. They intended to continue the use of the ATI's e-Learning program because they could access a wide array of free digital resources like the course materials used that were placed online and the instructions provided were clear and easy to understand. It enhanced their knowledge and skills that are relevant to their field of specialization. They perceived the course contents as sufficient and related to their interests and they could easily contact the online support team anywhere to answer their queries. In addition, they perceived the instructions provided as sufficiently clear and easy to understand. Learners' ability towards the e-learning program, as well as their perceived satisfaction and effectiveness of the program were significantly related with their intention to continue using the ATI's e-Learning program.

Keywords e-learning, learners' intention, e-extension Philippines, ATI, extension, agriextension

INTRODUCTION

People who care for personal growth and development need to continue learning. This is anchored on the idea that learning is a never-ending process. Losing the drive to learn and explore new methods to enhance the innate knowledge is a plain manifestation of ceasing to grow.

Working for community development is a noble endeavor; thus, it needs continuous learning. It also entails crossing boundaries from the so-called traditional learning to modernized kind of learning in order to achieve what is ought to be achieved and accomplished.

Leary and Berge (2006) disclosed that there is a need to improve agricultural education throughout the world. With agricultural technologies that can facilitate increase in food security especially in the developing world, there is a greater chance that income generating activities of the rural people can be modified, enhanced or improved.

Stienen et.al (2007) pointed out that majority of the rural population in the developing countries depend on agriculture. With the dwindling supply of natural resources needed for agricultural production, this sector faces major challenges of enhancing crop production activities and programs. The increasing demand for agricultural products, however, offers opportunities for producers to improve their livelihoods. Thus, there is a need to inform and educate farmers about the technologies they can possibly use to improve crop production. The use of information and communication technology (ICT) has been identified as a potential information dissemination strategy.

As stipulated in the Philippine Government's Medium Term Philippine Development Plan Year for 2010-2016 (http://www.neda.gov.ph/wp-content/uploads/2013/10/pdprm2011-2016.pdf), the Department of Agriculture (DA) is responsible for boosting the income of farmers as well as reducing the incidence of poverty in the rural sector. The Agricultural Training Institute (ATI), which is the extension arm of DA is responsible for training the agricultural extension workers and their clientele. It facilitates the conduct of multi-level training programs to ensure that research results are communicated to the target farmers thus, promotes rural development

Because the Philippine government only has meager resources, and since there are priority plans set by the government, agricultural training and extension activities have little share in the annual budgetary allocation. Indeed, much of the budget goes to infrastructure development and improvement.

Moreover, Viñas (2010), in her presentation during the Strategic Review of Decentralization for the In-depth Study of Decentralization, pointed out that the major issues and challenges faced by the agriculture sector include the rising number of extension workers in local government units (LGUs) who are slowly deteriorating due to (a) lack of opportunity for technical trainings; (b) lack of scholarship grants; (c) demoralization and non-motivation from the local executives; (d) political appointment/accommodation; and (e) no authority to provide policy, allocate extension resources and monitor the implementation of agricultural extension.

Against this backdrop, Republic Act 8435 of the Philippines, otherwise known as the Agriculture and Fisheries Modernization Act of 1997 or AFMA, was put into law to strengthen the support services for modernizing agriculture and fisheries, and at the same time empower people particularly the stakeholders to help attain sustainable agricultural development with the hope that the food security program will be given highest priority in response to poverty alleviation. The DA-ATI is tasked to assist the local government units' extension system in improving its effectiveness and efficiency through capacity building and complementary extension activities such as technical assistance, training of personnel, improvement of physical facilities, extension cum research and information support services in coordination with state universities and colleges. Among the DA-ATI's main clients are the agricultural extension workers (AEWs) who need to be updated with the new agricultural technologies and extension delivery modalities.

With this, the Department of Agriculture mandated ATI, through the Department Order No. 3, Series of 2007, to lead in the provision of e-Extension services in collaboration with various agencies, bureaus and organizational units of DA. This aims to integrate and harmonize Information and Communication Technology (ICT) - based extension delivery system for agriculture and fisheries.

Raab, Ellis and Abdon (2002 as cited by Liaw, 2007) stressed that e-Learning "is the latest breakthrough of distance learning where instructors and learners are separated by distance, time, or both. Through network technologies, e-Learning creates, fosters, delivers and facilitates learning anytime and anywhere."

Thereby, this study intends to investigate the determinants of learners' intention to continue using the ATI's e-learning program for agriculture and fishery in the Philippines.

METHODOLOGY

This study was conducted in the 16 networks of ATI Regional Training Center in the Philippines. A total of 960 respondents composed of adult-learners (both e-learning enrollees and graduates from 2009-2012.

These respondents were chosen through purposive random sampling at a fixed number of 60 per region from the total population of 5,200 by which the researcher believed that this number is considered to be doable (http://e-extension.gov.ph/elearning/course/report/stats/index.php). However, such method was not materialized for the following reasons: a) some of the respondents from other regions were no longer employed in the Local Government Unit in the municipality since they were hired on casual and/or contractual basis. With the change of administration, these personnel were co-terminus with the incumbent elected officials; b) contact numbers and e-mail addresses were no longer active, hence, they were not contacted and reached; c) most of the students in the state colleges and universities graduated and they were not from the locality and their contact information such as mobile numbers and e-mail addresses were no longer active.

Thus, the researcher opted to send randomly via electronic mail on the addresses given by ATI-Central Office; whereby, each region varied in terms of number, some had higher while others got lower and a few stick to the desired number.

Table 1 Distribution of Respondents

Region	Number of Respondents
CAR	62
ITCPH	37
Region I	60
Region II	51
Region III	42
Region IVa	44
Region IVb	88
Region 5	59
Region VI	50
Region VII	115
Region VIII	65
Region IX	38
Region X	70
Region XI	23
Region XII	38
Region XIII	118
TOTAL	**960**

A survey questionnaire was administered and it was duly supplemented with a focus-group discussion and is implemented and duly managed by e-Extension Coordinators who are responsible in the full operation and implementation of e-learning and other activities per region, respectively.

Aside from actual distribution and retrieval of survey questionnaire, the researcher also sends and generates it through electronic mail.

RESULTS AND DISCUSSION

The respondents in this study included 960 adult-learners (both e-Learning enrollees and graduates from 2009-2012) in all 16 regions in the Philippines.

Descriptive statistics such as frequencies, totals, percentages, and ranges were used to analyze the respondents' attitudes; perceived satisfaction; perceived usefulness of the e-Learning and their intention to continue using the ATI's e-Learning program for agriculture and fishery and their socio-demographic characteristics.

To analyze the relationships among independent and dependent variables, Spearman Rank Correlation and Chi-Square test were used. Cronbach's alpha, on the other hand, estimated the internal reliability of all the items in the survey.

More than half (58.9%) of the respondents were females. Majority (66.1%) were married. The age of the adult-learners ranged from 16 to 63 years with a mean of 36 years. The respondents got high educational attainment which consisted of college graduates (56%); post graduate (28.4%); college level (10.4%); high school (4.8%) and vocational (0.3%). Most (67.9%) of the respondents were agricultural extension workers.

Generally, the respondents had fair level of experience from the scale of 1 having no experience and 5 as very well experienced in terms of typical software applications plus web development with a mean of 3.12; with all of the above skills plus some programming with a mean of 2.76 and extensive programming with a mean of 2.42. However, the adult-learners who already experienced using the internet had obtained a mean of 4.03 and those who had experienced word processing and/or spreadsheet (Microsoft Applications) got a mean of 3.84.

Basically, the respondents agreed with a mean rating of 3.76 as to their beliefs on the stability of ATI's e-Learning program system used because it is already established and secured.

The adult-learners' agreed on all given items towards course lab satisfaction, having an over-all mean rating of 4.17.

In terms of likelihood of using the multimedia instruction on their intention to continue using the ATI's e-learning program for Agriculture and Fishery in the Philippines, the respondents agreed with a mean of 3.96. As a whole, the respondents' perception agreed on their use of the multimedia instruction.

As to the adult-learners' satisfaction of the e-Learning System Quality of the program, the respondents agreed that they were satisfied with a mean rating of 4.04.

In terms of learners' perception on interactive learning activities, the respondents agreed with an over-all mean rating of 4.24 that there was assistance provided for the interactive learning activities of ATI.

All respondents agreed that they were confident in using and operating the e-Learning program with almost the same mean results of 4.0. Moreover, this result was strengthened since their responses were found to be consistent with the same standard deviation of 0.8.

As for the respondents' perceived self-efficacy, all of the respondents agreed that they were confident in using and operating the e-Learning program with almost the same mean results of 4.0. Moreover, this result was strengthened since their responses were consistent with the same standard deviation of 0.8.

For the respondents' perceived e-Learning effectiveness, majority agreed that they believe e-learning can assist learning efficiency; learning performance and motivation.

When asked for the respondents' intention to continue the use of the ATI's e-Learning program, they agreed to further use the program because they could access a wide array of free digital resources, like the course materials used that were placed online and the instructions provided were clear and easy to understand. These responses were generated both on the survey questionnaire and focus group discussion. Moreover, they also agreed that the course contents of the said program were sufficient and related to their interests. Furthermore, they could also easily contact the online support team anywhere to answer their queries.

Generally, the respondents intended to continue using the ATI's e-Learning program to enhance their knowledge and skills that are relevant to their field of specialization with a grand mean of 4.14.

As to the most consistent responses among the five given items, the second statement which is to continue using the e-Learning program because instructions provided are sufficiently clear and easy to understand, got the least standard deviation which is 0.740.

On the Relationship between the Learners' Attitude towards the Program, findings revealed that the learners' attitude towards the system stability has a positive moderate values of correlation with multi-media instruction, e-Learning system quality and perceived satisfaction with the program, having 0.433, 0.456 and 0.454 respectively. However, the learners' attitude towards the system stability appeared to have a positive weak correlation with the interactive learning activities,

perceived effectiveness and the intention to continue the program with values 0.380, 0.374 and 0.390, respectively.

Furthermore, having ranges between 0.40 and 0.59 correlation coefficient, the learners' attitude towards course lab satisfaction showed to have a positive moderate correlation among all environmental factors that affect learners' intention to continue using the ATI's e-Learning program, the perceived satisfaction and perceived effectiveness of the program as well as their intention to use the said program.

Meanwhile, all the correlation coefficients that ranged between 0.40 and 0.59 showed that the environmental factors that affect learners' intention to use the program also appeared to have a desirable moderate correlation with the results of their perceived satisfaction, perceived effectiveness and intention to continue using the ATI's e-Learning program.

Furthermore, the findings illustrated a positive moderate correlation between the learners' perceived satisfaction and the learners' perceived effectiveness of the program and their intention to continue using the said program with values 0.444 and 0.527, respectively.

To sum up, all the Spearman correlation analyses on the selected variables illustrated that the respondents' attitude towards the program, how they perceived the satisfaction and effectiveness of the program and their intention to continue the use of ATI's e-Learning program were most likely related to all other items answered.

The above mentioned findings were also strengthened by the use of Chi-square analyses that examined the significance of relationships among the responses on the items answered to all selected variables.

As to the strengths and challenges of the e-learning program, the adult-learners considered the stated challenges in terms of their participation as manageable and that they could cope with it despite the hindrances that could possibly occur in the e-Learning program with an over-all mean rating of 2.92.

In terms of the extent of influence on the implementation of the program, the respondents answered neutral with an over-all mean of 2.67 wherein they considered these given statements as manageable.

CONCLUSION

The following conclusions are drawn:

1. Most of the adult-learners are in the middle-age category and are college graduates, married and agricultural extension workers and generally have a fair experience with e-Learning.
2. The ATI's e-Learning program is well-established, secured and stable. In its entirety, the respondents are satisfied with the course lab used by ATI.
3. The respondents prefer to use a multi-media instruction program. The adult-learners have recognized that the e-Learning system quality of the program is important as well as the interactive learning activities.
4. Operating the e-Learning system of ATI can boost self-efficacy/confidence of extension workers. The e-Learning program is effective because it assists them in their learning efficiency, performance and motivation.
5. The adult-learners intend to continue the use of the ATI's e-Learning program because they can access a wide array of free digital resources. Consistent with FGD results where learner's said that: *"I intend to continue with e-learning for it gave me satisfaction whenever I see my grades; the knowledge I gained, and the multimedia presentation is enjoyable," quoted by a student-learner*. Moreover, an agricultural extension worker-learner said that: *"Agriculture is a very dynamic field. I need to update my know-how in my field."*

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REFERENCES

E-extension Website of the Philippines. (n.d.) (Retrieved March 27, 2014, from http://e-extension.gov.ph/ elearning /course/report/stats/index.php).

Leary, J. and Berge, Z. 2006. Trends and challenges of e-learning in national and international agricultural development. International Journal of Education and Development using Information and Communication Technology (IJEDICT), 2006, 2, 51-59

Liaw, Shu-Sheng. 2007. Investigating students' perceived satisfaction, behavioural intention, and effectiveness of e-learning: A case study of the Blackboard system. Science Direct. 2007

The National Economic and Development Authority. (Retrieved October 13, 2012, from http://e-extension.gov.ph/elearning/course/report/stats/index.php)

Stienen, J., Bruinsma, W. and Neuman, F. 2007. How ICT can make a difference in agricultural livelihoods. International Institute for Communication and Development (IICD) Agriculture. The Commonwealth Ministers Reference Book

Viñas, Y.G. 2010. Decentralization in agriculture sector. Drawn from the presentation during the strategic review of decentralization for the indepth study of decentralization. (Retrieved November 7, 2012, from: searca.org/index./da decentralization agriculture/download)

Research article

Educational Benefits of Green Tourism School Trips in Japan

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Abstract In Japan, green tourism (rural tourism) continues to grow in popularity. This form of tourism is expected to increase the nation's interest in agriculture and promote more interactions between urban and rural people. In Hokkaido, school trips that include hands-on agricultural activities are becoming widely accepted as a new type of green tourism. However, despite wide acceptance, the effects of these trips and related hands-on activities have not been sufficiently evaluated. In this research, the author investigated the educational benefits of school-trip-style green tourism. Surveys were conducted on students from three high schools (n = 597 students) after they had participated in school trips in 2013. The surveys showed that students without any past experience in agriculture tended to have stronger positive feelings towards agricultural activities and farmers. In addition, students also became more interested in becoming farmers in the future. Moreover, because of such visits, the students showed increased interest in food and crops. However, their awareness of agricultural water-use facilities, management organization, and the multifunctional benefits of agriculture was low; this lack of awareness was not related to previous agricultural experience. Therefore, to understand the fundamental benefits of agriculture, simple hands-on activities are not enough. In addition, the program must include lectures that explicitly demonstrate how agriculture preserves natural resources, contributes to a green society, and feeds the nation.

Keywords green tourism, questionnaire research, agricultural experience, school trip

INTRODUCTION

In Japan, green tourism (GT) has been recently promoted and tested as a way to help revitalize rural communities and stimulate interactions between urban and rural people. Green tourism is also called rural tourism, agro-tourism, or ecotourism. Over the current decade, the number of facilities involved in rural tourism has doubled in Hokkaido, which is in the northern part of Japan. This increase is especially prominent in the Kamikawa and Sorachi districts. The increase in the number of facilities is mainly due to increase in the number of visits to farms, farm homesteads, and other agricultural activities. This increased interest correlates with increases in the number of school trips to agricultural areas that were triggered by the *Children's Rural Area Interaction Project* (2008–) and the *Integrated Study in Schooling* (2004–) (Ikegami, 2003, Sawauchi et al., 2009). The diffusion of GT is believed to be contributing to growing public interest in agriculture and rural areas. Green tourism is also believed to be improving public understanding of land improvement projects because young people who have had experiences in rural areas will be part of the next generation that will implement policies for managing those areas. Therefore, it is important for us to understand how participants are affected by school trips to rural and agricultural areas.

However, there have been few evaluations of the effects of GT on participants or of whether current GT programs provide an adequate educational experience. Many previous studies of GT have been confined to its institution worldwide or to the possibility of using GT as a marketing strategy for activating interest in local agriculture. Moreover, few studies have been performed on any impact that GT may have on visitor awareness, appreciation, or understanding of agricultural problems. A few studies of using agricultural visits as educational platforms have involved

elementary students in the research (Yamada, 2006, 2008), and a few studies were intended for high school students. In analyzing student and farmer attitudes to rural tourism with agricultural activities, Kuraoka et al. (2009) found that many students reported positive reactions to their interactions with farmers and to farmer lifestyles. Sawauchi et al. (2009) surveyed high school students who had participated in school trips with agricultural activities; their findings showed that students tended to appreciate the connections with nature and the influence on social life provided by the agricultural experience. These studies serve as the theoretical foundation for this study.

The purpose of this study is to determine how school trips with agricultural activities affect students awareness towards agriculture and whether such trips affect students attitude towards rural communities.

METHODOLOGY

The author surveyed second-grade high school students in ordinary senior high school "A" in Tokyo and in ordinary senior high schools "B" and "C" in Hiroshima Prefecture. These students were participants in school trips with agricultural activities in Naganuma Town, Hokkaido Prefecture. Each set of students participated in agricultural activities over three days and two nights from September to October in 2013. For students from the A and C high schools, questionnaires were returned within one week after their trip. For students in the B high school, the questionnaires were collected soon after their visit. Naganuma Town has participated in these school trips for a decade, and each school has participated for over two years.

The questionnaires addressed three main issues: (a) awareness of land improvement and water management facilities, (b) satisfaction with the school trip experience, and (c) educational evaluation after the experience. Questions addressing parts (b) and (c) were based on previous studies by Yamada (2006) and Sawauchi et al (2009). Statistical analyses of student responses were performed using Microsoft Excel and statistics software R.

Table 1 Respondent attributes

Question	Responses		
Gender (n=596)		Male 268 (45.0)	Female 328 (55.0)
Farmland situation around the residence (n=596)	No existence 204 (34.2)	In patches 305 (51.2)	Spreading around 87 (14.6)
Are your family or relatives farmer? (n=594)		Yes 243 (40.9)	No 351 (59.1)
Did you have an agricultural experience before this school trip? (n=597)		Yes 373 (62.5)	No 224 (37.5)
When have you experienced agriculture at first? (multiple answers allowed) (n=373)	Before entering elementary school 81 (21.7)	Elementary school days 304 (81.5)	Junior high school days 130 (34.9)
Have you ever stayed in farmer house for trip? (n=597)		Yes 171 (28.6)	No 426 (71.4)

(n: valid respondents number, The values in parentheses mean % of valid responses)

RESULTS AND DISCUSSION

Respondent Attributes

More than 50% of respondents reported at least partial farmland near their residences, while about 35% stated that there was no farmland near their residences. About 40% of the students were in a

family of farmers or had relatives who were farmers. Almost 60% of students had had an agricultural experience before this school trip, and many of them had experiences in their elementary schools. About 70% of respondents had not stayed overnight in a farmhouse. The results are summarized in Table 1.

Awareness of Land Improvement District and its Facilities

Regarding awareness of land improvement districts, agricultural water-use facilities, and agricultural multi-functionality, more than 85% of the students answered *they don't know* (Fig. 1). Since the survey was carried out after the agricultural visit, the author presume that students did not receive specific instruction about these issues during trip preparation or during the agricultural visit itself.

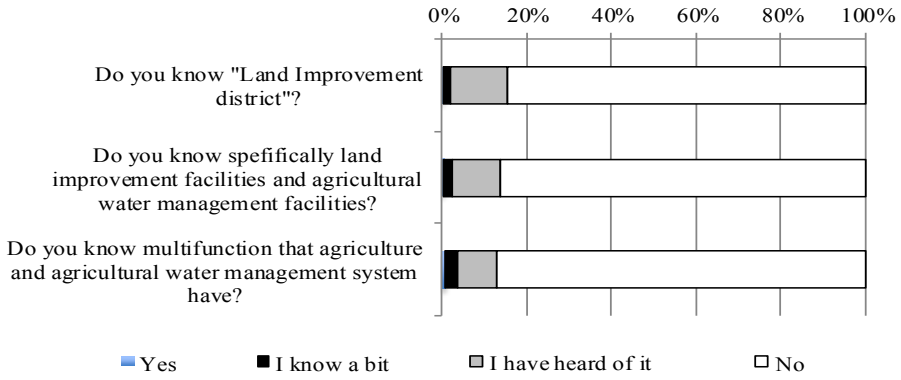

Fig. 1 Survey results for student awareness of land improvement district and its facilities

Impression of the Tour

Table 2 shows the results concerning impressions about the agricultural experience and staying in farmhouses. The table clearly shows that most students had positive interactions with the farmers and they were impressed by the surrounding landscape. As to the particular agricultural activities, more than 60% of the students participated in harvesting, about 41% did other work, and about 35% did weeding. These percentages sum to more than 100% because many students performed more than one activity. Many of the other-work activities involved shipping, such as sorting and packing associated with the harvest season during which the visits were done. Majority students reported that their most memorable activity was spending time with the host farmers; they were less affected by the agricultural activities or with looking at the landscape.

Educational Effects of Agricultural Activities

Table 3 shows the results for educational effects of the agricultural activities. Students were asked to rate their degree of change in awareness at one of five levels via one of these possible responses: agree (5), agree a little (4), neither agree or disagree (3), disagree a little (2), or disagree (1). The table gives the average of these possibilities for each question. Moreover, for each question, a large average score corresponds to a large change in awareness. As in previous studies (Yamada, 2008, Kurauchi, 2009), the questions were divided into three categories: connections with nature, mental attitudes, and connections with social life.

For many questions, the average scores fell between 3.0 and 4.0; this indicates that the school trips generally had a positive influence on the mental attitudes of the students. These results are generally corresponding to those in a previous study. In this study, there were four questions that had scores above 4.0, while in the previous study, less than six had scores above 4.0. Scores were less than 4.0 for the following two questions: "you felt a joy or pleasure to take harvests" and "you

became to mind an importance of cooperation and partnership." But in the previous study, the same questions had scores above 4.0.

For the question "you felt a joy or pleasure to take harvests," responses of "agree" were segregated by high school as follows: about 50% in high school A, about 40% in B, and less than 30% in C. These differences between schools caused the smaller average compared to the previous results. These differences might be related to the relative amounts of time students in each school actually spent in harvesting. Comparing the different farming activities, the ratios of students that did harvesting were in the order A > C > B. So participation in harvesting was not lower in high school C. However, overall work times were generally shorter for students in school C. In particular, for students in school C, 51% of the work time was within two hours. But for students in schools A and B, only 30% of the work time was within two hours (Table 4).

For the question "you became to mind an importance of cooperation and partnership," 70% of the students in each school answered "agree" or "agree a little." However, for high school C, the percentage of "agree" was lower than those for the other two schools. This explains the smaller average score for this question. Responses to the two questions, "you became to mind an importance of cooperation and partnership" and "you felt a joy or pleasure to take harvests" had a higher correlation (0.695) than other relations. So, although we anticipated that the amounts of work time would influence the responses to these two questions ("mind of cooperation and partnership" and "joy or pleasure to harvesting"), correlations were low between work time and the responses.

Table 2 Impressions of agricultural activities and living in a farmhouse

Question	not at all	a little	neither	quite a lot	very much
Could you enjoy the interaction with farmers in this school trip?	10 (1.7%)	8 (1.3%)	13 (2.2%)	98 (16.4%)	467 (78.2%)
Could you enjoy the rural landscape in this school trip?	7 (1.2%)	13 (2.2%)	16 (2.7%)	132 (22.1%)	429 (71.9%)
Which kinds of farming work did you do ? (Multiple answers allowed)	seeding	transplantation	weeding	harvesting	others
	17 (2.8%)	6 (1.0%)	206 (34.5%)	353 (59.1%)	247 (41.4%)
Which matters do you stand out in your memory in this school trip? (Multiple answers allowed)	life in farmers house such as meal or sleep	talking and spending along with host farmer	spending days along with friends	agricultural experiences	viewing of rural landscape
	319 (53.4%)	367 (61.5%)	309 (51.8%)	284 (47.6%)	211 (35.3%)

Only one question had a score below 3.0:"you'd like to become a farmer in the future." Responses to this question for each high school were 2.72 in school A, 3.16 in B, and 2.46 in C. The average for the three schools was 2.72 (Table 3). Schools B and C are in the same prefecture. It is somehow expected that more local students would prefer to become farmers than urban students but results show that, even in the same prefecture, attitudes towards employment differ greatly. Correlations were comparatively higher between "you'd like to become a farmer in the future" and each of these questions: "mind to care about nature and creature grew up," "your knowledge and understanding to food and crops deepened," and "your knowledge to agriculture deepened." This means that more activities in agricultural programs like these have the potential to encourage certain students to engage in farming in the future.

Compared to other relations, correlations were lower between respondent attributes and perceived educational benefits of the visits. This suggests that earlier agricultural experiences and student residential environments were not direct factors in changing students attitudes towards agricultural activities. This indicates the possibility that future education can improve students attitudes towards agriculture.

Table 3 Educational effects of school trip with agricultural activities

	Question	Score	Previous Score*
(a)	Connection with nature		
	you felt a joy or pleasure to take harvests.	3.95	4.46
	mind to care about foods grew up.	4.29	4.18
	mind to care about nature and creature grew up.	4.10	4.17
	you have become interested in food and crops.	4.03	4.02
	you have become interested in nature and creature.	3.78	3.84
	your knowledge and understanding to food and crops deepened.	3.77	3.61
	you developed abilities of observation and scientific knowledge to nature and creature.	3.46	3.22
(b)	Mental phase		
	you became to be cheerful and vigorous person.	3.86	3.79
	you are able to get widly sense of value.	3.67	3.71
	your sensibility was cultivated.	3.30	3.49
	Aggressiveness and independence grew up.	3.69	3.42
	you became to be even-tempered person.	3.46	3.38
	you became to be a patient person.	3.58	3.33
	your expressiveness improved.	3.49	3.28
	your imagination faculty improved.	3.43	3.28
(c)	Connection with social life		
	you understood an importance of sweating with effort.	4.09	4.27
	you became to mind an importance of cooperation and partnership.	3.95	4.21
	you'd like to live in this region.	3.63	3.69
	you became interested in agriculture.	3.73	3.63
	your knowledge to agriculture deepened.	3.73	3.63
	you have thought seriously about your future (e.g., occupation).	3.68	3.60
	your knowledge to region you stayed in deepened.	3.72	3.52
	you'd like to become a farmer in the future.	2.72	2.46
		3.78	3.84

note：Score means the average point of the following answer.
5=Agree, 4=Agree a little, 3=Neither agree nor disagree, 2=Disagree a little, 1=Disagree.
**Quoted from Sawauchi et al.（2009）*

Table 4 Working time in a day

	How many hours did you work in a day? (average)					
School	0-1	1-2	2-3	3-4	4-5	Over 5(hr)
A	6.1%	25.0%	38.3%	17.9%	6.6%	6.1%
B	5.4%	21.8%	22.4%	19.7%	17.0%	13.6%
C	18.0%	33.2%	21.2%	17.6%	6.8%	3.2%

CONCLUSION

In this study, surveys were administered to high school students who had participated in school trips to farms in rural areas. During the trips, students interacted with farmers and their families and engaged in agricultural activities. The surveys were designed to measure the educational benefits in particular agricultural, provided by the trips. The results show that agricultural activities during the trips were effective in increasing students interests in agriculture, particularly for those students who had had no previous exposure to farming. These results were generally corresponding to those in a previous study. The author expected that students attitudes would depend on their place of residence and on earlier agricultural experience; however, no such tendency was exhibited in this study. Although many students had strong positive reactions to their time spent with farmers, the students had little awareness of land improvement policies that support rural agriculture or of the multifunctional effects of agriculture on society. To deepen students awareness of these issues, not

only should students participate in agricultural activities, but farmers should also explain the role of land improvement and the many benefits agriculture provides to society.

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REFERENCES

Ikegami, K. 2003. Agricultural education in elementary education, agriculture/ agricultural education/ diffusion of agriculture (editorial supervisor; Soda O.). Rural Culture Association Japan, 399-461.

Kuraoka, K., Sawauchi, D., Yamamoto, T., Sajiki, T. and Toguchi, T. 2009. An analysis on agricultural experiences of a school trip. The Review of Agricultural Economics, 64,105-111.

Sawauchi, D., Kuraokaoa, K., Sajiki, T., Toguchi, T. and Yamamoto, T. 2009. Evaluation of high school students' agricultural experiences during a school trip, Journal of Rural Problems, 45 (1), 133-136.

Yamada, I. 2006. A tool of planning programs of agricultural experience for children based on the relation between way of programs and educational effects. Technical Report of the National Institute for Rural Engineering, 204, 23-31.

Yamada, I. 2008. The effects of agricultural experience on the emotion and interest of children: A comparative study of three urban primary schools, Journal of Rural Problems, 170, 326-336.

Research article

Assessment on the Solid Waste Management and Sanitation Programs in the Municipality of Balilihan

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Abstract The study was conducted to assess the sanitation and solid waste management (SWM) programs and its practices implemented by the Municipality of Balilihan, Bohol during the Academic Year 2013-2014. This study used the descriptive-survey method with the aid of a researcher's made questionnaire which was administered to 1,152 respondents representing 31 barangays of Balilihan. Based on the result, it was found out that most of the respondents oftentimes practice the proper SWM and the programs are oftentimes observed. In terms of Sanitation, majority of the respondents always practice the proper way and the programs are always observed. The conclusions revealed that SWM programs and SWM practices have a consistent result of oftentimes observed and oftentimes practiced. These simply explained that the programs and measures were known to some respondents and some did not give attention to support the programs. Sanitation programs and practices were also consistent of always observed and always practiced. The result shows that the residents nowadays learned to care for sanitation unlike in the past where sanitation was given less attention. It is recommended that the Local Government Unit of Balilihan should collaborate with other stakeholders for public campaigns on proper sanitation and SWM practices. Also, strict monitoring and evaluation should be developed to provide clear strategic direction to Local Integrated Solid Waste Management and procurement of additional vehicles to enhance the efficiency in the garbage collection. Another, that activities such as Barangay Participatory Evaluation and Assessment, House-to-House Campaign, convene the residents for an Orientation Seminar on solid waste segregation, Posting of streamers, posters, house tags and bill boards should be undertaken to raise awareness on solid waste management and encourage the public to recycle recyclable items.

Keywords solid waste, solid waste management, sanitation, sanitation management

INTRODUCTION

One of the problems confronting the country today is the solid waste disposal. The disposal of waste materials has become a race between education and catastrophe. Through man's activities, his own environment has been disturbed and so, degraded resulting to the disruption of the ecological balance (Cunningham and Cunningham, 2008). It implies that future waste will pose greater health and environmental risks. Meanwhile, in the present condition in Balilihan, it is evident that in the past ten years, municipality's population, infrastructure facilities and business activities have been increasing. These socio-economic changes, however, have resulted in rising solid waste generation and it is aggravated by improper SWM practices of waste sources. At present not only the poblacion barangays are being served by the municipal waste collection services, but the entire 31 barangays are included.

Recognizing the need to take steps in addressing this solid waste problem and pursuing the thrust to make Balilihan as an eco-tourism site, the Local Government of Balilihan has developed the Ten-Year Integrated Solid Waste Management Plan (ISWM) for 2009-2018 (Municipality of Balilihan, 2009). The town is implementing strategies to improve local solid waste management. This plan was not made only to satisfy the mandate of the Ecological Solid Waste Management Act of 2000 or RA 9003, but also to guide the LGU to achieve its Vision, Mission, and Goals for an effective ISWM Program that would aid in the LGUs general long term objective for a responsible development in the municipality.

As for that basis, to show that BISU Balilihan Campus as an educational institution supports the program of the local community, the faculty were motivated to conduct a study that determine how far the local government unit of Balilihan have implemented their Solid Waste Management and Sanitation Programs and to further assess the practices of the Balilinhon on solid waste management and sanitation and in one way helped enrich the consciousness of the people and become responsible in their actions. Besides, this will serve as a guide in improving the well-being of the town and could further upgrade the living standards through a clean and healthy environment (Austral, 2008; Bordador, 2005; Navarro, 2010).

OBJECTIVE

The study was conducted to assess the status of implementation of the sanitation and solid waste management programs of the Municipality of Balilihan, Bohol and to assess further the practices of the Balilinhon on solid waste management and sanitation during the Academic Year 2013-2014.

METHODOLOGY

Research Design

The study used descriptive survey method with the aid of a questionnaire. Its main purpose is to assess the implementation of the SWM and Sanitation Programs set by the Local Government of the Municipality of Balilihan. This study was also designed to assess the practices of solid waste management and sanitation in every household.

Sampling Procedure

The local of the study was the municipality of Balilihan. It was composed of 31 barangays with a total household of 3840. 30% of the total household population which is 1152 was the sample size. The respondents were chosen through random sampling in which, 30% of the population of every purok in every barangay was randomly selected.

Methods of Data Collection

The researchers asked permission from the office of the Municipal Mayor to conduct this study. Barangay Captains of the different barangays were also informed before the questionnaires were distributed.

The prepared questionnaires were validated through pilot testing to neighboring town. The final copy of the questionnaire was translated into Mother tongue language for the respondents to fully understand each statement.

The validated copy of the questionnaire was distributed personally to the respondents. Retrieval was done immediately after answering. It was tabulated and interpreted when all the data were gathered.

Hundred percent of the respondents answered all items in the questionnaire. Since the researchers personally distributed the questionnaire to the respondents, they will be able to emphasize the importance of their responses.

Analytical Procedures

To determine whether the programs are properly implemented by the Local Government of Balilihan, the average weighted mean was used.

$$\text{Formula: WM} = \frac{\sum fw}{\sum f} \quad (1)$$

where WM = weighted mean, f = frequency, w = weight

The means were interpreted and given the scale values for Programs and Practices.

Weighted Mean	Description	
3.25 – 4.00	Always Practiced/ Always Observed	(Habitual-Above the median)
2.50 – 3.24	Oftentimes Practiced/Oftentimes Observed	(A little above the median)
1.75 – 2.49	Seldom Practiced/Seldom Observed	(A little below median)
1.00 – 1.74	Never Practiced/Never Observed	

RESULTS AND DISCUSSION

Table 1 Assessment on solid waste management programs

	Waste Management Programs	WM	Description
1.	Full waste segregation of wastes into biodegradable, recyclable, residual and special wastes;	3.23	Oftentimes Observed
2.	No segregation, no collection policy;	3.15	Oftentimes Observed
3.	Information dissemination campaign through general assemblies, stickers are posted in public areas and leaflets for the use of biodegradable environmental friendly materials.	3.20	Oftentimes Observed
4.	Livelihood programs for recyclable materials	3.14	Oftentimes Observed
5.	Prohibition of burning and dumping of waste in an open area or vacant public lots.	3.16	Oftentimes Observed
6.	Give incentives at the Barangay level for greater implementation on Solid Waste Management and Environmental clean-up.	3.07	Oftentimes Observed
7.	Requiring local farmers to practice organic fertilizer.	3.11	Oftentimes Observed
8.	Promote the following waste practices: waste reduction, recycling and composting.	3.18	Oftentimes Observed
9.	Prohibition of dumping of waste in an open area or vacant public lots.	3.19	Oftentimes Observed
	Average Weighted Mean	**3.15**	**Oftentimes Observed**

Table 1 shows the Solid Waste Management Programs in the household sector. This shows that most of the programs are "oftentimes observed" with an average weighted mean of 3.15 in spite of its strict implementation.

The government is one of the agencies that take a very critical rule in conserving the environment since they have the full authority to control the massive negative effect against the destructive environmental practices.

Likewise, the government is doing a massive campaign on the use of biodegradable environmental friendly materials. However, the result indicates the need to further empower the campaign to elevate their responses as shown in item no. 3 with an WM of 3.20. On the other hand, one way of motivating residents to promote proper implementation on Solid Waste Management is to give incentives to those who are good followers to the imposed policy. However, the respondents revealed that there is a need to initiate "gimmick" to encourage the residents to participate in such program. This item has a WM 0f 3.07.

Furthermore, the responses of the remaining items fall into "oftentimes practiced". These are item number 4 and 7 which is an indication that there are still SWM programs which are not fully recognized by the people within the area.

On the other hand, hundred percent of the respondents answered all items in the questionnaire. Since the researchers personally distributed the questionnaire to the respondents, they will be able to emphasize the importance of their responses.

Table 2 Actual solid waste management practices

Solid Waste Management Practices	WM	Description
A. Disposal of Waste		
1. Biodegradable Waste		
a. No burning	3.03	Oftentimes Practiced
b. Used as fertilizer	3.07	Oftentimes Practiced
c. Placed in the compost pit	3.58	Always Practiced
d. Practice segregation	3.03	Oftentimes Practiced
e. Leave it to decompose elsewhere	2.30	Seldom Practiced
Average Weighted Mean	**3.14**	**Oftentimes Practiced**
2. Non-biodegradable such as plastic, cellophane, bottles, styrofore		
a. No burning	3.03	Oftentimes Practiced
b. Placed in the garbage can for non-biodegradable waste.	3.12	Oftentimes Practiced
c. Send to the garbage collector	3.05	Oftentimes Practiced
d. Self recycling to those that can be utilized	3.3	Always Practiced
e. Market sellable waste	3.75	Always Practiced
Average Weighted Mean	**3.25**	**Oftentimes Practiced**
3. Breakable		
a. Put/throw to garbage container intended for delicate and fragile.	3.03	Oftentimes Practiced
b. Market sellable wastes	3.28	Always Practiced
c. Recycle and utilize	3.25	Always Practiced
d. Sent to the garbage collector.	2.99	Oftentimes Practiced
Average Weighted Mean	**3.13**	**Oftentimes Practiced**
B. Other Practices		
1 . Comply waste collection schedule.	2.94	Oftentimes Practiced
2 . Refrain from using disposable plastic materials.	2.45	Seldom Practiced
3 . Participate community clean-up activities	3.85	Always Practiced

Table 2 indicates the SWM Practices of the respondents. It shows that item "Placed it in the compost pit got the highest mean response of 3.58 with the qualitative response of "Always Practiced". The result implies that the respondents often practiced to decompose their biodegradable waste and placing it in the compost pit. Item on "Leave it to decompose elsewhere got the lowest weighted mean of 2.3. The respondents are cognizant of the possible health and environmental problems if their wastes are scattered anywhere.

In terms of non-biodegradable wastes, it shows that item "Market sellable wastes and self recycling to those that can be utilized" got the mean of 3.75 and 3.3 respectively with a descriptive rating of "Always Practiced. The respondents observe thrift and even make money out of their wastes. While on the other hand, items, "Placed it in the garbage can for non-biodegradable waste, no burning, and sending it to the garbage collector were rated as Oftentimes practiced by the respondents. This means that there are still respondents who are not fully aware of the negative outcome of their activities.

Table 2 also indicates the SWM practices in terms of fragile/breakable and hazardous wastes. The practices that always perform by the respondents are the marketing of sellable waste and

recycling and utilizing wastes. Other important practices are leaved behind. It means that majority of the people are not so careful of the probable accidents or other problems which their acts may cause.

On the other hand, other practices aside from waste disposal waste are shown on the table. As manifested, participating community clean-up activities were always practiced by the respondents. This is a manifestation that the people are cautious in maintaining the cleanliness of their surroundings. However complying collection schedule and refraining from using disposable plastic materials were oftentimes practiced.

Table 3 Assessment on sanitation programs

	Sanitation Programs	WM	Description
1 .	Municipal ordinance requiring all household to use water sealed toilet.	3.91	Always Observed
2 .	Regular checking of water supply by sanitary inspector.	3.62	Always Observed
3 .	Municipal ordinance requiring all household to create safety septic tank.	3.86	Always Observed
4 .	Conducting symposium, lectures, forum or campaign about sanitation.	3.21	Always Observed
5 .	Regular monitoring of commercial water refilling station and private water sources by sanitary inspector.	3.61	Always Observed
6 .	Ordinance prohibiting the dumping of solid waste, toxic materials and garbage in canals and drainage.	3.73	Always Observed
	Average Weighted Mean	**3.66**	**Always Observed**

Table 3 shows the various sanitation programs formulated by LGU Balilihan. Based on the results, the implementation of the programs and measures was always observed by its constituents. It garners an average weighted mean of 3. 66. Based on the results, item 1 which is "Municipal ordinance requiring all household to use water sealed toilet" got the highest rating of 3.91 which means always observed. Authorities strictly implemented, evaluated and monitor the program. They also provide free water sealed toilet for the less fortunate just to ensure full implementation of the program.

In addition, the item 3 which is "requiring all households to create safety septic tank" and item 6 "The ordinance prohibiting the dumping of waste in canals and drainage" got second in the rank. Based on the result, majority of the respondents are already disposing their wastes in a septic tank. However, there are still few, especially those who are situated far from their neighbors, who just throw their wastes in their yard or drainage. They believed that as long as they cannot bring any problem to other people, it is just fine to throw their garbage anywhere.

The Municipality of Balilihan has abundant water supply. Based on the result, the residents of Balilihan always observed that these sources of water (water refilling stations, private water sources and other water supply) were regularly checked by the public sanitary inspector. In fact, there were only rare cases of health problems among the residents which is caused by contaminated water supply.

Table 4 presents the Sanitation Practices related to toilet facilities; water supply; sewage, refuse container, laboratory, canals and drainage system in the household area. Based on the result, the respondents were always using clean water sealed toilet with the average weighted mean of 3.96, functional septic tank with 3.93, adequate supply of water for toilet maintenance with 3.93. The respondents are educated already of these proper sanitation practices.

In terms of water supply, majority of the respondents answered "always practiced" that bottled drinking water from a supplier is handled, stored and protected from contamination with the highest average weighted mean of 3.73. This means that the respondents were very cautious of the water they drink. It's a good sign that they are protecting their health against illnesses and diseases.

It also revealed in the table that the respondents always dispose sewage discharge in a proper receptacle, make use of functional lavatory, provide tight fitting lids to refuse container, and make sure that drainage are in good working condition with an average weighted mean of 3.92, 3.90, 3.86 and 3.74 respectively. The respondents have responded positively the programs of the municipality.

Table 4 Actual sanitation practices

Sanitation Practices	WM	Description
Toilet		
1. Use of clean water sealed toilet.	3.96	Always Practiced
2. Make use of adequate supply of water for maintenance.	3.93	Always Practiced
3. Utilize functional septic tank.	3.93	Always Practiced
Average Weighted Mean	**3.94**	**Always Practiced**
Water Supply		
1. Make use of drinking water from a source (pipe) that passed the requirements of sanitary inspection.	3.39	Always Practiced
2. Bottled drinking water from a supplier is handled, stored and protected from contamination.	3.72	Always Practiced
3. Regular checking of water stored in the container against contamination and insects.	3.68	Always Practiced
Average Weighted Mean	**3.60**	**Always Practiced**
Refuse Container, Lavatory, Canals and Drainage		
1. All sewage discharge are disposed in a proper receptacle.	3.92	Always Practiced
2. All refuse containers are provided with tight – fitting lids or cover and maintained to be vermin (pests, rats, mice, cockroach, etc.) proof.	3.86	Always Practiced
3. Make use of functional lavatory.	3.90	Always Practiced
4. Make sure that canals and drainage are in good working condition that allow the flow of water and free from vermin (pests, rats, mice, cockroach, etc.)	3.74	Always Practiced
Average Weighted Mean	**3.85**	**Always Practiced**

CONCLUSION

1. Solid Waste Management Programs were not fully enforced in the Municipality of Balilihan as supported by the Solid Waste Management Practices in the household.
2. Lack public awareness and information campaign of the significant impact of the proper solid waste management.
3. Decomposed waste is not properly used for fertilizer by the farmer.
4. There are still residents who dispose biodegradable waste within their compound.
5. Irregular schedule of garbage collection result to dumping of garbage in the roadside.

REFERENCES

Austral, L.P. 2008**.** Awareness on environmental issues, college students, university of Bohol, Tagbilaran city: Proposed Enhancement Program. University of Bohol, Phillipine.

Bordador, M.C.V. 2005. College biology. Anvil Publishing, INC.

Cunningham, W. and Cunningham M. 2008. Principles of environmental science, inquiry and applications. Published by McGraw-Hill, USA.

Navarro, V.N. 2010. Biodegradable waste management in duero vermi composting model. University of Bohol, Phillipine.

Salgados, J.M. 2010. Solid waste awareness, practices, problems and issues of households in Tagbilaran City**:** Intervention Program**.** Unpublished Dissertation, Cebu Normal University, Cebu City, Phillipine.

Municipality of Balilihan. 2009. Ten (2009-2018) years integrated solid waste management plan. Municipality of Balilihan, Phillipine.

Research article

Impacts of Pyroligneous Acid to Biological and Chemical Properties of Depleted Soil in Bohol, Philippines

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Abstract This paper presents a part of a bigger research project to validate the use of Coconut Shell Pyroligneous Acid (CSPA) in agriculture and to find out its efficacy in rehabilitating a depleted soil in Bohol, Philippines. Specifically, this study will find out the impacts of CSPA on the biological and chemical properties of depleted soil. Pyroligneous acid used in this study is a by-product of coconut shell charcoal making. The CSPA was used in combination with rain water. There were three concentrations used: 10%, 20% and 30%. Soil samples from depleted site in an upland farm were brought to the laboratory for analysis. Soil acidity changes in all treatments in an indirect proportion and organic matter has increased by 1 in soils receiving 10% and 30% CSPA and 0.5 in soils receiving 20% CSPA. From a baseline data of an "extremely acid soil", soils receiving 10% and 20% CSPA lowers to "strongly acid" category while those receiving 30% changed to "very strongly acid". Soils applied with 10% and 20% CSPA did not change the phosphorous value but it decreased by 3 in those applied with 30% CSPA. All treatments did not make any changes in potassium deficiency. For its biological study, it was found out that soil fauna in all treatments has a moderate Simpson's index value. There were seven groups of arthropods found: order Acarina of class Arachnida and orders Coleoptera, Collembola, Dermaptera, Diptera, Hemiptera, and Hymenoptera of class Insecta. It was found out that treatments that received high percentage of pyroligneous acid got a high faunal population. The study concluded that pyroligneous acid has demonstrated impacts to the biologicl and chemical aspects to a depleted soil. The higher the rate of CSPA, the higher the population of arthropods. Pyroligneous acid has changed the chemical property in terms of soil pH value, Organic Matter value and phosphorous value. Potassium remains deficient before and after treatment in all levels.

Keywords pyroligneous acid, depleted soil, arthropods, soil fauna, coconut shell

INTRODUCTION

Soil degradation is now a global problem that requires global efforts to mitigate. This requires new approaches in managing this very important resource for food security and sustainability. It is imperative that for us to mitigate we will find alternative technologies in agriculture to replace those that are considered "destructive" to the life of the soil especially those which are proven to be one of the causes of soil degradation like synthetic fertilizers and pesticides.

According to Stan Cox in his opinion column of Aljazeera, one-third of Earth's soil is degraded because of unsustainable farming methods, which could lead to a major food crisis. He said that "countries whose land is in the worst trouble are often, but not always, countries where large numbers of people live in poverty. In just 10 countries - India, Bangladesh, Brazil, China, Thailand, Mexico, Philippines, Democratic Republic of Congo, Vietnam and Burma - more than 530 million people are feeling the impact of land degradation directly. Worldwide, 1.5bn people are feeling it (Cox, 2012).

In its project preview of Australian Center of International Agricultural Research (ACIAR) Project in Bohol, the World Agroforestry Center noted that "soil erosion and associated losses of nutrients from arable land are an important economic problem in the Philippines and closely associated with ecosystem health and function. These are also issues which are predominantly associated with the steeply sloping uplands and areas with highly erodible soils. Within the agricultural province of Bohol, 45% of the island is designated as agricultural land and supports 80 % of the island's population. However, nearly two thirds of the agricultural land has a slope of greater than 18 % and receives more than two meters of rainfall per year. In a previous ACIAR project LWR/2001/003 it was concluded that activities that have the highest adverse impact on agricultural sustainability (and therefore long term economic sustainability) in the upper Inabanga (the largest watershed on Bohol), included: up and down cultivation on sloping lands, continuous use of nutrient-depleting crops such as corn and cassava, and extensive cultivation of steep upland soils (World Agroforestry Center, nd.).

Pyrolysis can serve as wood waste recycling process which will reduce environmental hazards. Its by-product, the pyroligneous acid is a potential input to replace chemical pesticides for organic agriculture purposes. In a slide presentation of Laemsak N. as cited by Tiilikkala et.al. (2010), it is noted that one of the fast growing areas of bio-business is based on the use of pyrolysis technologies. Charcoal (biofuel and biochar) has been the main product of the conventional pyrolysis for a long time in most of the cases but recently by-products of the process (green chemicals) have become more and more important. Locally produced wood vinegar has been used as a pesticide in countries where synthetic chemicals have not been available, or where the price of the chemicals has been too high for small scale farmers. Globally, the need to minimize the environmental risks resulting from pesticides leaching to ground water and waterways has bolstered the use of wood vinegar as a biocide and pesticide (Tiilikkala et al., 2010). Hence, there is a need also to look into the impacts of this input to the biological and chemical aspects of the soil to help determine its usefulness in pest and fertilizer management and therefore can be of benefit in restoring depleted soils.

The aim of this research was to find out the impacts of coconut shell pyroligneous acid on the biological and chemical properties of a depleted soil in Bohol, Philippines.

METHODOLOGY

Research Location

This research project was conducted in a controlled condition at Oikos Garden, Bilar, Bohol, Philippines. However, soil samples were taken from a degraded upland community of Carmen, Bohol.

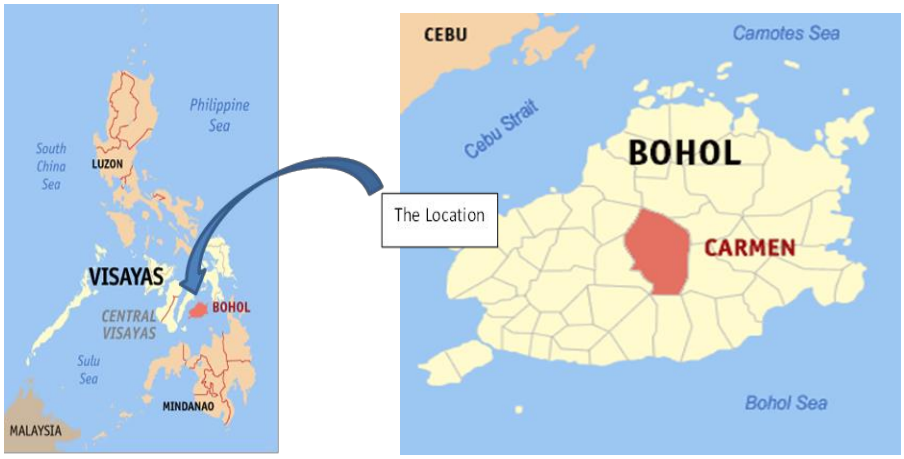

Fig. 1 Map of research site

There were two experimental set-ups established: one for the study of soil fauna and one for the study of chemical properties.

Soil Fauna

This aspect of the study was to find out the effect of coconut shell pyrolignoeus acid on the soil inhabitants of degraded soil. Soil samples were taken from the degraded uplands of Carmen, Bohol. Soil was analyzed as clay loam with a pH value of 4.1 which is "extremely acidic" and 3.0% organic matter. It has a phosphorous content of 12 ppm and deficient in potassium.

Polyethylene terephthalate (PET) bottles (1.5 liter soda bottle) were used as observation containers. PET bottles were cut crosswise leaving the straight portion and holes were made on the sides of the bottles. These bottles were filled up with the collected soil and treatments were assigned. The treatments were as follows: Control, 10% CSPA, 20% CSPA and 30% CSPA by volume. There were four bottles assigned for each treatment as observation of soil fauna was done four times in a weekly basis. Hence, 16 PET bottles with soil were embedded on the ground at 20 cm deep and secured in a secluded area of the experimental field. Four observations for each treatment were done 7, 14, 28 and 42 days after the PET bottles with soil were embedded on the ground.

To collect the organisms present in the soil, an improvised Berlese funnel was prepared using a one gallon empty plastic water container. Soil was placed on the funnel with a 100 w bulb on top of the soil. Underneath the funnel was a glass with alcohol to catch the soil organisms. Soil arthropods extracted from the soil were identified under the microscope.

Fig. 2 Soil samples in PET bottles (a), improvised Berlese funnel (B), and identification of arthropods (C)

Chemical Property

Fig. 3 Experimental set-up (A) and pechay 30 days after planting (B)

Experimental set-up was established in a nursery of the Oikos Garden. This part of the study was to find out the impact of CSPA on soil property. Black plastic potting bags were used. Using the soil

samples collected from the degraded upland of Bohol, a randomized complete block design (RCBD) was installed. Four bags were planted with pechay for each treatment and replicated four times. The treatments were as follows: Control (No CSPA), 10% CSPA, 20% CSPA and 30% CSPA. First application of CSPA was done one week before planting and the second was done one week after planting. Subsequent application was done on a weekly basis. Soil analysis was done before and after the study

RESULTS AND DISCUSSION

Soil Fauna

Data collection showed one order of Arachnida (Acarina) and six orders of Arthropods that were identified in all treatments. The arthropods identified included the following: Coleoptera, Collembola, Dermaptera, Diptera, Hemiptera and Hymenoptera. Each treatment has a population of 8, 8, 33 and 55 for Treatments 1, 2, 3 and 4, respectively. Figure 4 shows the total population of arthropods in all treatments after four collection and counting periods that is 7, 14, 28 and 42 days after the PET bottles were embedded on the ground.

Simpson's dominance index indicated that all treatments had a moderate value. However, based on population data, Treatments 3 and 4 showed higher population than Treatments 1 and 2. It means high percentage of CSPA will increase population of soil organisms.

Chemical Properties

Baseline information about the soil used in this study was obtained and it was found out that such soil is characterized as clay loam with a pH value of 4.1 which is extremely acid. It has an organic matter content of 3% with 12 ppm phosphorous and deficient in Potassium.

After one season of pechay (one month), soil analysis indicated some changes as reflected in Table 2.

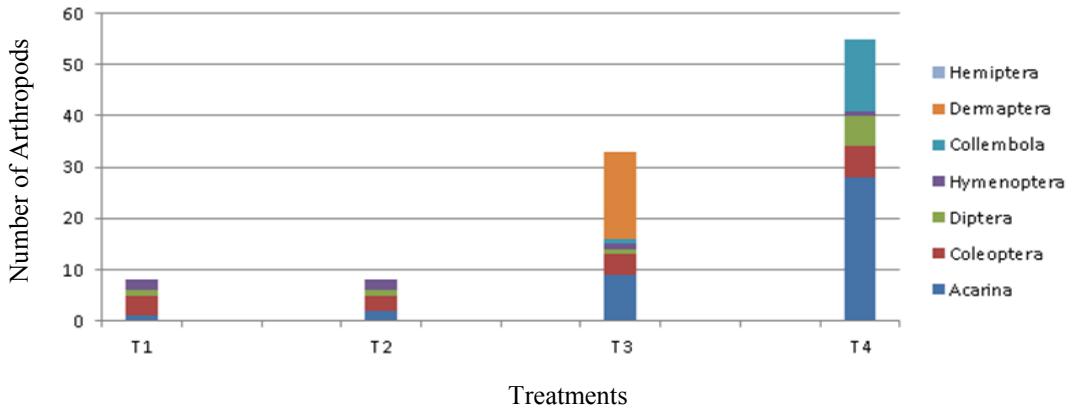

Fig. 4 Total arthropod population by treatment

Fig. 5 Representative arthropods collected from soils in PET bottles

Table 1 Arthropod population by order per treatment

Treatments	Arthropods	Population by Order	Total Population Per Treatment
Treatment 1 (Control)			8
	Acarina	1	
	Coleoptera	4	
	Diptera	1	
	Hymenoptera	2	
Treatment 2 (10%)			8
	Acarina	2	
	Coleoptera	3	
	Hemiptera	1	
	Hymenoptera	2	
Treatment 3 (20% CSPA)			33
	Acarina	9	
	Coleoptera	4	
	Collembola	1	
	Dermaptera	1	
	Diptera	1	
	Hymenoptera	17	
Treatment 4 (30% CSPA)			55
	Acarina	28	
	Coleoptera	6	
	Collembola	6	
	Dermaptera	1	
	Hymenoptera	14	

Table 2 Soil aanalysis before and after treatment

Baseline Soil Analysis		Treatment 1 (Control)	Treatment 2	Treatment 3	Treatment 4
Soil pH	4.1	4.1	5.2	5.1	4.5
Organic Matter (%)	3.0	3.0	4.0	3.5	4.0
Phosphorous (ppm)	12	12	12	12	9
Potassium (ppm)	Deficient	Deficient	Deficient	Deficient	Deficient

Soil acidity or pH value changes in all treatments in an indirect proportion. This implies that CSPA can lower the pH value of soil and so it can neutralize soil acidity. From a baseline data of an "extremely acid soil", Treatments 2 and 3 lowers to "strongly acid" category while Treatment 4 changed to "very strongly acid". Treatments 2 and 3 did not change the phosphorous value but it decreased by 3 in Treatment 4. All treatments did not make any changes in potassium deficiency. The organic matter has increased by 1 in Treatments 2 and 4 and 0.5 in Treatment 3. This study confirms the work of Li and Wang (2014) that addition of wood vinegar to the soil decreases soil pH.

CONCLUSION

Based on the result of the study, it is concluded that coconut shell pyroligneous acid has demonstrated impacts to the biological and chemical aspects of depleted soil. The higher the rate of CSPA, the higher the population of arthropods. CSPA has changed the chemical property in terms of soil pH value, Organic Matter value and Phosphorous value. Potassium value remains deficient before and after treatment at all levels.

REFERENCES

Cox, S. 2012. The world can't afford to keep wasting soil (updated Jan 12; 2012. cited September 20, 2014. Available from: http://www.aljazeera.com/indepth/opinion/2012/01/20121992725118465.html)

Tiilikkala, K., Fagernas, L. and Tiilikkala, J. 2010. History and use of wood pyrolysis liquids as biocide and plant protection product. The open agriculture journal, 2010 (4).

Li, Z-H. and Wang, X-D. 2014. Effect of wood vinegar on soil properties and plant growth. Journal of Plant Nutrition and Fertilizer, 20(2), 510-516. (Available from: http://www.plantnutrifert.org/EN/10.11674/zwyf.2014.0229)

World Agroforestry Center. n.d. ACIAR Bohol - Evaluation and adoption of improved farming practices on soil and water resources in Bohol Island. Los Banos, Laguna, Philippines. (cited July 12, 2014 Available from:http://www.worldagroforestry.org/regions/southeast_asia/philippines/projects/aciar-bohol)

Research article

Pre-Rice or Post-Rice Mungbean Productivity with Chemical and Bio-Compost Fertilizer under Rainfed Conditions

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Abstract The objective of this research was to investigate the effect of chemical and bio-compost fertilizer application on growth and yield of mungbean when grown as pre-or post-rice under rainfed conditions, as well as economic return of growing mungbean. A randomized complete block design (RCBD) was used, with four fertilizer application treatments; soil applied as basal NPK, folia applied chelate EDTA compound, folia applied bio-compost and control. The results showed that soil applied NPK produced the maximum seed yield when mungbean grown as pre-or post-rice crop. In economic return, soil applied as basal NPK provided the maximum net benefit (565US $/ha) when mungbean grown as pre-rice crop. While, folia applied bio-compost gave the highest net benefit (295US $/ha) mungbean grown as post-rice crop.

Keywords mungbean, chemical fertilizer, bio-compost fertilizer, chelate EDTA compound, rice-based cropping systems

INTRODUCTION

Mungbean (*Vigna radiata* L.) is an excellent source of high quality protein (25%). It has also proved to be an ideal crop for pre-rice or post-rice crop in early and late rainy season with the short maturing, legume crop (Choudrary et al., 2011). Northeast Thailand is generally considered to have rice fields with particularly infertile soils with coarse texture (Wade et al., 1999). Mungbean is a high responsive to nutrients (Choudrary et al., 2011). Hence, nutrients requirement of mungbean can be met by supplying nutrients through chemical fertilizers, organic manures and bio-fertilizers with different application methods such as application to soil, seed priming and foliar application. Numerous studies have shown the usefulness of spraying micronutrients on grain crops (Schnappinger et al., 1969; Agrawal, 1992; Modaihsh, 1997). However the information on use of bio-compost to improve productivity of mungbean is neglected. The objective of this research was to investigate the effect of chemical and bio-compost fertilizer application on growth and yield of mungbean when grown as pre-rice or post-rice crop under rainfed conditions.

METHODOLOGY

Field experiments were conducted during May to July 2014 for pre-rice mungbean and December 2013 to March 2014 for post-rice mungbean. Rainfed lowland rice in Northeast Thailand is

commonly sloping land, which determines groups of paddy land type, upper, medium and lower fields. Pre-rice mungbean crop grown in the upper field, while post-rice mungbean crop grown in the lower field. Since, the upper fields have a low chance of encountering to waterlogging condition with rainfall intensity during the early wet season. For the lower fields, stored soil water at the end of wet season may be sufficient for a quick maturing legume crops. The soil was sandy in texture of upper fields with pH (5.05), total N (0.025%), available P (7.02 mg/kg), exchangeable K (16.78 mg/kg) and organic matter (0.544%). For lower fields, soil was sandy loam in texture with pH (5.55), total N (0.022%), available P (6.81 mg/kg), exchangeable K (52.44 mg/kg) and organic matter (0.234%). Bulk density value average at 0-15 cm soil depth was about 1.61 and 1.45 g/cm^3 for pre and post-rice mungbean plots at planting, respectively.

The treatments consist of four fertilizer application; soil applied as basal NPK of fertilizer grade 15-15-15 (N - P_2O_5 – K_2O) at rate of 156 kg/ha, folia applied chelate EDTA compound at rate of 2 gm/liter of water, folia applied bio-compost (producing from pig placenta) at rate of 10 cc/liter of water. Bio-compost were analyzed for total N 3.8%, total P 0.15% and total K 0.78%. Soil applied as basal dose just before seed sowing. Folia Chelate EDTA (micronutrients) and bio-compost were sprayed to the crop at 15, 30 and 45 days after planting (DAP). Zero-tillage was practiced for post-rice mungbean and conventional tillage was used for pre-rice mungbean. The mungbean cultivar Chainat 72 was seeded in December 17, 2013 and May 15, 2014 with spacing 50 cm × 20 cm between row and plant. The mungbean crops were thinned to two plants per hill at 10 DAP. Weed control was done by hand once at 15 DAP in pre-or post-rice mungbean crop. No pesticide was used in pre-rice mungbean crop.

Data on top dry weight (stem + leaf) were recorded by drying samples in an oven at 60 °C for 72 h. The pods number per plant, seeds number per pod, 100 seeds weight and seed yield were measured at harvest. The nutrient concentration of mungbean leaf was determined for N, P and K at flowering in pre-rice mungbean crop. The nutrient uptake was calculated by leaf dry weight (kg/ha) x concentration (%) and divided by 100 for N, P and K uptake.

Soil moisture content was determined by gravimetric measurements at 0-15, 15-30 and 30-45 cm depth. Field capacity (FC) and Permanent Wilting Point (PWP) were estimated with pressure plate equipment. The crop received rainfall about 26 mm in December 2013 at 5 DAP. Later, rainfall did not occur in the entire the growing period when mungbean grown as post-rice crop. Soil moisture content observed which close to PWP at 45 DAP until harvest (Fig.1). The minimum air temperature during the growing period was about 14.5, 13.7 and 19.2°C in December 2013, January and February 2014, respectively. When mungbean grown as pre-rice, the crop received rainfall about 257 mm. Soil moisture content was observed in available range (FC and PWP) throughout the growing period (Fig. 2). The minimum air temperature was recorded about 25.0, 25.8 and 24.7 °C in May, June and July 2014, respectively.

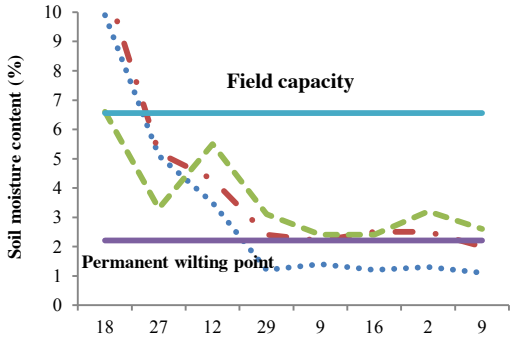

Fig. 1 Soil moisture content (%) at 0-15 cm (●●●), 15-30 cm (---) and 30-45 cm (- - -) depth during the growing period in post-rice mungbean

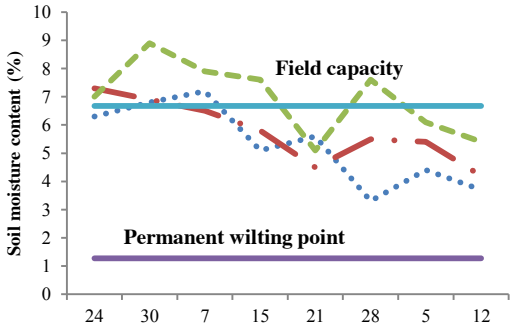

Fig. 2 Soil moisture content (%) at 0-15 cm (●●●), 15-30 cm (---) and 30-45 cm (- - -) depth during the growing period in pre-rice mungbean

RESULTS AND DISCUSSION

Growth, Yield and Yield Components of Mungbean at Harvest

Fertilizer application was not significantly affected on pod number per plant, seed number per pod and 100 seeds weight, but it was significantly difference on top dry weight and seed yield of mungbean when mungbean grown as pre-rice crop (Table 1). The maximum top dry weight and seed yield were obtained in soil applied NPK treatments.

Fertilizer application had no significant effect on top dry weight and pod number per plant, but had significant effect on seed number per pod, 100 seeds weight and seed yield of mungbean when grown as post-rice crop (Table 2). The soil applied NPK treatments produced maximum seed number per pod, 100 seeds weight and seed yield of mungbean.

Table 1 Growth, yield components and yield of mungbean at harvest as affected by fertilizer application when grown as pre-rice crop

Treatment	Top dry weight per plant (g)	Pod no. per plant	Seed no. per pod	1000 seed weight (g)	Seed yield (kg/ha)
Control	11.8 b	9.6	5.7	8.2	427.1 c
Soil applied NPK	19.8 a	13.9	7.4	8.5	666.9 a
Folia applied chelate	18.4 a	12.4	7.1	8.1	571.7 b
Folia applied bio-compost	16.7 ab	11.5	6.3	8.0	566.2 b
F-test	*	ns	ns	ns	*
CV (%)	23.3	24.4	22.4	8.1	11.6

*NS = Not significant, * Significant at P < 0.05*
Mean followed by the same letter at the same column was not significantly difference by LSD.

Table 2 Growth, yield components and seed yield of mungbean at harvest as affected by fertilizer application when grown as post-rice crop

Treatment	Top dry weight per plant (g)	Pod no. per plant	Seed no. per pod	1000 seed weight (g)	Seed yield (kg/ha)
Control	4.4	4.4	5.1 c	8.3 b	229.8 c
Soil applied NPK	5.5	6.1	7.4 a	8.9 a	324.7 a
Folia applied chelate	4.6	5.6	6.7 b	8.6 ab	276.8 b
Folia applied bio-compost	4.6	5.3	6.6 b	8.6 ab	273.4 b
F-test	ns	ns	*	*	*
CV (%)	13.4	17.2	3.5	36.	7.5

*NS = Not significant, * Significant at P < 0.05*
Mean followed by the same letter at the same column was not significantly difference by LSD.

Table 3 Nutrient concentration in leaves and nutrient uptake of mungbean at flowering as affected by fertilizer application when grown as pre-rice crop

Treatment	Concentration (%)			Nutrient uptake (kg/ha)		
	N	P	K	N	P	K
Control	4.10	0.322	2.30	36.3 b	2.8 b	19.3 b
Soil applied NPK	5.26	0.361	2.49	86.6 a	6.1 a	43.8 a
Folia applied chelate	4.73	0.335	2.34	66.1 ab	4.6 ab	31.6 ab
Folia applied bio-compost	4.41	0.336	2.28	46.5 b	3.6 b	21.5 b
F-test	ns	ns	ns	*	*	*
CV (%)	13.0	9.9	8.9	25.3	26.1	32.4

*NS = Not significant, * Significant at P < 0.05*
Mean followed by the same letter at the same column was not significantly difference by LSD.

Nutrient Concentration and Uptake of Mungbean at Flowering

Fertilizer application had no significant effect on N, P and K concentration of mungbean leaves at flowering when grown as pre-rice crop (Table 3). However, soil applied NPK tend to give the highest N, P and K concentration of mungbean leaves at flowering.

Fertilizer application was significantly affected on N, P and K uptake of mungbean leaves at flowering (Table 3). The maximum N, P and K uptake were recorded in the soil applied NPK treatments.

Economic Return of Growing Mungbean

All fertilizer application treatments provided good net income than control treatments. The maximum net benefit was obtained in soil applied NPK treatments when mungbean grown as pre-rice crop, while the highest net benefit was observed in folia applied bio-compost treatments when mungbean grown as post-rice crop (Tables 4 and 5).

Table 4 Yield, gross income, production cost and net income of mungbean when grown as pre –rice crop by different fertilizer application

Treatment	Yield (kg/ha)	Gross income (US $/ha)	Production cost (US $/ha)	Net income (US $/ha)
Control	427.1	533.9	175.8	358.1
Soil applied NPK	666.9	833.6	268.6	565.0
Folia applied chelate	566.2	707.8	203.9	503.9
Folia applied bio-compost	571.7	714.6	182.9	531.7

Note : Planting material = mungbean seed 50 baht/kg, NPK 19 baht/kg, chelate EDTA compound 400 baht/kg and bio-compost 20 baht/liter; Market price of mungbean seed 40 baht/kg; 1 US $ = 32 Thai baht; Production cost = Material cost + land preparation for mungbean growing; Household labor is considered as farming labor

Table 5 Yield, gross income, production cost and net income of mungbean when grown as post –rice crop by different fertilizer application

Treatment	Yield (kg/ha)	Gross income (US $/ha)	Production cost (US $/ha)	Net income (US $/ha)
Control	229.8	287.3	39.1	248.2
Soil applied NPK	324.7	405.9	131.9	274.0
Folia applied chelate	276.8	346.0	67.2	278.8
Folia applied bio-compost	273.4	341.8	46.2	295.6

Note : Planting material = mungbean seed 50 baht/kg, NPK 19 baht/kg, chelate EDTA compound 400 baht/kg and bio-compost 20 baht/liter; Market price of mungbean seed 40 baht/kg; 1 US $ = 32 Thai baht; Production cost = Material cost + land preparation for mungbean growing; Household labor is considered as farming labor

In pre-rice mungbean, soil applied NPK produced the maximum seed yield. However, all fertilizer application treatments gave higher seed yield than the control treatments. The soil applied NPK produced the maximum seed yield due to better plant development through nutrient uptake, where primary growth elements were available in sufficient amount. The obtained results are in agreement with the findings of Graham and Ascher (1993).

The sufficient N, P and K concentration in leaves of legumes crops at flowering stage was about 5.1%, 0.4% and 2%, respectively (Makay and Leefe, 1962). In this study, The N, P and K of leaves at flowering stage in soil applied NPK treatments were 5.26%, 0.361% and 2.49%, respectively. This indicates that N, P and K in soil provided an adequate amount for mungbean growth at flowering stage in soil applied NPK treatments.

Folia application of chelate EDTA increased seed yield over control. This agree with research work by Modaihsh (1997) and Mondal et al. (2011). Similarly, folia spray of bio-compost fertilizer produced higher seed yield than in control, due to better in plant growth. This agree with study by Buasri et al. (2010).

In post-rice mungbean, soil applied NPK also gave the highest seed yield. However, all fertilizer application treatments produced higher seed yield than the control. This was due to fertilizer application provided better shoot growth and subsequently produced good quality of all yield components. Soil application NPK as well as folia sprays of chelate EDTA and bio-compost supplemented availability of nutrients to mungbean crop. This agree with many research works by Graham and Ascher (1993); Ali et al. (2008); Modaihsh (1997) and Thalooth et al. (2006).

Mungbean seed yield in post-rice crop was lower than in pre-rice crop. This was due to post-rice mungbean the crop subjected to water stress at pod formation growth stage. This caused the highest reduction of pods number per plant. Similarly results were also reported by Thalooth et al. (2006). In addition the mungbean suffered from low temperature (below 15 °C) at seedling growth stage during December 2013 to January 2014. The temperature recorded below 15 °C may inhibited mungbean seeding growth was reported by DOA (2000).

CONCLUSION

All fertilizer application treatments produced higher seed yield than control. The soil applied as basal NPK gave the highest seed yield when mungbean grown as pre-rice or post-rice crop. However, in economic return the soil applied NPK provided the maximum net benefit when mungbean grown as pre-rice crop. While, folia applied bio-compost gave the highest net benefit when mungbean grown as post-rice crop. The results of those studies also suggested that mungbean is suitable to grow as pre-rice rather than post-rice crop.

REFERENCES

Agrawal, H.P. 1992. Assessing the micronutrient requirement of winter wheat. Communications in Soil Science and Plant Analysis, 23, 2555-2568.

Ali, S., Riaz Khan, A., Mairaj, G., Arif, M., Fida, M. and Bibi, S. 2008. Assessment of different crop nuturient management practices for yield improvement. Australian Journal of Crop Science, 2 (3), 150-157.

Buasri, P., Lauprasert, P. and Udomporn, T. 2010. Efficiency of bio-compost liquid produced from golden apple snail *(Pomacea canaliculata)* on mungbean growth. KKU Journal for Public Health Research, 3 (2), 37-45.

Choudhary, H.R., Sharma, O.P., Yadav, L.R. and Choudhary, G.L. 2011. Effect of organic sources and chemical fertilizers on productivity of mungbean. Journal of Food Legumes, 24 (4), 324-326.

Department of Agriculture (DOA). 2000. Good agriculture practices for mungbean. Department of Agriculture, Ministry of Agriculture and Cooperative, Bangkok, Thailand. 49p.

Graham, R.D. and Ascher, J.S. 1993. Nutritional limitations of sub-soils. In: Plant nutrition from genetic engineering to field practice. pp. 739-742. Kluwer Academic Publishers, Dordercht.

Makay, D.C. and Leefe, J.S. 1962. Optimum leaf level of N, P and K in sweet corn and snap beans. Can. J. Plant Sci., 42, 238-246.

Modaihsh, A.S. 1997. Foliar application of chelated and non-chelated metals for supplying micronutrients to wheat grown on calcareous soil. Experimental Agriculture, 33, 237-245.

Mondal, M.M.A., Rahman, M.A., Akter, M.B. and Fakir, M.S.A. 2011. Effect of foliar application of nitrogen and micronutrients on growth and yield in mungbean. Legume Research, 34 (3), 166-171.

Schnappinger, M.G., Martens, D.C. and Hankins, G.W. 1969. Response of corn Zn-EDTA and $ZnSO_4$ in field investigations. Agronomy Journal, 61, 834-836.

Thalooth, A.T., Tawik, M.M. and Magda Mohamed, H. 2006. A comparative study on the effect of folia application of zinc, potassium and magnesium on growth and yield of mungbean grown under water stress. World Journal of Agricultural Sciences, 2 (1), 37-46.

Wade, L., Fukai, S., Samson, B.K., Ali, A. and Mazid, M.A. 1999. Rainfed lowland rice-physical environment and cultivar requirements. Field Crops Research, 64, 3-12.

Research article

Biodiversity of Soil Invertebrates in Sugar Cane Plantations with the Different Application of Sugar Distillery Spent Wash

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Abstract The objective of this study was to compare the biodiversity of soil invertebrates in the various utilization of spent wash liquor in sugar cane plantations. Soil invertebrates were collected in the four different spent wash liquor applications: 1) control plot, 2) applied with spent wash liquor for 1 year plot, 3) applied with spent wash liquor for 2 years plot and 4) applied with spent wash liquor for 4 years plot. The soil invertebrate samples were collected by random sampling during November 2012 to October 2013. The results showed that a total of 7 orders comprising 42 species of 31 families were collected in this study. The density of soil invertebrates in the areas of spent wash liquor application was significantly higher than those in the control plot. The Shannon-Wiener's species diversity index indicated that the diversity was the highest in the plantation applied with spent wash liquor for 2 year (2.26), followed by that of applied with spent wash liquor for 4 years (2.06), applied with spent wash liquor at 1 year (2.04) and lastly the control plot (1.57).

Keywords soil invertebrates, spent wash liquor, sugar cane

INTRODUCTION

Thailand is a major producer of sugar and sugar industry offers employment potential and contributes substantially to economic development. There are about 47 sugar cane mills in Thailand. The sugar industry produces a huge amount of wastes every day, which is rich in organic material and characteristically less toxic and easily amenable for microorganisms. Alcohol is produced by the fermentation of molasses. The liquor left after the sugar production is spent wash. The application of spent wash liquor in the sugar cane area can increased nutrients content in soil such as phosphorus potassium calcium and magnesium (Soongsud et al., 2007). Soil invertebrates are important in the functioning of nearly all environments, with changes in species composition potentially reflecting changes in the ecosystem (Madden and Fox, 1997). Knowledge of diversity helps in understanding changes in ecosystem complexity. Soil macro-invertebrates play a fundamental role in soil processes. They are integral to the cycling of organic matter and associated nutrients, and physically alter soil structure through movement (Jouquet et al., 2006; Wolfe and Klironomos, 2005). Loss or high of invertebrate diversity can adversely affect soil processes, ultimately altering the availability and composition of nutrients within the soil (Ehrenfeld and Neal, 2001; Jouquet et al., 2006; Belnap and Susan, 2001). Soil invertebrates also contribute to the succession of above ground vegetal communities through provision of resources, as well as selective consumption of available resources (De Deyn et al., 2003). Thus, maximum retention of invertebrate biodiversity is beneficial to biotic communities above and below the soil surface. The function of soil invertebrates within their communities, and their effects upon the environment, are

often disproportionate to their abundance (Lavelle, 1996). The objective of this study was to compare the biodiversity of soil invertebrates in various utilization of spent wash liquor in the sugar cane areas.

METHODOLOGY

The study was carried out monthly in the Nampong district, Khon Kaen province in the north-eastern part of Thailand during November 2012 to October 2013 (Fig. 1). The study sites were located within four sugar cane plantations were selected based on different management: 1) control plot, 2) applied with spent wash liquor for 1 year, 3) applied with spent wash liquor for 2 years and 4) applied with spent wash liquor for 4 years. The soil insect and soil invertebrate were collected using hand collecting and Berlese funnel methods (Southwood, 1994) (Fig. 2). For hand collecting on soil surface was set five sampling sites (1 m^2/site) in each plot. The sampling sites were sampled for soil invertebrates lived on soil surface and within soil depth at 10 cm using Berlese funnel methods. The samples were then classified by morphospecies and stored in 75% ethanol. All insect specimens were identified at least up to taxonomic order using the identification guides of Triplehorn and Johnson (2005) and Bolton (1994). The specimens were also compared with the reference collections at the Insect Museum, Faculty of Agriculture, Khonkaen University. The Shannon-Wiener's diversity index (Krebs, 1999), was used to calculate the diversity of soil invertebrates collected. The formula of the Shannon-Wiener's diversity index used is presented as follow

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

where H'= Species diversity index, s = Number of species and p_i = Proportion of the total sample belonging to i_{th} species.

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

$$\text{Evenness} = \frac{H'}{H'MAX} \quad (2)$$

where H' = Observed index of species diversity and H'_{MAX} = Maximum possible index of diversity.

The diversity values for Shannon-Weiner were classified based on scale developed by Fernando (1998) and is presented in Table 1.

RESULTS AND DISCUSSION

The result showed that a total of fourteen orders comprising 51 species in 24 families were collected in this study (Fig. 3). The diversity of soil invertebrates in applied with spent wash liquor area was significantly higher than those in the control plot. The dominant insects in all areas were Hymenoptera (42.43%) followed by Coleoptera (23.06%), and Araneae (5.75%), respectively (Fig. 4 A and B). The sugarcane area applied with spent wash liquor for 2 years (Plot 3) has the highest abundance of Order Hymenoptera followed by the control plot (Fig. 5). Only one subfamily of Formacinae under Hymenoptera has been found in all areas.

Table 1 Classification of species richness indices (*adopted from Fernando 1998*)

Relative values	Species diversity	Evenness
Very high	>3.50	>0.75
High	3.00 – 3.49	0.50 – 0.74
Moderate	2.50 – 2.99	0.25 – 0.49
Low	2.00 – 2.49	0.15 – 0.24
Very low	<1.99	< 0.14

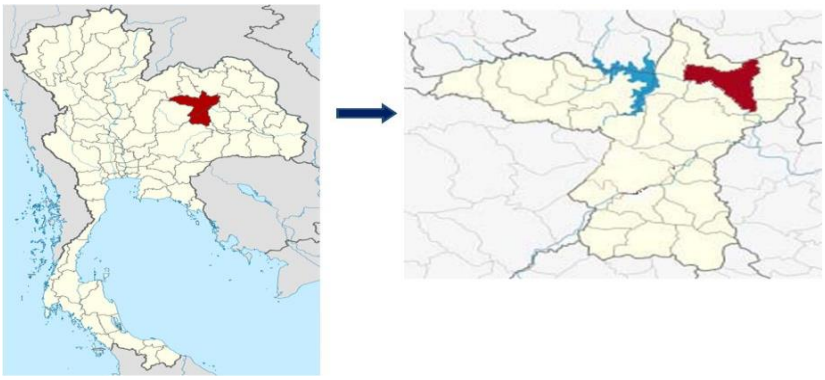

Fig. 1 Study area at Nam Phong district in Khon Kaen Province (red) in Northeastern Thailand

Fig. 2 Soil invertebrate sampling methods

Fig. 3 Example of soil invertebrates (A) Order Coleoptera (B) Order Isoptera (C) Order Hymenoptera (D) Order Diplura

The diversity of insect in this study is presented in Fig 6. Overall, the results show that insect diversity value for all of the sugarcane plantation areas was low diversity with H′=2.04-2.32 while the evenness index were similar in all areas with 0.56-0.46. The Shannon-Wiener's species diversity index indicated that the diversity was the highest in the plantation applied with spent wash liquor for 1 year (2.32), followed by the plantation applied with spent wash liquor for 4 years (2.23), applied with spent wash liquor for 2 years (2.15) and lastly the control plot (2.04).

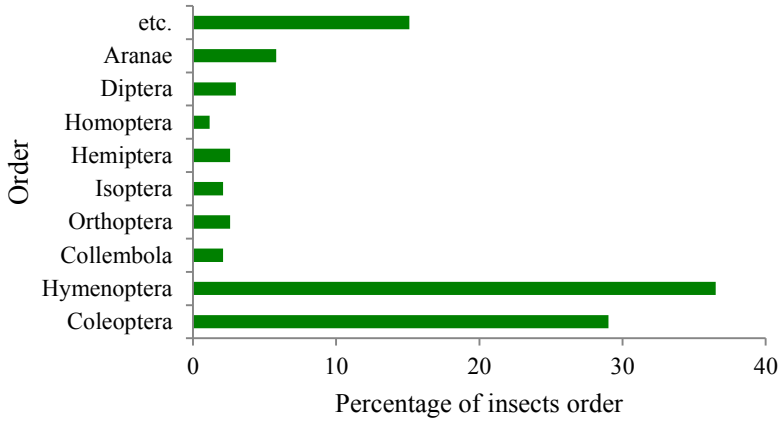

Fig. 4 Taxonomic of soil invertebrate in all areas

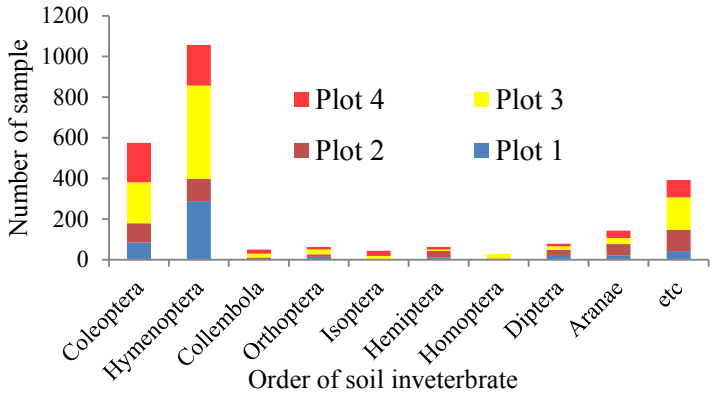

Fig. 5 Taxonomic of soil invertebrate in different land management

Plot 1 = control plot, Plot 2 = applied with spent wash liquor for 1 year , Plot 3 = applied with spent wash liquor for 2 years and Plot 4 = applied with spent wash liquor for 4 years

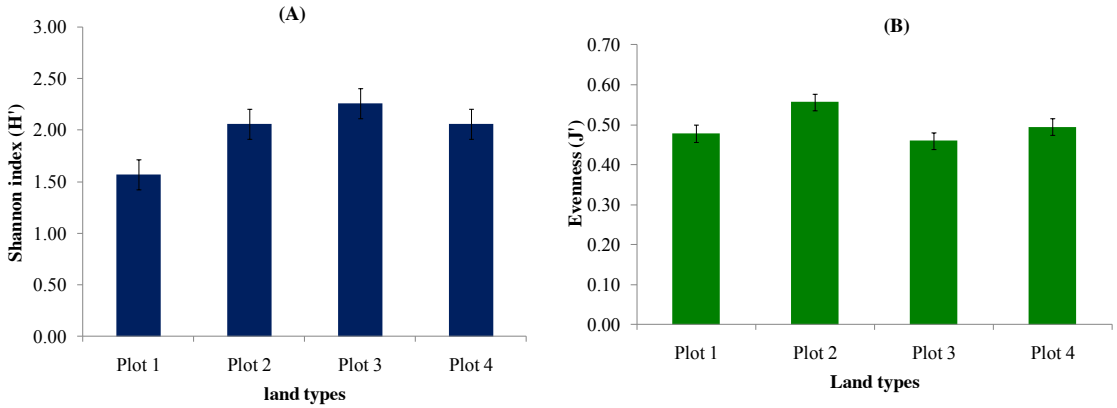

Fig. 6 Comparison between Shannon index (A) and evenness (B) of species diversity in each plantation

Plot 1 = control plot, Plot 2 = applied with spent wash liquor for 1 year, Plot 3 = applied with spent wash liquor for 2 years and Plot 4 = applied with spent wash liquor at 4 years

Results of this study show that the sugar cane plantations after land application of spent wash liquor has high diversity and abundance of insect fauna compare with the control plot. The increase in soil invertebrate diversity in the application of spent wash liquor area may be due to increased

nutrients content in soil. The majority of insects found in this study were Hymenoptera (ants) and Coleoptera (beetles). This is because the ants and beetles may be occurred most of the time in this study. We observed that the ants were the most common and the greatest number of insect species at the sugarcane plantation. Nigel and Paul (1992) stated that ants are found in the most terrestrial habitats. Most are predators and as such are critical component of aboveground and soil communities. They are usually less spectacular effects on the environments.

CONCLUSION

It may be concluded that the diversity of soil invertebrates in the sugar cane plots applied with spent wash liquor was significantly higher than those in control plot. If an understanding of microhabitats used by specific ant species can be developed, along with the key trophic interactions, then the potential of using insects as terrestrial indicator species for detecting environmental changes can potentially be reliably and easily with low cost and time.

ACKNOWLEDGEMENTS

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REFERENCES

Belnap, J. and Susan, L.P. 2001. Soil biota in an ungrazed grassland: Response to annual grass (*Bromus tectorum*) invasion. Ecological Applications, 11, 1261-1275.

Bolton, B. 1994. Identification guide to the ant genera of the world. Harvard University Press, Cambridge, USA. 222 pp.

De Deyn, Gerlind B., Raaijmakers, Ciska E., Rik Zoomer, H., Matty P. Berg, Peter C. de Rulter, Herman A. Verhoef, T. Martijn Bezemer, and Wim H., van der Putten. 2003. Soil invertebrate fauna enhances grassland succession and diversity. Nature, 422, 711-713.

Ehrenfeld, J.G. and Neal S. 2001. Invasive species and the soil: Effects on organisms and ecosystem processes. Ecological Applications, 11, 1259-1260.

Fernando, E.S. 1998. Forest formations and flora of the Philippines: Handout in FBS 21. (Unpublished).

Jouquet, P., Dauber, J., Lagerlof, J., Lavelle, P., Lepage, M., 2006. Soil invertebrates as ecosystem engineers: Intended and accidental effects on soil and feedback loops. Applied Soil Ecology, 32, 153-164.

Krebs, C.J. 1999. Ecological methodology. Addison-Educationall Publishers, California, USA. 581 pp.

Lavelle, P. 1996. Diversity of soil fauna and ecosystem function. Biology International, 33, 3-16.

Madden, K.E., and Fox, B.J. 1997. Arthropods as indicators of the effects of fluoride pollution on the succession following sand mining. Journal of Applied Ecology, 34, 1239- 1256.

Nigel, E.S. and Paul, E. 1992. Invertebrates as determinants and indicators of soil quality. American Journal of Alternative Agriculture, 7, 38-47.

Soongsud, P., Luangchaisri, N., Homchan J. and Boonthai Iwai, C. 2007. Utilization of spent wash liquor from ethanol factory for agricultural used. KKU Res J, 7 (4), 13-19.

Southwood, T.R.E. 1994. Ecological methods: With particular reference to the study of insect populations. Chapman & Hall, London, UK. 524 pp.

Triplehorn, C.A. and Johnson, N.F. 2005. Borror and Delong's introduction to the study of insects. 7th ed. Brooks/Cole. 864 pp.

Wolfe, B.E. and Klironomos, J.N. 2005. Breaking new ground: Soil communities and exotic plant invasion. Bioscience, 55, 477-487.

Research article

Efficiency of Vermicompost on Growth and Nutrients Content of Young Rubber Trees (*Hevea brasiliensis*)

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Abstract Vermicompost originates from the breakdown of organic matter by earthworms. Its microbial activity is 10 to 20 times higher than in the soil and contains a higher saturation of nutrients than organic materials. Moreover, vermicompost is also believed to contain hormones and enzymes which it acquires during the passage of the organic matter through the earthworm gut. The hormones and enzymes are believed to stimulate plant growth and discourage plant pathogens. The analysis of the ability of vermicompost through their interactions on seedling growth and nutrients content of *Hevea brasiliensis* will enable to decrease the use of chemical fertilizers while increasing crops yield and for sustaining crop production. In this study, the effect of using vermicompost on growth and nutrients content of rubber seedlings has been studied. Four treatments were supplied with ratios of 1) 100 g/plant of 15-15-15, 2) 50 g/plant of 15-15-15 combined with 500 g/plant of vermicompost, 3) 500 g/plant of vermicompost and 4) 100 g/plant of 15-15-15 combined with 500 g/plant of vermicompost. The results showed a significant rise in growth and nutrients content of rubber seedlings by increasing ratio of vermicompost combined with 50 g/plant of 15-15-15. Obviously, rubber seedlings were mostly appeared in the stem dry weight, N and K content in the leaves part and N, P and K content in the stem part after 6 months in vermicompost applying.

Keywords growth, major nutrients, rubber seedling, vermicompost

INTRODUCTION

In Northeast Thailand, natural rubber is mainly produced by smallholder farmers. N, P and K are essential elements for plant growth and development. Additionally, the majority of soils in Northeast Thailand are acid and sandy. Soils have low water holding capacity, low organic matter content, low cation exchange capacity and low availability of nutrients for plant uptake (Bruand et al., 2004). This poor inherent soil fertility decreases further when the soil is cropped. This has resulted in decreasing quality and quantity of crop yields (Leaungvutiviroj et al., 2006). Applications of chemical fertilizers at high levels can degrade soil and water resources in the long term, leading to the loss of ecosystem services and decrease of agriculture sustainability. Latex yield indicates the growing condition and yield potential of rubber tree. Growth and development depends on many factors such as weather, clone planted, location, water and fertilizers. Akpan et al. (2007) reported that soil constitutes the major aspect of the environment that greatly affects the growth and productivity of rubber trees. The use of organic and inorganic fertilizers increases the efficiency use of chemical fertilizers and soil remediation (Rubber Research Institute of Thailand, 1997).

Vermicomposts are products derived from the accelerated biological degradation of organic wastes by earthworms and microorganisms. Its microbial activity is 10 to 20 times higher than in the soil (Chaoui, 2010). Vermicompost contains a higher saturation of nutrients that believed to contain hormones and enzymes which acquires during the passage of the organic matter through the earthworm gut. The hormones and enzymes are believed to stimulate plant growth and discourage plant pathogens (Gajalakshmi and Abbasi, 2004). Hua et al. (2008) found that water and nutrients are the two main factors limiting *Hevea brasiliensis* growth and its latex yield. Akpan et

al., (2007) suggested that fertility status of soil has some influence on rubber latex yield. Especially, acid sandy soils in Northeast Thailand are low levels of soil parent materials. This has resulted in decreasing quality and quantity of crop yields (Leaungvutiviroj et al., 2006). The aim of this research was to investigate the effect of vermicompost on growth and nutrients content of *Hevea brasiliensis*.

MATERIALS AND METHODS

Experimental Treatments

The *Hevea brasiliensis* RRIM 600 field experiments were conducted at Khon Kaen University, Khon Kaen province, Northeast Thailand in 2013. Northeast Thailand is characterized by a tropical climate with an acid sandy soil. Vermicompost produced from cow manure was applied at rates of 500 g/plant (d.w.) to young rubber trees. Chemical fertilizer (15-15-15 kg NPK) was applied at rates of 100 g/plant after a month of sowing date. Four treatments were supplied with ratios of 1) 100 g/plant of 15-15-15, 2) 50 g/plant of 15-15-15 combined with 500 g/plant of vermicompost, 3) 500 g/plant of vermicompost and 4) 100 g/plant of 15-15-15 combined with 500 g/plant of vermicompost (Table 1).

Table 1 Treatments studied at Khon Kaen University, Khon Kaen province, Northeast Thailand in 2013

Treatment	15-15-15 kg NPK	Vermicompost	Plants
Tr1 Control	100 g/plant	-	Young rubber tree (RRIM 600)
Tr2	50 g/plant	500 g/plant	Young rubber tree (RRIM 600)
Tr3	-	500 g/plant	Young rubber tree (RRIM 600)
Tr4	100 g/plant	500 g/plant	Young rubber tree (RRIM 600)

Young Rubber Trees Plantation and Sampling

The *Hevea brasiliensis* RRIM 600 were transferred to cement blocks with 1 plant/block to control the organic and chemical fertilizers applied. The plants were grown under natural raining and field condition. Growth and development were measured at the end of each month for 6 months. Whole plant samples were harvested for assessment of shoot dry weight, number of leaves, plant high, trunk circumference, stem diameter and macronutrients content (N, P and K) in the shoot. All leaves and stems of young rubber trees were placed into paper bags, oven-dried at 80 °C for 3-4 days before the weight of shoots was determined.

Nitrogen (N), Phosphorus (P) and Potassium (K) Measurements and Ash Alkalinity

For each sample of above-ground biomass N content was measured by micro-Kjeldahl with indophenol blue, P content by wet oxidation and spectrophotometry and K content by wet oxidation and flame photometry.

Statistical Analysis

The experiment was conducted in Completely Randomizing Design (CRD) with 4 replications. An analysis of variance was done on data obtained from each parameter in each treatment. All analysis were carried out using Statistical analysis version 8.0. Least significant differences (L.S.D.) were calculated at $p < 0.05$ and Duncan's multiple-range test was used to test significant differences between treatments. Standard deviation was also calculated for the variance.

RESULTS AND DISCUSSION

Growth and Nutrients Uptake of Young Rubber Trees

Acid-weathered soils of the tropics and subtropics are particularly prone to P deficiency. Worldwide, phosphorus is considered as the principal yield-limiting nutrient along with nitrogen (Zahran, 1999). Phosphorus deficiency is a primary constraint to plant growth in many terrestrial ecosystems (Bonser et al., 1996). Under low soil pH, phosphate is adsorbed on clay minerals and other factors such as low soil moisture affect the availability of phosphorus (Karmarkar et al., 1997; Roychaudhary et al., 2003). P deficiency has two main causes: (i) the low content in total P of some soils poor in organic matter or highly weathered, and (ii) the complexation of P with cations such as Ca, Al or Fe, which makes P unavailable to the plants, as in acid soils. Nitrogen (N) elements is a key component of amino acids, proteins, chlorophyll, enzymes and it's also involved with the metabolic effect. Phosphorus (P) affects the rate of growth of the circumference and latex during the beginning of rubber growth (Punnoose et al, 1976). Potassium (K) is a critical component of enzymes that aid in the protein synthesis, carbohydrate and sugar delivers, acid – base control, the opening - closing of the stomata. Moreover, allows all parts of the plant and root system are strong and resistant to disease and insects. However, excessive amounts of K fertilizer will decline Mg and Ca of rubber trees and P fertilizers are not always available or affordable to farmers in the tropics. The experimental strategy employed during this research enabled to determine the possibility of vermicompost applying for 6 months on growth and nutrients uptake of young rubber trees cv. RRIM600. The results founded that no statistical difference was significantly greater for the growth of leaves and stems of young rubber (Fig. 1). As the suitable chemical formula fertilizer for small rubber trees is 20-8-20 with the rate of 410 g/plant (Rubber Research Institute, 1997) which its far from our practices. However, the application of 15-15-15 by 50 g/plant with 500 g/plant of vermicompost statistically significant difference in K accumulation in the trunk (Fig. 4) and their rates of application likely tends to produce vegetative growth, N and P accumulation of young rubber trees (Figs. 2 and 3). This probably related to phosphorus element in the vermicompost and also other important nutrients are found such as calcium, magnesium and potassium nitrate. However, not only macronutrients those are vital to the growth of rubber trees. Micronutrients including manganese (Mn), zinc (Zn), iron (Fe), copper (Cu), boron (B) and the molybdenum (Mo) are also necessary which are typically found in humus. Future research the increasing in volume of vermicompost application with a suitable chemical formula fertilizer may enable to promote the growth and nutrients uptake of young rubber trees cv. RRIM600.

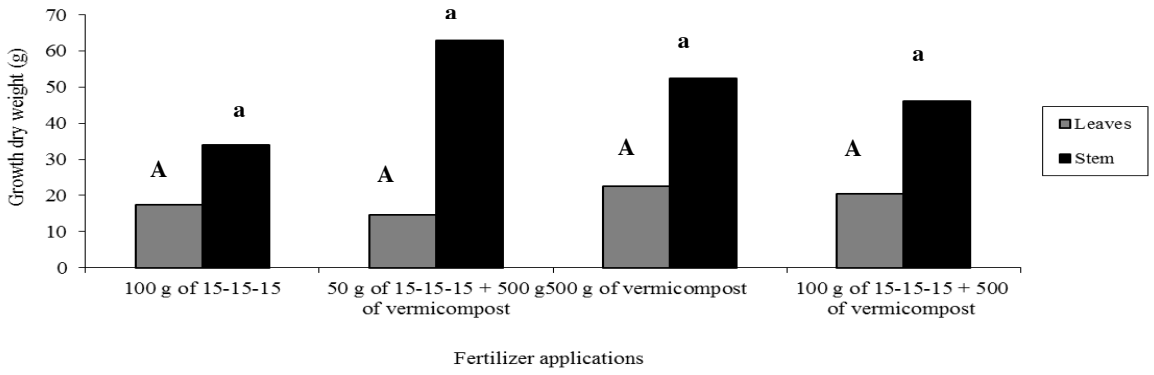

Fig. 1 Vegetative growth of rubber seedling cv. RRIM600 after 6 months

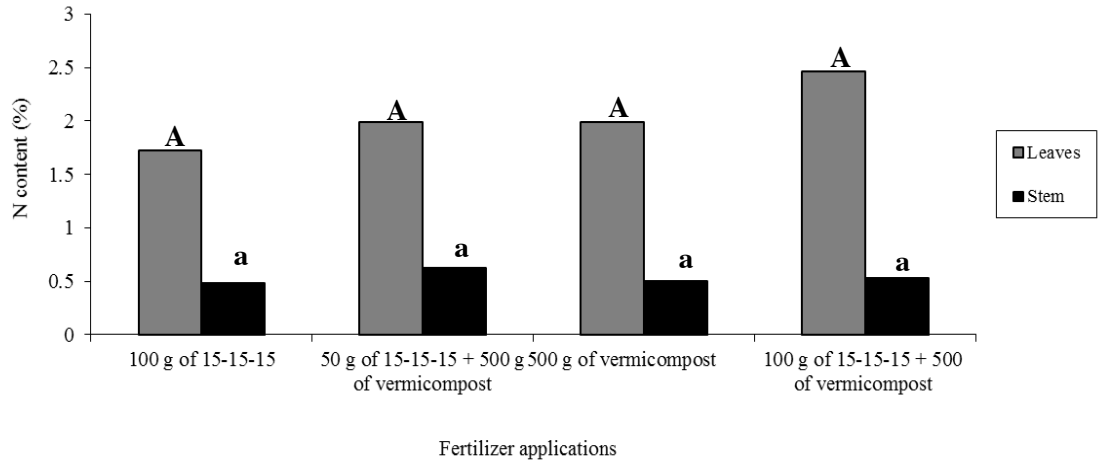

Fig. 2 N content of rubber seedling cv. RRIM600 after 6 months

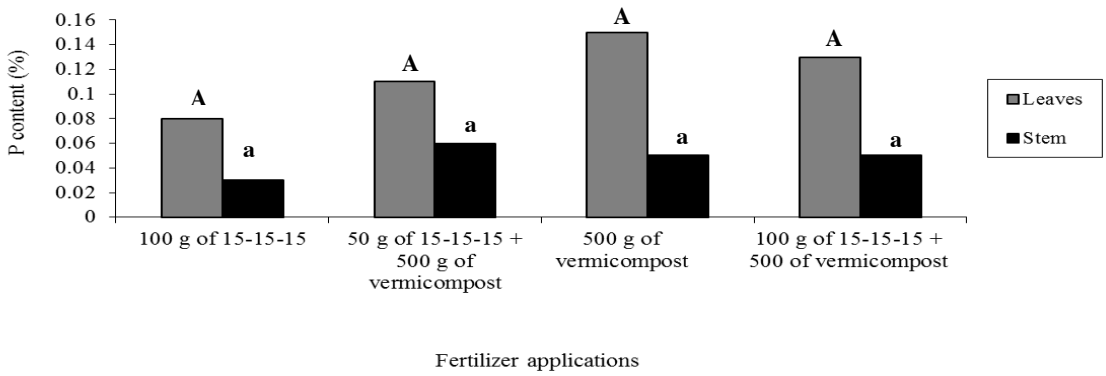

Fig. 3 P content of rubber seedling cv. RRIM600 after 6 months

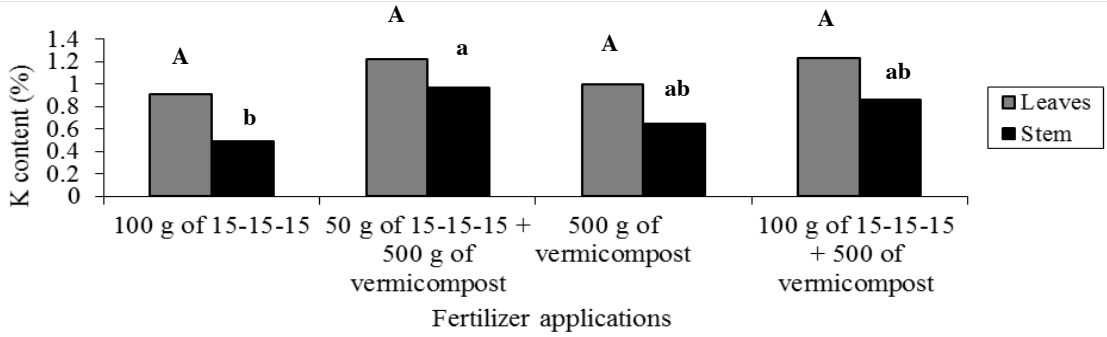

Fig. 4 K content of rubber seedling cv. RRIM600 after 6 months

CONCLUSION

The application of vermicompost with chemical fertilizer with the young rubber trees cv. RRIM 600 found that 50 g/plant of 15-15-15 combined with 500 g/plant of vermicompost significantly increase in K content and tend to promote the growth and N, P content after 6 months. While the

application of 100 g/plant of 15-15-15 combined with 500 g/plant of vermicompost and 500 g/plant of vermicompost are not significantly increase in leaves growth and N, P and K content. This work provides a first step towards by using vermicompost as bio-fertilizers for improving rubber growth and nutrient uptake, soil fertility and sustainable crop production in nutrient poor systems.

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REFERENCES

Akpan, A.U., S.O. Edem and N.U. Ndaeyo. 2007. Latex yield of rubber (*Hevea brasiliensis* Muell Argo) as influenced by clone planted and locations with varying fertility status. Journal of Agriculture & Social Sciences, 3, 28-30.

Bonser, A.M.Y.M., Lynch, J. and Snapp, S. 1996. Effect of phosphorus deficiency on growth angle of basal roots in *Phaseolus vulgaris*. New Phytol, 132, 281-288.

Bruand, A, Hartmann, C., Santi, R.A., Pramuanpong, S., Poss, R. and Hardy, M. 2004. Composition, fabric, and porosity of an Arenic Haplustaff of Northeast Thailand: Relation to penetration resistance. Soil Science Society of America Journal, 68, 185-193.

Chaoui, H. 2010. Vermicasting (or Vermicomposting): Processing organic wastes through earthworms. Factsheet. 1-7.

Gajalakshmi, S. and Abbasi, S.A. 2004. Earthworms and vermicomposting. Indian Journal of Biotechnology, 3, 486-494.

Hua, Y.G., Chen, Q.B., Lin, Z.M. and Luo, W. 2008. Coupling effects of water and chemical fertilizers on *Hevea brasiliensis* latex yield. Chinese Academy of Tropical Agricultural Sciences, 19, 1211-1216.

Karmakar, S., Mittra, B.N. and Ghosh, B.C. 1997. Comparative efficiency of organic and industrial wastes in improving productivity of acid lateritic soil under rice-groundnut cropping system, p. 24-27. *In* First All India Peoples Technology Congress, February 21-23, Calcutta, India.

Leaungvutiviroj, C., Piriyprin, S. and Limtong, P. 2006. Study on relationship between soil microorganisms and nutrient elements of Vetiveria zizanioides and Vetiveria nemoralis in some problem soils of Thailand. Thailand DC16 Speaker: Pitayakorn Limtong.

Punnoose, K.I., Potty, S.N., Mathew, M. and George, C.M. 1976. Response of *Hevea brasiliensis* fertilizers in south India. Proceedings, International Natural Rubber Conference, 1975, Kuala Lumpur, Malaysia. 84-107.

Raychaudhury, M., Ngachan, S.V., Raychaudhury, S. and Singh, A.L. 2003. Yield response of groundnut to dual inoculation and liming of an acid hill Ultisol of Manipur. Indian J. Agric. Sci., 73, 86-88.

Rubber Research Institute of Thailand. 1997. Application of rubber. 27.

Zahran, H.H. 1999. *Rhizobium*-legume symbiosis and nitrogen fixation under severe conditions and in an arid climate. Microbiol. Molecu. Bio. Rev., 63, 968-989.

Research article

Floodplain Mapping Using HEC-RAS and GIS in Nam Phong River Basin, Thailand

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Abstract Floodplain management and mapping is a new and applied method for the river engineering and is essential for prediction of flood hazards. The lower Phong Basin area regularly goes more or less under flooding every year in the monsoon season due to lack of flood protection and limited resources. Most of the flood protection works are carried out at the local level without preplanning and considering the problems at the river basin scale. Traditionally, individuals or communities have been trying to develop their own strategies for minimizing the effects of floods. However, due to limitation of resources and knowledge, many householders are unable to protect their properties or possessions from floods. A methodology was applied to integrate hydraulic simulation model, HEC-RAS and GIS analysis for delineation of flood extents and depths within a Nam Phong River in northeast of Thailand. It is necessary to simulate complicated hydraulic behaviour of the river in a more simple way for the purpose of managing and performing all river training works. In this research, the steady flow was used to simulate flood along 148 km end of Nam Phong River starting at upstream from Ubolratana Dam to Chi River in Northeast of Thailand. Floodplain mappings were derived using integrating of HEC-RAS and GIS analysis. Delineation of flood extents and depths within the floodplain were conducted in different return periods. Critical flooding area along the river was distinguished based on the grid layer of flood depths. The results indicated that hydraulic simulation by integrating with GIS analysis could be effective for various kinds of floodplain management and mapping and give as different scenarios for river training works and flood mitigation planning.

Keywords Nam Phong river, floodplain mapping, GIS, HEC-RAS model, Thailand

INTRODUCTION

The Nam Phong Watershed is the largest basin in the northeast of Thailand which provides an important water resources for agriculture, electricity generation, aquaculture, domestic uses, industrial and recreational purposes (KKU, 2003). In Nam Phong flood prone areas, flood causes severe economic and social disruptions to many living households. Nevertheless, floodplain in Lower Phong Basin is still in a very rudimentary stage and no serious concern on comprehensive flood damages. In this area, most of the flood protection works are carried out at the local level without preplanning and considering the problems at the river basin scale. Traditionally, individuals or communities have been trying to develop their own strategies for minimizing the effects of floods. However, due to limitation of resources and knowledge, many householders are unable to protect their properties or possessions from floods.

The most important factors affecting the intensity and flood return period in each region are: volume and time of upstream surface runoff and river or flood conditions, physical characteristics of watershed (area, morphology), hydrological characteristics of the watershed (rainfall, storage, evapotranspiration), and human activities (Noori, 2001). Flooding is a hazard with serious

socioeconomic consequences for all activities and infrastructure within an affected floodplain. Thus, accurate delineation of flood extents and depths within the floodplain is essential for flood management officials to make sensible and fair decisions regarding construction, insurance and other regulated practices on land and property potentially affected by flooding (Noman et al., 2003).

Computer models play a pivotal role in facilities such as storm drains, culverts, bridges, and water quality as well as quantity-control structures which is an important design component of these facilities involving with hydraulic analysis to determine conveyance capacity. Recently, computer models are developed and used for predicting and preventing natural disasters worldwide (Barbad et al., 2002; Earles et al., 2004; Abdalla et al., 2006; Yang et al., 2006).

Barbad et al. (2002) made flood zoning maps of the Sepid Rood River in Gilan Province, Iran, using Iranian cartographical maps of 1: 25000, cross sections measured by Iran Rasad Consulting Engineers, and ArcView, HEC-RAS and HEC-GeoRAS software. They concluded that a combination of GIS and the HEC software is feasible and makes the calculations easily. Earles et al. (2004) demonstrated the utility of the HEC-GeoRAS model for floodplain delineation and determination of key hydraulic parameters and also, HEC-RAS capability of producing hydraulic results in Los Alamos, New Mexico, USA. Abdalla et al. (2006) introduced hybrid approach for flood risk assessment through GIS. The results indicated that the developed methodology was efficient in modeling and visualizing the spatial extent of different flood scenarios and in determining flooded areas at risk. Yang et al. (2006) developed a direct-processing approach to river system floodplain delineation by using GIS and HEC-RAS. Due to the efficiencies of the mentioned methods, the purpose of this research was to identify the flood frequency analysis and flooded area and further created floodplain mappings based on the change of return periods or flood events in Lower Phong Basin using HEC-RAS and GIS.

METHODOLOGY

Study area: This research was conducted in Lower Phong Basin located in the northeast of Thailand bordering to Udon Thani, Mahasarakham, Chaiyaphum and Nong Bua Lamphu provinces. The length of river is approximately 148 km that flows northwestward to southeastward to join Chi River and ultimately draining into the Mekong River. The area of study was approximately 2993.95 km^2 (Fig. 1). The lower part of the watershed consists mainly of paddy fields, agricultural land, and factories and is heavily populated. The land surface in the watershed is generally undulating and sloping towards the east and southeast. The elevation of the relatively flat area around the Ubolratana reservoir is about 190 m. The western watershed consists of many mountain ranges with an average elevation of 900 m, and up to 1,300 m (FAO, 1985). Geographic location of the study area is in between Latitude N 16^0 23’ 39” to N 16^0 46’ 37” and Longitude E 102^0 36’ 22” to E 102^0 57’ 51”.

Datasets: The analyses of this research relied on two types of data; annual peak flow and GIS data including cross-sections, elevation points and topographic map. Peak flow data of Nam Phong basin was simulated from SWAT model with 12-year rainfall records from 2000-2012 water year, and with the daily model calibration from 2004-2007 (R^2=0.93). After evaluation of the accuracy of the data, Gumbel Distribution Method was employed for flood frequency analysis (only 14 major sub-basins were calculated, whereas the small sub-basins were ignored). The analyzed data used as input for the hydraulic simulation of the river reaches which divide into upper reach from Ubolratana Dam to Nong Wai Weir and lower reach from Nong Wai Weir to Chi River.

Calibration for roughness coefficient: The roughness coefficients, which represent the surface’s resistance to flow and are integral parameters for calculating water depth, were initially estimated using the Chow classification by Chow (1959). The Manning’s coefficients used for different zones of the Nam Phong River varies between 0.025 and 0.075. Flood inundation results are derived separately for each cross section in the main channel. Model parameters can largely be divided into two categories (Gilard, 1996): (i) parameters that can be directly inferred from observation, such as area, extent, depth, volume etc., and (ii) parameters that cannot be directly observed at the model scale and will need to be estimated, such as roughness. Manning roughness coefficient *n*, together

with the channel geometry is considered to have the most important impact on predicting inundation extent and flow characteristics. Most of the methods from literature for estimating roughness values are useful in establishing the range of roughness values for a river reach. Calibrated roughness values are, however, effective at the reach scale (Beven and Carling, 1992). Calibration is an inverse problem associated with identification, and is used to determine unknown constants or parameters in a model. Calibrating the Nam Phong River model roughness values involved running the hydraulic model several times and changing the Manning roughness coefficients, first estimated from Chow tables, until the best fit between the simulated and observed water level and water extend is found.

Floodplain mapping: For the floodplain delineation, the ArcView GIS software package, developed by the Environmental Systems Research Institute, was used as the computer development environment for this research. Topographic map of the study area with scale of 1:50,000 were applied for based map using 3D analyst capability of ArcView GIS. DEM is used for preparation required data for hydraulic simulation in HEC-RAS, whereas the 113 surveyed cross-sections of the Nam Phong River have relative elevation which GPS have been used for determining absolute and correct positioning of all cross-sections and elevation points. The HEC-GeoRAS extension is used in conjunction with 3D analyst for interpolation of digital terrain data and Spatial Analyst for proper display of the output flow depth grids and velocity grids. HEC-GeoRAS had been used to import RAS geometry form HEC-RAS which represents stream floodplains as a computed water surface elevation at each cross-section. During the data import step, these elevations, along with the distance from the stream centerline to the left and right floodplain boundaries, are brought into ArcView GIS and stored in the cross-section parameter table. As inputs, the script requires the cross-section line theme and the cross-section parameter table. The output is a line theme that is identical to the cross-section theme in location and orientation. Using the water surface profile at each cross-section, DEM with resolution 5 m obtained from Water Resources and Environmental Institute (WREI, 2012) was represented the entire floodwater surface. The water surface lines were used as break-lines, and the cross-section bounding polygon was used to bind the aerial extent of the water surface. When they were viewed in conjunction with the terrain DEM or TIN, flooded areas can be seen. The three-dimensional floodplain view is quite useful for floodplain visualization.

RESULTS AND DISCUSSION

In the present finding, flood frequency analyses were carried out with peak discharge data for 12 years (2000–2012) by the Gumbel's Distribution method which it is a suitable method in the condition like Thailand. The maximum annual water discharge from sub-watershed was calculated for flooding occurrences for 5-year, 10-year, 25-year, 50-year and 100-year return periods (Table 1). Flood frequency analysis was used as the steady flow data for simulation in order to further analysis the floodplain area at the Nam Phong watershed. Critical depth for upstream and critical depth for downstream was considered as boundary conditions for this analysis. Other inputs such as Manning's n value, river system schematic, contraction and expansion coefficients, flow regime entered to model and HEC-RAS model has run for steady flow regime. The result indicated only three-major rivers: Huai Sai Bat, Huai Suea Ten, Huai Khum Mum could reach to the big discharges based on changing of return period of flooding, whereas the other small sub-basins could produce less discharge which would be caused less effect to the floodplain area. Fig. 2 show floodplain mapping of the affected area and depth for the 10 and 100 years flooding events. Critical flooding area along the river could be distinguished basing on the grid layer of flood depths, and the flooding occurred mainly at the downstream of the basin which it is more populated, economical and industrious areas.

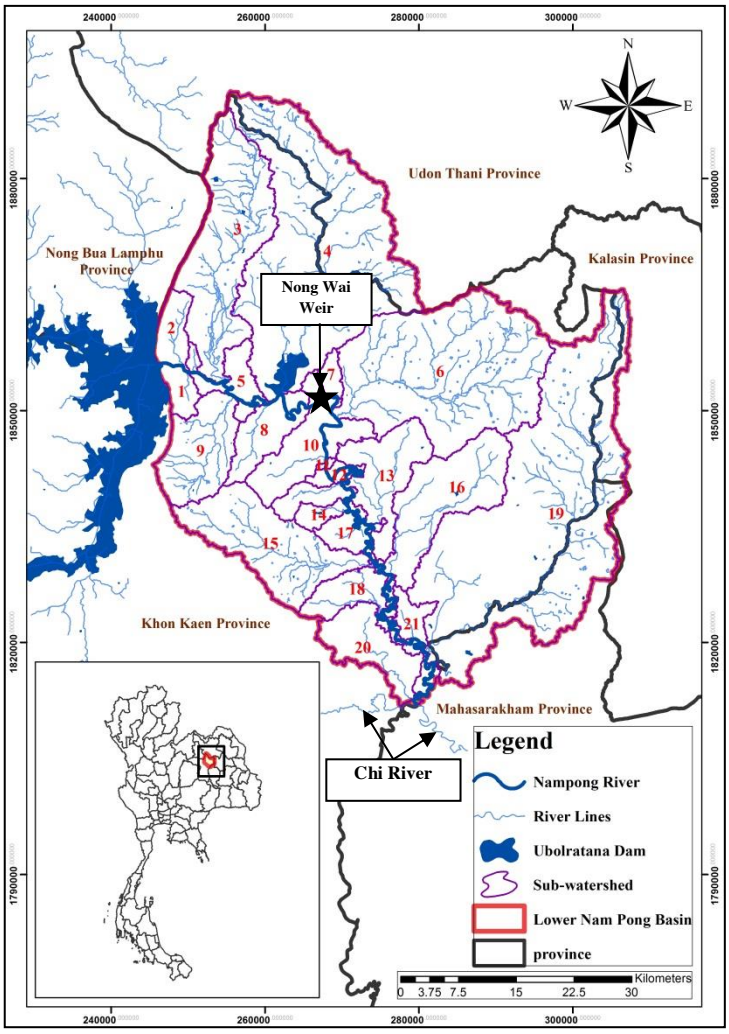
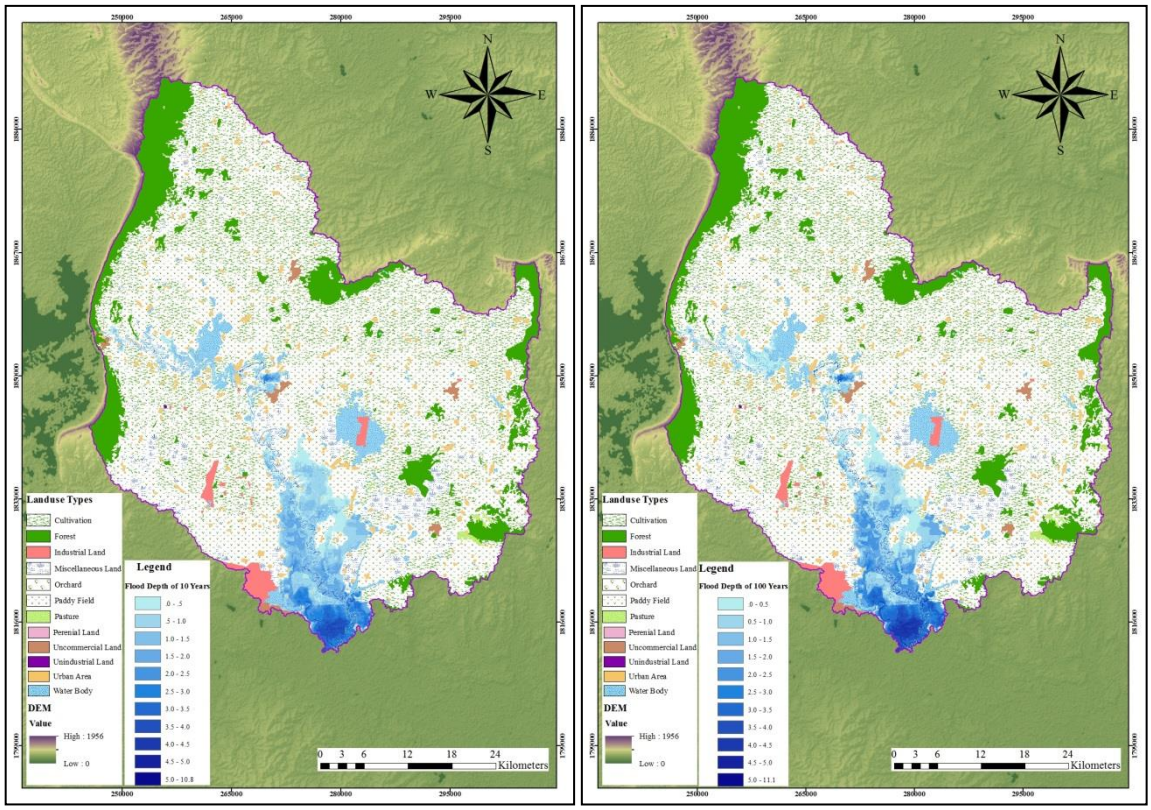


Fig. 1 Location of the study area

Table 1 Maximum discharge (m^3/s) of 14 sub-basins from the SWAT model based on return periods (2000-2012)

Nam Phong River	Tributary Name	Sub-basin Name	Peak Flow (m^3/s)	β	u	Return Periods of Flood Frequency Analysis				
						5 YR	10 YR	25 YR	50 YR	100 YR
Upper Reach	Huai Chot	Sub-basin 08	27.26	5.37	8.19	16.24	20.27	25.36	29.14	32.88
	Huai Khum Mum	Sub-basin 03	189.90	39.25	54.28	113.15	142.61	179.83	207.44	234.84
	Huai Sai	Sub-basin 02	565.10	6.31	8.94	18.41	23.15	29.13	33.58	37.98
	Huai Suea Ten	Sub-basin 04	169.70	17.76	113.91	140.54	153.86	170.70	183.19	195.59
	Huai Yang 1	Sub-basin 09	84.67	16.30	27.37	51.82	64.05	79.51	90.97	102.35
Lower Reach	Huai Hin Lat	Sub-basin 12	9.09	0.87	6.29	7.59	8.24	9.06	9.67	10.27
	Huai Kao Khot	Sub-basin 13	48.03	1.40	42.98	45.08	46.13	47.45	48.44	49.41
	Huai Nong Pla	Sub-basin 16	68.36	6.81	43.15	53.37	58.48	64.94	69.73	74.48
	Huai Pha Khue	Sub-basin 20	40.37	3.82	26.49	32.22	35.09	38.71	41.40	44.07
	Huai Plalai	Sub-basin 18	36.26	2.53	27.11	30.90	32.79	35.19	36.96	38.73
	Huai Sai Bat	Sub-basin 19	478.00	73.72	155.74	266.31	321.63	391.53	443.38	494.85
	Huai Siao	Sub-basin 06	185.80	33.37	91.46	141.51	166.55	198.19	221.66	244.96
	Huai Yai	Sub-basin 15	95.75	12.62	46.44	65.37	74.84	86.81	95.68	104.49
	Huai Yang 2	Sub-basin 10	22.52	2.72	13.07	17.16	19.20	21.78	23.70	25.60



a) 10-year-flood event **b) 100-year-flood event**

Fig. 2 Flood-affected area of 10 and 100 years flood event

Table 2 shows the analysis of the flooded areas revealed that a larger percentage more than 76% and 17% of paddy field and miscellaneous land lied in a floodplain area followed by urban, cultivation and forest area comprising 2%, 1.35% and 1.15%, respectively in accordance with the flooded areas of 5-year, 10-year, 25-year, 50-year and 100-year return periods. Anyways, there was not much (almost no flood) affected by the flood to the industrial land based on these various return periods it was because the topography of this area was too high to be effected by the flooding. It also illustrated that 2.56 km^2, 2.85 km^2, 0.10 km^2, 36.87 km^2, 154.89 km^2, 1.93 km^2, 3.59 km^2 of cultivation area, forest, industrial land, miscellaneous land, paddy field, uncommercial land and urban are respectively inundated by 5-year flood. Similarly, 3.59 km^2, 3.08 km^2, 0.21 km^2, 43.33 km^2, 192.18 km^2, 2.60 km^2, 5.01 km^2 of cultivation, forest, industrial land, miscellaneous land, paddy field, uncommercial land and urban are respectively inundated by 100-year flood, which it is showed that the flooded area increased with flooding intensity, mostly paddy field was moderately inundated (0.49 % changes) by different year flooding from 5 - 100 years, and slightly followed by urban area, and cultivation, whereas the uncommercial and industrial are the least effected.

Table 2 Flooded areas (%) according to the landuse types based on return periods

Landuse Types	Total flood damage area (km^2)									
	5 years Flood		10 years Flood		25 years Flood		50 years Flood		100 years Flood	
	Area	%	Area	%	Area	%	Area	%	Area	%
Cultivation	2.56	1.26	3.44	1.45	3.47	1.44	3.50	1.44	3.59	1.43
Forest	2.85	1.41	3.05	1.28	3.07	1.28	3.08	1.27	3.08	1.23
Industrial land	0.10	0.05	0.21	0.09	0.21	0.09	0.21	0.09	0.21	0.08
Miscellaneous land	36.87	18.18	41.13	17.27	41.65	17.33	42.24	17.40	43.33	17.33
Paddy Field	154.89	76.38	182.76	76.76	184.36	76.72	186.16	76.69	192.18	76.87
Uncommercial land	1.93	0.95	2.60	1.09	2.60	1.08	2.60	1.07	2.60	1.04
Urban Area	3.59	1.77	4.91	2.06	4.93	2.05	4.96	2.04	5.01	2.00
Total	202.78	100.00	238.10	100.00	240.28	100.00	242.75	100.00	250.01	100.00

CONCLUSION

This study focused on a systematic approach in the preparation of floodplain modeling integrating of hydraulic simulation with GIS analysis. The major tools/models used in this method were one-dimensional numerical model HEC-RAS and ArcView GIS for spatial data processing and HEC-GeoRAS for interfacing between HEC-RAS and ArcView GIS. Results of this study can separate high-hazard from low-hazard areas in the floodplain to minimize future flood losses. Hydraulics simulation for floodplain mapping could be beneficiary in several aspects for land and water resources management and also engineering purposes. It can be applied to prevent unwise land use in flood prone areas and flood insurance studies, based on modeling of water surface elevations for design flood events. The evaluation of floodplain delineation are rather complex and demanding activities, which require a comprehensive approach to hydraulic floodplain simulation and can be largely enhanced by using GIS capabilities. It can be concluded that the usage of GIS for the undertaking of a hydraulic simulation is as the potential to both of accuracy improvement and cost-saving for floodplain and flood hazard mapping. Moreover, the combination of ArcView GIS and HEC-RAS provides powerful tools for planners and decision makers.

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REFERENCES

Abdalla, R., Vincent, T.C., Wu, H., and Maqsood, I. 2006. A GIS-supported 3D approach for flood risk assessment of the Qu'Appelle River, Southern Saskatchewan. Int. J. Risk Assess. Manage., 6, 440-455.

Barbad, M., Behnia, A., and Motiei, H. 2002. Flood zoning in watersheds by combining GIS and mathematical models. 6th International Seminar of River Engineering.

Beven, K., and Carling, P.A. 1992. Velocities, roughness and dispersion in the lowland River Severn. In: Lowland Floodplain Rivers: Geomorphological Perspectives (ed. by Carling, P.A. and Petts, G.E.), 71-93, John Wiley, Chichester, UK.

Chow, V.T. 1959. Open Channel Hydraulics. McGraw Hill Inc., Singapore.

Earles, T.A., Wright, K.R., Brown, C., and Langan, T.E. 2004. Los Alamos forest fire impact modeling. J. Am. Water Resour. Assoc., 4, 371-384.

Food and Agricultural Organization (FAO). 1985. Inland fisheries in multiple-purpose river basin planning and development in tropical Asian countries three case studies. (Retrieved from http://www.fao.org /DOCREP/ 003/ X6861E/X6861E00.)

Gilard, O. 1996. Flood risk management: Risk cartography for objective negotiations. Proc., 3rd IHP/IAHS George Kovacs colloquium, UNESCO, Paris.

Khon Kaen University (KKU). 2003. Research on environmental management of the Pong watershed. Khon Kaen University, Thailand.

Noori, S.A. 2001. GIS in flood warning systems. M.Sc. thesis, University of Ferdowsi Mashhad, Iran.

Noman, N.S., Nelson, E.J., and Zundel, A.K. 2003. Improved process for floodplain delineation from digital terrain models. J. Water Resour., 129, 427-436.

Water Resources and Environmental Institute (WREI). 2012. GIS topographic data of Lower Nam Phong watershed. Unpublished.

Yang, J., Townsend, R.D., and Daneshfar, B. 2006. Applying the HEC-RAS model and GIS techniques in river network floodplain delineation. Can. J. Civil Eng., 33, 19-28.

Research article

The Application of Deficit Water and Fertilizer upon Yield and Water Footprint in Baby Corn

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Received 15 December 2014 Accepted 31 May 2015 (*Corresponding Author)

Abstract Baby corn (*Zea mays* L.) is one of the most significant and lucrative agricultural products grown in Thailand. Thailand, the largest exporter of baby corn in the world, has an average export income of 33 million dollars each year. However, Thai farmers income levels were lower for baby corn cultivation whereas a result of an increase in production factors. The objective of this study is to assess the appropriate water usage and fertilizer application on clay loam soil, in order to create higher yields of baby corn production. The experiment involved split-plot in randomize complete block design with three replications. Treatments consisted of three main plots of variable irrigation supply 1) 40% allowable depletion content (ADC), 2) 60% ADC, and 3) 80% ADC. Each plot acted in combination with four sub plots: 1) control, 2) 94-31-31 kg/ha (N-P_2O_5-K_2O), 3) 47-16-16, and 4) 47-47-47 kg/ha. The results found 40% ADC irrigation the most favorable to increase pod weight and water usage efficiency. The findings also proved this method to have the least amount of reduction in green, blue, and total water footprint amounts. Past fertilizer applications found that 94-31-31 kg/ha fertilizer enhanced pod weight and length, as well as corn height, and water usage in both amount and efficiency. The fertilizer 47-47-47 kg/ha resulted in decrease of green, blue, and total water footprint amount compared with other sub plots. A 40% ADC irrigation combination with 94-31-31 kg/ha yielded the highest pod weight and water usage efficiency compared with all other treatments. Moreover, the water footprint demonstrated the least amount of decrease in green, blue, and total water footprints compared with other treatments.

Keywords baby corn production, water depletion, water footprint, fertilizer utilization.

INTRODUCTION

Baby corn (*Zea mays* L.) is one of the most significant and lucrative agricultural products grown in Thailand. Thailand, the largest exporter of baby corn in the world, has an average export value of 33 million dollars each year (98% of which is frozen baby corn). The majority areas of baby corn plantation on 4 provinces such as Supanburi, Kanchanaburi, Nakhon-Phatom and Phathum-Thani in central region of Thailand were approximately 75% of all baby corn plantation areas. However, Thai farmers income levels were lower for baby corn cultivation whereas a result of an increase in production factors. While the average yield of baby corn per hectare was relatively low (7,500 to 9,375 kg/ha). Thai farmers struggled to increase production to more profitable levels (12,500 to 15,625 kg/ha). The demand of larger yields, under a reduced budget, required farmers to seek optimal irrigation and fertilization applications for baby corn production (Agriculture Economic Bureau, 2010). The relationship between crop yield and water and fertilizer usage, has been a major focus of agricultural research (Howell, 1990).

The 'water footprint' was introduced as an assessed indicator of water usage in plant production by Kongboon and Sampattagul (2012). Their study of the water footprints for sugarcane and cassava in northern of Thailand found that the water footprint in cassava (509 L/kg) was greater than that of the sugarcane (202 L/kg), as a result of different climates and cultivation areas. The Department of Agriculture (2005) reported that baby corn assimilated macro nutrients, in the order of nitrogen, potassium and phosphorus. The optimal soil properties of baby corn were found to be loam, sandy loam, and clay loam soil texture class sufficient aeration, organic matter of at least 1.5%, and available P of more than 10 mg/kg, and exchangeable K of more than 40 mg/kg. Research of the interaction and effects of plant irrigation requirements and fertilizer applications in baby corn production has become essential.

OBJECTIVE

The objective of this study was to determine the optimum water usage and fertilizer application on clay loam soil for baby corn production.

METHODOLOGY

Climate and Location of Experimental Areas

This study was conducted in 2011 and 2012 on a farm in Phathum Thani province, in the central region of Thailand. The experimental field is located in Alluvial Plain (altitude 4 m, 14°11′ North and 100°53′ East) where the climate is moist and tropical. The hot season, February to May; and the rainy season, June to October; are expressed in Fig. 1 (Thai Meteorological Department, 2010).

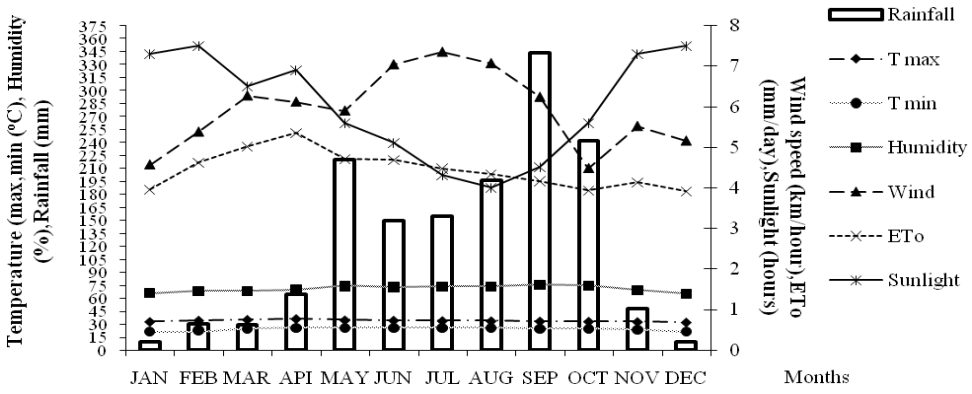

Fig 1. Weather data of 30 years (1980) to (2010) in Pathum Thani province of Thailand

Treatments and Data Collected

Soil samples were collected on the farmer's field at depths of 0-60 cm (Rangsit soil series, Very-fine, mixed, semiactive, acid, isohyperthermic Sulfic Endoaquepts). Soil texture classes were clay loam to clay (sand 27 - 40%, silt 25 - 28%, and clay 35 - 45%), soil bulk density 1.99 to 1.33 g/cm^{-3}, hydraulic conductivity 0.002 to 0.02 cm/hr^{-1}, and available water depth of 9.67 to 10.77 mm. Chemical properties of soil samples were pH 3.87 to 4.19, organic matter 1.60 to 2.42, available P 3.4 to 70.1 mg/kg, exchangeable K 270.7 to 349.0 mg/kg, and exchangeable Ca 634.2 to 1,542.0 mg/kg. The experiment was designed split in RCBD with three replications. Treatments consisted of three main plots: 1) 40% allowable depletion content (ADC), 2) 60% ADC, and 3) 80% ADC. Irrigation treatments were provided through a trickle irrigation system of tape lines; which were spaced to emit 20 cm at the rate of 2 L/hour, in combination with four sub

plots: 1) control, 2) 94-31-31 kg/ha (N-P_2O_5-K_2O), 3) 47-16-16, and 4) 47-47-47 kg/ha. In this study, the SG-17 hybrid variety of baby corn was used as the crop material. Each plot consisted of eight rows, ten meters in length. The rows were spaced 50 cm apart, with 50 cm spacing between plants in each row. The seeds were grown between 2 April to 31 May 2011 in the first year; and between 10 February to 9 April 2012 in second year. Baby corn pods were collected from each of the six rows and six plants, from the center of each plot. The data of this experiment were analyzed with analysis of variance (ANOVA) and the means compared by Duncan's multiple rank tests (DMRT), using MSTAT-C statistical software (Cochran and Cox., 1957).

Calculating Plants Water Usage

The amount of irrigation supply was determined by the Penman-Monteith equation, and reference evapotranspiration in the treatments was computed using Eq. (1).

$$\mathrm{ETo} = \frac{0.408\,\Delta(R_n - G) + \gamma(900/(T+273))\,U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$

Where ET_o is the reference evapotranspiration (mm/d),Δ slope vapor pressure curve (kPa/^{o}C), R_n net radiation at the crop surface (MJ/m^2/d), G soil heat flux density (MJ/m^2/d), T mean daily air temperature at 2 m height (^{o}C), γ psychrometric constant (kPa/^{o}C), U_2 wind speed at 2 m height (m/s), and e_s-e_a saturation vapor presser deficit (kPa). Actual evapotranspiration was calculated by following Eq. (2), (Allen et al., 1998).

$$\mathrm{ET_{c\ adj}} = \mathrm{K_s\,K_c\,ET_o} \quad (2)$$

$ET_{c\ adj}$ is actual evapotranspiration (mm/d), Ks water stress coefficient either non soil water stress Ks = 1 or soil water limiting Ks < 1 and Kc crop coefficient; crop coefficient in the initial growth stage 0.65, mid-season growth stage 1.22, and at the end of late growth stage 0.61. Evaluations followed protocol according to the (Irrigation Research Bureau, 2010).

Computing the Water Footprint

Water footprints consist of three components: green, blue, and grey water. The green water footprint, consisting of rainwater, evaporated during crop growth. The blue water footprint refers to surface and ground water usage in plant areas, which also evaporates during crop growth. The grey water footprint is the volume of freshwater for dilution, in which waste water becomes the drinking water quality standard. The computation of green and blue components of crop water usage (CWU) was calculated by summation of the daily evapotranspiration and irrigation supply; by following Eqs. (3) and (4), (Hoekstra et al., 2011).

$$CWU_{green} = 10 \times \sum_{d=1}^{lgp} ET_{green} \quad (3)$$

$$CWU_{blue} = 10 \times \sum_{d=1}^{lgp} ET_{blue} \quad (4)$$

CWU is crop water usage (m^3/ha), ET_{green} daily evapotranspiration (mm/d), ET_{blue} irrigation amount (mm/d); lgp denotes the length of growing period (in days), and 10 is the value used to convert units from (mm) into (m^3/ha). Calculations of green and blue water footprints within each period are determined by Eqs. (5) and (6), (Hoekstra et al., 2011).

$$WF_{proc,green} = \frac{CWU_{green}}{Y} \quad (5)$$

$$WF_{proc,blue} = \frac{CWU_{blue}}{Y} \quad (6)$$

Where WF_{proc} is the water footprint (m^3/ton or L/kg), and Y is the economic yield (ton/ha). The grey water footprint is calculated by following Eq. (7)

$$WF_{proc,grey} = \frac{(\alpha \times AR)/(c_{max} - c_{nat})}{Y} \quad (7)$$

Where α is leaching–run off fraction of nitrogen fertilizer assumed 10%, AR perform chemical fertilizer application (kg/ha), C_{max} is the maximum acceptable concentration of nitrate found (drinking water quality standard is 50 mg/l), and C_{nat} the natural concentration for pollutant nitrate from cultivation. The total water footprint of the crop growing process is the sum of green, blue, and grey water footprints, demonstrated in Eq.(8), (Kongboon and Sampattagul, 2012).

$$WF_{proc} = WF_{proc,green} + WF_{proc,blue} + WF_{proc,grey} \quad (8)$$

RESULTS AND DISCUSSION

Yield Components

This results were achieved when 40% allowable depletion content (ADC) increased corn height, pod weight, pod length, and water use efficiency to 188.75 cm, 7.75 ton/ha, 9.61 cm, and 3.26 kg/m^3, respectively. Production of 60% ADC measured 180.61 cm, 7.54 ton/ha, 7.54 cm, and 3.19 kg/m^3. A yield of 184.37 cm, 6.81 ton/ha, 923 cm, and 2.54 kg/m^3 was produced of 80% ADC. Enhancement of the 80% ADC's finest pods showed no significant difference when compared with both the 40% ADC and 60% ADC.

Aydinsakir et al., (2013) reported that sweet corn production, affected by deficit water, reduced corn height, pod diameter, pods length, and seed weight/1,000 seeds. The pod amount, however, was not reduced. Past applications of fertilizer, applied at 94-31-31 kg/ha (N-P_2O_5-K_2O), yielded the highest corn height, pod weight, pod length, amount of pods, and amount and water use efficiency (192.61cm, 8.82 ton/ha, 9.57 cm, 146,234 pods/ha, and 3.59 kg/m^3 , respectively). In comparison, the fertilizer application of 47-47-47 kg/ha yielded 188.82 cm, 8.62 ton/ha, 9.64 cm, 141,111 pods/ha, and 3.50 kg/m^3.The application of 47-16-16 kg/ha yielded 179.20 cm, 6.98 ton/ha, 9.34 cm, 123,889 pods/ha, and 2.84 kg/m^3. Lastly, the control treatment yielded 177.67 cm, 5.03 ton/ha, 9.19 cm, 95,679 pods/ha, 2.06 kg/m^3, and 2.16 kg/m^3 and was considered not significant. Cela et al., (2011) studied 0, 50, 100, 150, 200 and 300 kg N/ha application on sweet corn production in a semi-arid climate in Spain which found that 100 kg N/ha provided the greatest increase in sweet corn production. The interaction of the main plot combined with sub plots having 40% ADC was associated with 94-31-31 kg/ha fertilizer, which had the greatest affect upon pot weight and water efficiency. The exception was corn height, pod length, and pod amount, which proved to be insignificant.

Water Footprint

This study found that the 40% ADC showed the least reduction of green, blue, grey, and total water footprint amounts (490, 340, 16 and 845 L/kg), 60 % ADC yielded 606, 423, 23 and 1,051 L/kg^{-1}; and 80 % ADC at 809, 482, 22, and 1,313 L/kg, respectively. This result corresponded with Jeswani and Azapagic, (2011) who reported that total water footprint within sweet corn production, in each region of the world; ranged from 354 to 2,434 L/kg. In sub plots factors, in which the green, blue, and total water footprints were reduced the most using 47-47-47 kg/ha obtained results of 444, 303 and 763 L/kg.

Table 1 Showed yield and water footprint of Baby corn production

Main plots	Sub plots (N-P_2O_5-K_2O kg ha^{-1})	Corn height (cm)	Pods weight (ton ha^{-1})	Pods length (cm)	Pods amount (pods ha^{-1})	Water use efficiency (kg m^{-3})	Green water footprint (L kg^{-1})	Blue water footprint (L kg^{-1})	Grey water footprint (L kg^{-1})	Total water footprint (L kg^{-1})
40 % ADC	Control	187.80a	5.78a	9.20a	103,899cd	2.45a	721b	487b	3e	1,211b
	94-31-31	190.93a	9.40a	9.57a	147,777a	3.96a	362b	256b	27b	644b
	47-16-16	183.35a	7.36a	9.60a	125,740b	3.10a	490b	342b	18bcd	850b
	47-47-47	192.91a	8.45a	10.07a	126,852b	3.54a	386b	276b	14cde	676b
	Mean	188.75A^{ns}	7.75A^{ns}	9.61A^{ns}	126,065A^{ns}	3.26A^{ns}	490B*	340B*	16A^{ns}	845B*
60 % ADC	Control	173.27a	5.41a	9.33a	97,963de	2.27a	657b	479b	7de	1,143b
	94-31-31	192.18a	8.86a	9.87a	142,037ab	3.77a	565b	385b	41a	991b
	47-16-16	175.35a	7.06a	9.27a	119,630bc	2.99a	661b	454b	24bc	1,139b
	47-47-47	181.65a	8.82a	9.40a	139,074ab	3.73a	541b	372b	20bc	933b
	Mean	180.61A	7.54A	9.47A	124,675A	3.19A	606B	423A	23A	1,051B
80 % ADC	Control	171.93a	3.91a	9.03a	85,185e	1.45a	1,547a	895a	4e	2,447a
	94-31-31	194.73a	8.21a	9.27a	148,889a	3.06a	529b	322b	39a	890b
	47-16-16	178.91a	6.53a	9.17a	126,297b	2.43a	757b	451b	28b	1,237b
	47-47-47	191.89a	8.60a	9.47a	157,407a	3.22a	404b	259b	15cde	679b
	Mean	184.37A	6.81A	9.23A	129,445A	2.54A	809A	482A	22A	1,313A
Mean sub plots	Control	177.67B*	5.03B**	9.19A^{ns}	95,679B**	2.06B**	975A**	621A**	5C**	1,600A**
	94-31-31	192.61A	8.82A	9.57A	146,234A	3.59A	485B	321B	36A	842B
	47-16-16	179.20B	6.98A	9.34A	123,889A	2.84A	636AB	416AB	23AB	1,075B
	47-47-47	188.82AB	8.62A	9.64A	141,111A	3.50A	444B	303B	16BC	763B
Interaction main plots x sub plots		ns	ns	ns	*	ns	**	**	*	**
% CV (main plots)		4.56	17.53	4.96	15.38	17.69	24.13	21.36	27.02	22.86
% CV (main plots x sub plots)		5.68	10.60	4.00	8.00	10.46	30.14	25.56	31.55	28.17

*Caution: ns = non significant)P>0.05(, * = significant at)P < 0.05(, ** = significant at)P <0.01(and Different letters indicated significant different by DMRT*

The proved less than the mixture of 94-31-31 kg/ha, which had results of 485, 321, and 842 L/kg; as well as the 47-16-16 kg/ha mixture, with 636, 416, and 1,075 L/kg. Another control treatment found 975, 621 and 1,600 L/kg to be significant. Whereas, the control treatment which held the lowest grey water footprint at 5 L/kg, less than 47-47-47 kg/ha was the 16 L/kg together with 47-16-16 kg/ha, the 23 L/kg and the 94-31-31 kg/ha at 36 L/kg, which were very significant. The interaction of both the irrigation and fertilizer applications, found 40% ADC combined with 94-31-31 kg/ha fertilizer, to produce the greatest decrease in green, blue, and total water footprints with the exception of the grey water footprint.

CONCLUSION

Results indicate that 40% ADC irrigation application yielded the highest corn height, pod weight, and water use efficiency; as well as producing the greatest decrease in green, blue, and total water footprints (compared with both the 60% and 80% ADCs). Past fertilizer applications found 94-31-31 kg/ha enhanced corn height; pod weight, length, and amount as well as water usage efficiency. In contrast, 47-47-47 kg/ha offered the least reduction of green, blue, and total water footprint content compared with other sub plots. The association of 40% ADC with the 94-31-31 kg/ha^{-1} application is recommended for farmers, in the parameters of pod weight, and water usage (including footprint contents) in both clay loam and clay soil. However, economic factors involving profit and budget for unit costs are not considered here.

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REFERENCES

Agriculture Economic Bureau. 2010. The effective for baby corn production. Ministry of Agriculture and Co-operation. 68 p.

Allen, R.G., Perreira, L.S., Raes, D. and Smith, M. 1998. Guidelines for computing crop water requirement. FAO Irrigation and Drainage Paper. 300 p.

Aydinsakir K., Erdal, S., Buyuktas, D., Bastug, R. and Toker, R. 2013. The influence of regular deficit irrigation application in water use, yield and quality components of two corns (*Zea mays* L.) Agriculture Water Management, 128, 65-71.

Cela S., Santiveri, F. and Lloveras, J. 2011. Optimum nitrogen fertilizer rates for second-years corn succeeding alfalfa under irrigation. Field Crops Research, 123, 109-116.

Cochran, W. and Cox, G. 1957. Experiment Design. Wiley. New York. USA.

Department of Agriculture. 2005. The recommend of economic agronomy fertilizer application. Ministry of Agriculture and Co-operative. 122 p.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. 2011. The water footprint assessment manual. Earthscan. 204 p.

Howell, T. 1990. Relationship between crop production and transpiration, evapotranspiration and irrigation. Irrigation of Agriculture Crops. Agronomy Monograph, 30, 391-434.

Irrigation Research Bureau. 2010. The 40 types of crop coefficient. royal irrigation department. 40 p.

Jeswani H.K .and Azapagic, A. 2011. Water footprint: methodologies and a case study for assessing the impacts of water use. Journal of Cleaner Production,.19, 1288-1299.

Kongboon, R. and Sampattagul, S. 2012. The water footprint of sugarcane and cassava in northern Thailand. Social and Behavioral Science, 40, 451-460.

Thai Meterological Department. 2010. Climate statistic. Thai Meteorological Department. Bangkok, Thailand.

Research article

Site-specific Soil Conservation Approaches in Desertification-prone Areas in the Inner Mongolia Region, China

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Abstract Desertification is still a severe problem in the Inner Mongolia region of China, despite the country's efforts to stop land degradation. The authors carried out periodic field surveys for over a decade in different desertification-prone arid lands of Northern China. Based on a series of experiments and analyses, this paper proposes locally-tailored technologies that can ensure greater participation, and lead to more effective, sustainable measures to combat desertification in the area. Specifically, the potential of both cotton and coal ash as water-holding materials was experimented with sandy soil. From the results, an amount of 0.5% (by weight) cotton and 3% (by weight) alkali-treated coal ash (named artificial zeolite) mixed with sandy soil could ensure water retention in the soil and so facilitate upland crops growing in arid environments. The results also showed that, if mixed individually with the soil, both of these materials demonstrated constant positive effect as water-holding materials. However, dual application (both the items mixed together with soil) did not show constant positive effect. In addition, to diversify the potential uses of coal ash, the effects of artificial zeolite as a particle film sprayed over plant-leaves were also tested. The results showed that cotton plants with a particle film that were grown in sandy soil tended to transpire less water than those plants without a particle film on their leaves. Finally, since the properties of applied forms of coal ash (i.e. the artificial zeolite) differ based on the processing methods (alkali treatment) used, proper selection of the type of artificial zeolite could further diversify its potential uses, for example as a salinity mitigator in arid soil.

Keywords desertification, site-specific, water-holding material, arid land, sustainability

INTRODUCTION

Afforestation has been the most popular measure used to combat desertification in many arid land areas of the world as well as in the Inner Mongolia region in China, which is experiencing severe desertification. Afforestation plays a very significant role in desertification control, but planting trees is not the only measure against desertification. Instead, when only the planting of trees is considered and no measures are considered regarding farmland to enhance the per area unit output, the prevention of desertification fails in many cases (Fan and Zhou, 2001). Massive man-made forests that include plants, such as poplar, larches, pines, birches, oaks, elms, lindens, and willows, have been established in the Inner Mongolia region to prevent desertification; however, the illegal cutting down of plants, i.e., deforestation, occurs frequently in the region (Liu, 2014). Despite different land conservation and restoration efforts undertaken by the Chinese communes based on ideological motivation and regulatory steps, the reality is that the encroaching rate of desertification due to deforestation exceeds the status of prevention (Cao, 2008). Such a situation emphasizes the

necessity of revising the basic strategies for participation in land conservation. In other words, site-specific sustainable soil conservation approaches could encourage the mitigation of the desertification syndrome in the Inner Mongolia region. This study thus investigated the potential natural resources in north China that could feasibly be used as a tool(s) to combat desertification in a sustainable way. We identified the cotton plant as an alternative/complementary plant in the Inner Mongolia region because China is the largest producer of cotton in the world and because domestic production is mainly concentrated in the northwest Xinjiang region (Xinjiang Uyghur Autonomous region), which is a neighbor province of Inner Mongolia. The climate and ecology of the Xinjiang and Inner Mongolia regions are very similar. Unlike other quick growing forest plants in Inner Mongolia, such as poplars and pines, perennial cotton plants have little value as an alternative fuel or precious wood, and are less likely to be the target of illegal wood-cutters. At the same time, cotton has a high potential to be a cash crop. Therefore, to introduce and to grow the cotton plant in Inner Mongolia would not be a difficult task from eco-environmental and socio-economic standpoints; however, since the existing status of the production, marketing, and distribution channels of cotton products (cotton wool and fibers) are concentrated in the Xinjiang region, and because the people in the Inner Mongolia region are not accustomed to growing cotton as upland crops, to make the cotton a cash crop in the Inner Mongolia region, problems associated with certain factors, such as extension, marketing, and price-fixing, would arise at the initial stage because of the imbalance in the demand-supply of the products in the locality. Therefore, the authors also attempted to diversify the usage of cotton products in the region. Due to its nature and properties, cotton wool is an organic substance and has good water-holding capacity. Therefore, wasted and/or un-used portions of cotton wool can be used as an organic water-holding material in sandy soil.

In addition, the Inner Mongolia region is an important coal production base with more than a quarter of the world's coal reserves located in the province, which produces millions of tons of coal fly ash as a by-product every year. Coal ash or fly ash, usually refers to ash/residue produced during combustion of coal, is the largest quantity of industrial waste residues in China (Tang et al., 2013). To find out effective/recycle use(s) of this product is a big issue in that region. The Chinese government has initiated some steps to recycle it as an alternative raw material for concrete and cement materials (Yi et al., 2012). In this regard, we attempted to use this waste material as a soil improver, which could facilitate plant growth in the sandy soil. Accordingly, we experimented with coal ash's nature as a water-holding material not by applying it to farmland soil in its original form but in the form of an artificial zeolite (alkali treated coal ash) because the latter has superior physico-chemical properties than in its original form (Henmi, 1997).

This paper aims for and focuses on the identification of the site-specific problems related to soil conservation in the Inner Mongolia region as well as the sustainable measures that involve introducing locally originated water holding materials by using cotton plants/wools and alkali-treated coal ash (waste) based on basic experiments and investigations. In addition, to diversify the uses and the application of cotton and coal ash in the region, other potential uses of the materials were investigated.

METHODOLOGY

Study Sites

Inner Mongolia is the third largest province (an autonomous region) in China, and it has a temperate continental monsoon climate with a sharp rainfall gradient from 50 mm to 450 mm in the west and northeast parts, respectively, while the evaporation capacity is above 1200 mm in most areas of this region. Most of the rainfall occurs in the summer season (May to September). The region is characterized by a diverse ecosystem, including vast forests and agricultural lands as well as the world's largest temperate grasslands and extensive sandy lands and deserts (Bai et al., 2004). Land degradation/desertification caused by deforestation and over-grazing has been severe. Between 1980 and 2000, Inner Mongolia's population increased by 26%, from 18.76×10^6 to 23.72×10^6. The

most affected degraded grassland area in the region is the Xilingol League (a prefecture level division of Inner Mongolia) where the population increased by 19%, livestock increased 177%, and the grassland productivity decreased by 30% within the period of 1980 to 2000 (Zhen et al., 2014). The authors carried out field surveys periodically in different parts of the Inner Mongolia region from 2000 to 2009. The surveyed sites included grasslands and agricultural lands at five different administrative areas named Xilinhot County, Erenhot County, Zhenglan Banner (a county level division of Inner Mongolia), Abag Banner, and Sonid Right Banner of the aforesaid Xilingol League along with one more site at Wuchuan County in Hohhot City (a prefecture level city). All of these sites were prominent for desertification. The Xilingol area in particular, located in central Inner Mongolia, had been a fertile prairie in northern China, but desertification and sand storms have increased in the past decades. Fig. 1 shows the locations of the surveyed sites at Xilingol League and Hohhot city, while Table 1 presents the major soil and vegetation types in the grassland-dominated study sites.

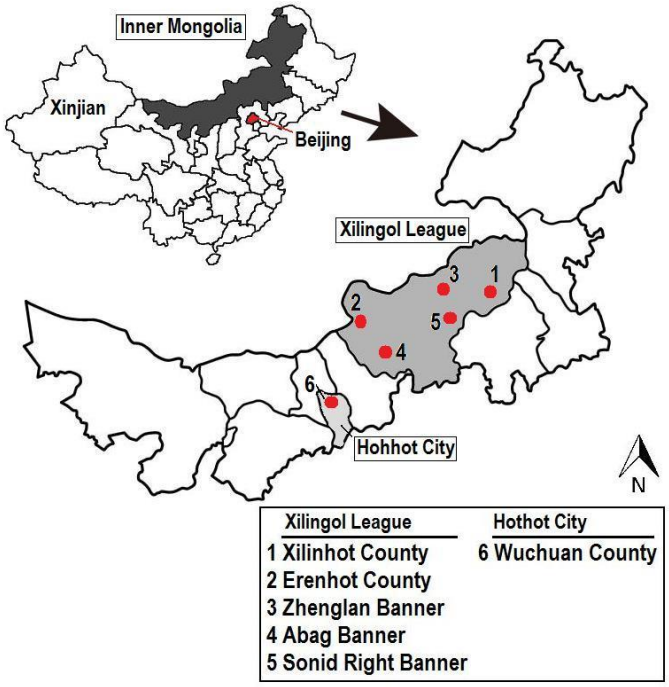

Fig. 1 Study sites at Xilingol League in Inner Mongolia region, China

Table 1 Major soil and vegetation types in the study sites of Inner Mongolia region

Study site	Soil type	Vegetation type	Dominant species
Xilinhot County	Chestnut	Typical steppe	*Stipa* species, *Cleistogenes* species
Erenhot County	Brown	Desert steppe	*Stipa* species
Zhenglan Banner	Chestnut	Typical steppe	*Stipa* species
Abag Banner	Chestnut	Typical steppe	*Artemisia* species, *Stipa* species
Sonid Right Banner	Brown	Desert steppe	*Artemisia* species, *Stipa* species
Wuchuan County	Chestnut	Desert steppe	*Stipa* species, *Artemisia* species

Materials and Methods

Cotton and coal ash as water-holding materials: A series of indoor and outdoor experiments were carried out by mixing cotton and alkali-treated coal ash (named artificial zeolite, henceforth AZ) with soils (sandy and loamy soils). The indoor experiments were carried out inside an artificial climate chamber (Fig. 2), whereas the outdoor experiments were conducted in farmland (Fig. 3). Both of these establishments are located within the campus of the College of Bioresource Sciences, Nihon University, Japan.

For the indoor experiments, seedlings of Chinese cabbage (*Brassica chinensis* L.) were used as test plants and grown in pots filled with river sand that is used for gardening purposes. Pieces of torn cotton wool were added at three different weight ratios (0.1%, 0.3%, and 0.5%), while Na-type artificial zeolite (Maeda Corporation, Japan) was added to the soil (sand) at the weight ratio of 3%. A total of 25 pots that included five replications of each item of the controls (non-treated), cotton-mixed (0.1%, 0.3% and 0.5%), and AZ-treated soils, were used to cultivate the test plants. The same doses of chemical fertilizer (N:P:K=8:8:6) and water were used to facilitate the natural growing of the plants. The soil moisture was measured by using a W.E.T sensor (DIK-691A; Daiki Rika Kogyo Co., Ltd.) coupled with a time-domain reflectometer, while the physiology of the shoot-part of each plant (shoot length and number of leaves) was measured periodically throughout the growing period. In addition, the pF values at each condition of the soil and plant weights (dry weights) were also measured.

On the other hand, for the outdoor experiments, cotton plants (*Gossypium hirsutum* L.) were grown in four adjacent plots (each with a dimension of 180cm length×30cm width) with the same soil texture (Andosol, also known as Kanto loam); however, the treatments of the soil in each plot were different, namely, the control (non-treated), the 0.5% (by weight) cotton-mixed soil, the 3% (by weight) AZ-mixed soil, and the cotton plus AZ-mixed soil. In the outdoor field, Ca-type AZ was used, and the same amount (g) of 0.5% cotton and AZ (g) was mixed in the dual application plot. To measure the periodic in-situ soil moisture and the pF, soil-moisture sensors (ECH2O-10; Decagon Devices, Inc.) attached to a data logger (Em5b; AINEX Co., Ltd.) and tensiometers (Daiki-8331; Daiki Rika Kogyo Co., Ltd.) were installed at each plot, respectively. The W.E.T sensor (DIK-691A; Daiki Rika Kogyo Co., Ltd.) was also used to cross check the recorded soil moisture values. Periodic measurements of the physiology of the plant-shoots (shoot length and number of leaves) as well as the biomass (dry weight, fresh weight) of the plant bodies were also carried out.

Coal ash as a particle film on plant-leaves: Inside a glass house (Fig. 4), a total of 24 cotton plants (*Gossypium hirsutum* L.) were grown in cultivation pots filled with two different textured soils (12 plants of each soil), namely, sand and Andosol/Kanto loam. A small amount of Ca-type AZ (Chubu Electric Power Co., Inc., Japan) with the pH value adjusted to 7 was mixed with water and sprayed over the foliage sections in equal numbers of the 6 young cotton plants (6 replications) from each soil type. The remaining 6 plants from each group (soil type) received no foliar-spray. After drying-up, the dust-like particle film created partial blockage to the stomata at the upper leaf surface. The plants were then grown by applying the usual doses of compound fertilizer (N:P:K=8:8:6). The parameters related to the plant growth, such as shoot length, number of leaves, stem-diameter, leaf-temperature, and leaf area as well as the daily transpiration rate were measured periodically. In addition, at the latter half of the growing stage, a 10-day long dry-down experiment was carried out on the plants by applying water equal to the 80% of their daily transpiration amounts. To identify the status between the transpiration and the available water for plant growth, this watering scheme followed a similar procedure as described by Sinclair and Ludlow (1986). Finally, the dry weights of the plants were measured.

Other potential uses of cotton and coal ash: Salinity is also an issue in many arid lands and in some areas of our study sites as well. To investigate the potential of coal fly ash and cotton as salinity mitigators, a number of experiments (Kaneuchi et al., 2008; Roy et al. 2009; Nishimura and Roy, 2010) have been carried out by applying AZ and waste cotton materials to different types of soil with different protocols. This paper will present an experiment in which a small amount of Ca-type AZ

Fig. 2 Experiments inside the artificial climate chamber

Fig. 3 Experimental plots with cotton-plants growing in different conditions

Fig. 4 Experiments inside the glass house with a particle film sprayed over cotton plants

Fig. 5 Experiments of artificial zeolite and cotton gauze as salinity mitigators

Table 2 Major physico-chemical properties of artificial zeolites (AZ) and soils used in the experiments

Type	Particle size	EC (dSm^{-1})	pH (H_20)	Exchangeable cation cmol(+) kg^{-1}				CEC cmol(+) kg^{-1}
				Na	K	Ca	Mg	
Sand	0.2～2 mm	0.12	6.9	0.8	0.1	0.5	0.1	6.5
Andosol	0.02～2 mm	0.33	6.2	0.3	2.9	2.6	0.6	18.7
Ca type AZ	5～100 μm	1.60	9.8*	122.0	15.3	151.0	1.9	260.8
Na type AZ	5～100 μm	1.10	11.2	160.0	11.4	111.0	0.2	210.0

*Note: * Except the pH adjusted to 7 for f_A zeolite during particle film spray*

(named f_A zeolite, Maeda Corporation, Japan) was applied to the top surface of artificially-prepared (by 5% sodium chloride solution) saline soil (Andosol/Kanto loam) filled in 8 Wagner pots (Fig. 5). The treatments in every two pots were different. Of the 8 pots, two had 5mm thin AZ-layers applied directly to the top of the soil, while the same amount of AZ was sealed in between the double-fold cotton gauze pockets in two other pots. Five-fold cotton gauzes were laid over the surface soil in two pots, and two remaining pots were kept under no-treatment (control) conditions. The pots with moist saline soil were placed in an artificial glass chamber (relative humidity: 60%, average temp: 25°C) for 30 days. The soil samples from the upper layers were collected, and the concentrations of specific ions (Na^+ and Ca^{++}) in the soil samples were investigated by using an

Atomic Absorption Spectrophotometer (AA-6800; Shimadzu Corporation, Japan). Also, the electrical conductivity of the soil samples was measured by using an EC meter (B-173; Horiba, Japan).

Table 2 presents the major physico-chemical properties of artificial zeolite (AZ) and farmland soil (Andosol/Kanto loam) used in the different experiments.

Statistical Analysis

All data were statistically analyzed using MiniTab statistical software. Particularly; mean, standard deviation, and percentage were determined using descriptive statistics. Mean of treatments were compared by One-way ANOVA (Analysis of Variance) at 0.50 significance level.

RESULTS AND DISCUSSION

Cotton and coal ash as water-holding materials: Fig. 6 and 7 show the variations in the average physiological growth (shoot length) and the soil moisture content under each condition (treatment) throughout the growing period carried out for the indoor experiments. As can be observed from the figures, while the AZ-treated soil had the highest soil moisture content accounting for an average of 3-5% higher than the other pots, the plant-growths (shoot lengths) were better in the order of 0.5% cotton-treated, 0.3% cotton-treated, and AZ-treated soil. Fig. 8 illustrates the pF-soil moisture curve in each treatment from which it was found that regarding the effective pF range to grow plants (pF=1.8

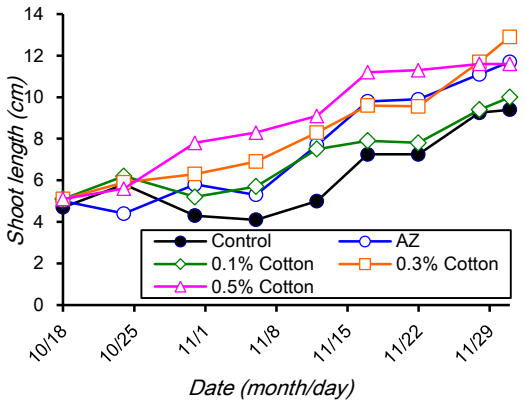

Fig. 6 Variations in the shoot length (*B. chinensis*) at different treatments of soil (indoor)

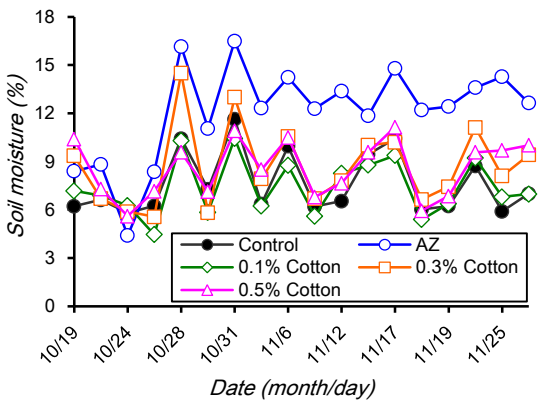

Fig. 7 Variations in the soil moisture content at different treatments of soil (indoor)

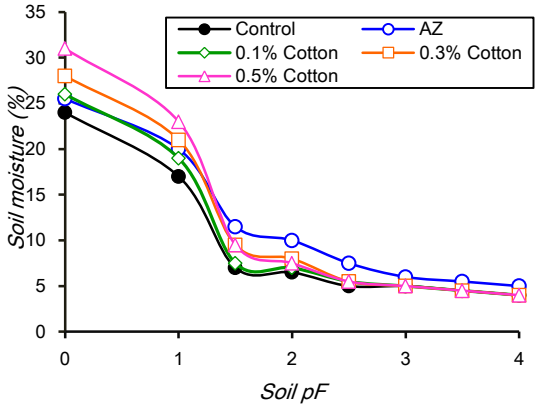

Fig. 8 Soil moisture retention curves at different treatments of soil (indoor)

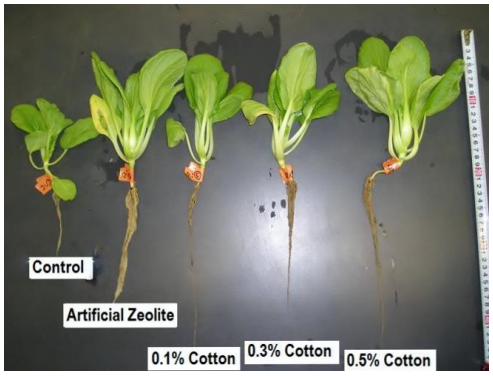

Fig. 9 Plant growth at different treatments of soil (indoor)

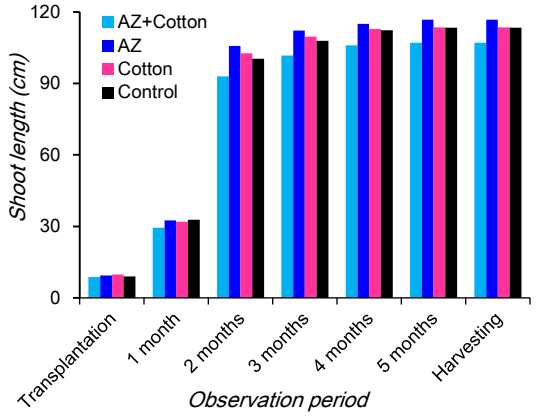

Fig. 10 Variations in the shoot length (*G. hirsutum*) at different treatments of soil (outdoor)

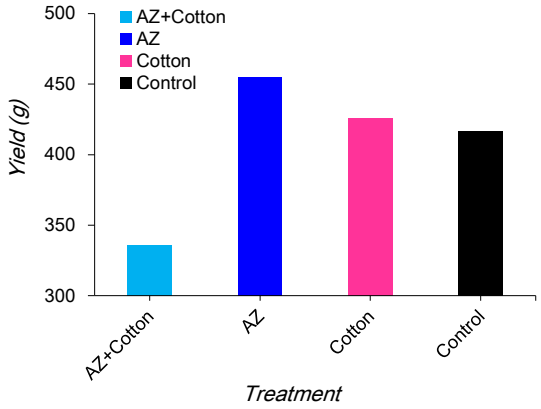

Fig. 11 Variations in the yields of cotton balls at different treatments of soil (outdoor)

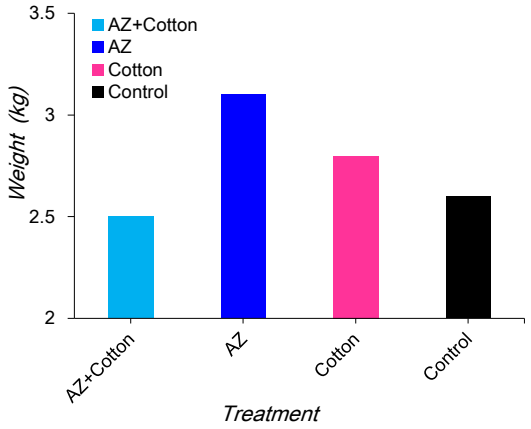

Fig. 12 Variations in the dry weights of plants at different treatments of soil (outdoor)

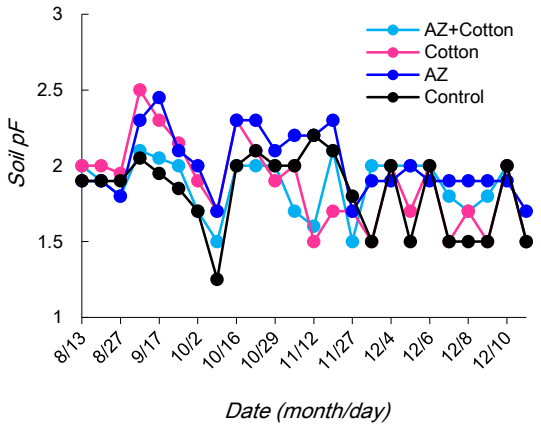

Fig. 13 Variations in the soil pF values at different treatments of soil (outdoor)

to 3.0), the AZ-treated soil followed by the 0.5% and 0.3% cotton-mixed soils had better soil moisture capacity. In addition, considering other measured parameters, such as the plant weight and the number of leaves, the AZ-treated soil and the 0.5% cotton-mixed soil were found to be the most suitable treatments among all of the treatments when using them as water-holding materials for the soil. Fig. 9 shows the average growing conditions of the plants under each condition.

Fig. 10, 11 and 12 show the average variations in the representative physiological parameters, including the shoot length, yield (weights of cotton balls), and dry weight of the plant bodies (shoot plus root), for cotton plants grown in outdoor plots. From the figures, it can be seen that AZ and cotton wool mixed independently with soil favored the cotton growth/production; however, when these materials were mixed together and applied jointly to the soil, the growth/production trailed behind the control (no-treatment) condition. A similar tendency was also found for other measured parameters (number of leaves, biomass). The specific problems related to the dual application of AZ and cotton wool that may be caused by poor function are: slaked finer *particles of soil*/AZ *blocked* pores of the cotton wool, the formation of a type of a *soil* crust, reduced infiltration and water movement through the *soil*, and the hampered growth/yield of the plants. Fig. 13 shows the periodic variations in the soil pF values with each treatment. While the pF values in all of the plots ranged from 1.25 to 2.5 (within the range suitable for plant growth; pF =1.8 to 3.0), the cotton-treated plot showed the most stable values that ranged from pF= 1.5 to 2.5 followed by the AZ-

treated plot with pF values that ranged from pF= 1.3 to 3.0 throughout the growing period. On the other hand, unlike the indoor experimental results, the soil moisture content did not show distinct differences among the treatments in the outdoor experiments.

Coal ash as a particle film: Variations in the transpiration rate of the plants grown with and without a particle film in both types of soil (sand and Andosol) are presented in Fig. 14, while Fig. 15 and Fig. 16 present the variation in the shoot lengths and the dry weights of the plant bodies. From the figures (Fig. 15 and Fig. 16), it can be observed that the plants with a particle film sprayed over the leaves had slightly higher average growths than the plants with no particle film in both types of soils. A similar tendency was also found in cases of other physiological parameters (number of leaves, stem-diameter, and leaf area); however, in the case of the daily transpiration rate, the tendency varied in the soil types both before and after the dry-down period (Fig. 14). To identify the specific effect of each treatment on the transpiration, the normalized transpiration rates (daily relative transpiration rates normalized against the plant growth) for each treatment were plotted against the fractions of transpired soil water (the ratio of daily transpired soil water to the water at field capacity) following the Sinclair and Ludlow (1986) method (Fig. 17). From the difference/degree of inclination between the two approximate straight regression lines of the same soil with and without a particle film, the results show that cotton plants with a particle film that were grown in sand transpired less water than the plants without a particle film on their leaves**.**

Uses of cotton and coal ash as potential salinity mitigators: Variations in the average ion-concentrations (Na^{+} and Ca^{++}) at the top surface soil in the pots with different treatments are presented in Fig. 18, while the average EC concentrations are presented in Fig. 19. The results show that the AZ application (direct application and inside cotton gauze packets) reduced the concentration of Na-ion in the topsoil; however, the Ca-ion concentrations also reduced slightly in comparison with the control and cotton gauze treatments (Fig. 18). The reason is that the type of artificial zeolite used in the experiment (Ca type) was not saturated by specific exchangeable ions (Ca^{++}) and was part of Ca-ion thus transmitted from the topsoil to the finer AZ particles. The variation in the average EC values at the end of the experiment as shown in Fig. 19 also supports the tendency found in the case of changes in the Na-ion concentration in the topsoil. Therefore, it can be said that AZ has a great potential to be used as a salinity mitigator; however, depending on the properties of AZ, such as the type/method of alkali used to process the coal ash, the extent of salinity mitigation will vary. Moreover, the salinity mitigation capacity can be maximized while using AZ in cotton packets.

CONCLUSION

The experiments carried out in this study focuses on different potential uses of cotton and coal ash as soil improvers by using them as soil water holding materials, as transpiration reducers by using them as foliar particle film materials, and as salinity mitigators by using them as salt absorbents in arid land soil (sandy and loamy). The results show that mixing small amounts of these items (artificial zeolite: 3% by weight; cotton wool: 0.5% by weight) with soil (sandy and loamy types) could facilitate plant growth in arid land soils (sandy and loamy). In addition, if used as a particle film, pH-adjusted (to 7.0) coal ash (artificial zeolite) can sustain plant growth with less transpiration, and this anti-transpiration capacity maximizes in sandy soil in comparison with loamy soil. Moreover, based on the type/processing of the materials, utilizing the higher cation exchange capacity (CEC) of artificial zeolite, specific ions responsible for salinization (Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} and Cl^{-}) can be removed from soil (loamy), and this salinity mitigation capacity maximizes if it is used in packs made of cotton gauze. These experimental findings demonstrate the diversified potential uses of cotton and coal ash in an arid land environment. In other words, potential and proper uses of two locally tailored items to combat desertification in the Inner Mongolia region are identified from this study.

The sustainable conservation of natural resources, such as soil and water, of an area incorporates many bio-physical and socio-cultural interdisciplinary actions regardless of being a developing or

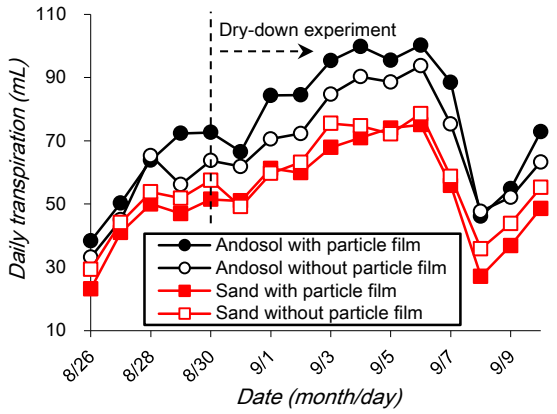

Fig. 14 Variations in the transpiration rate by plants with and without a particle film

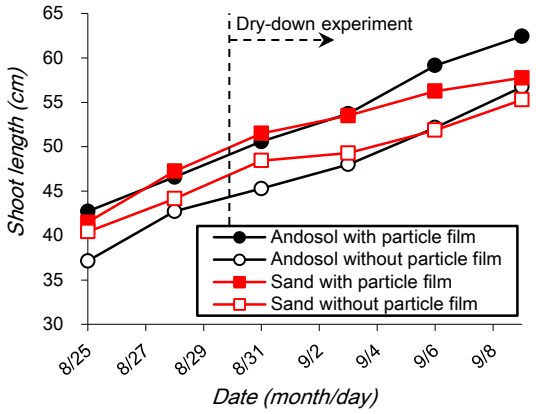

Fig. 15 Variations in the shoot length of plants with and without a particle film

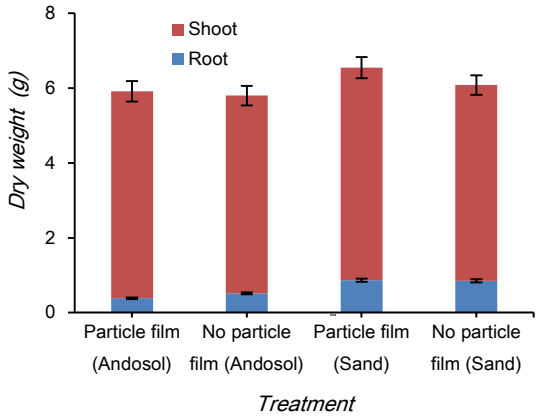

Fig. 16 Variations in the dry weights of plants with and without a particle film

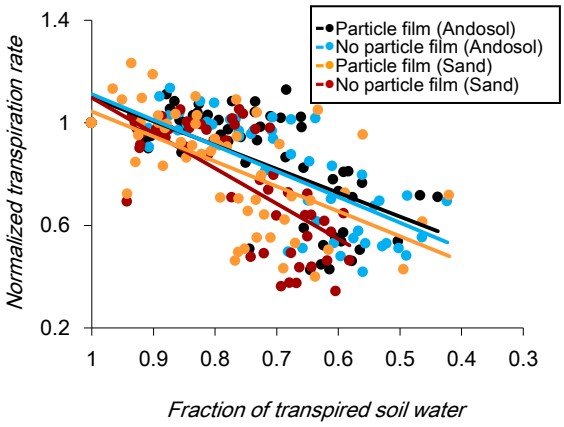

Fig. 17 Variations in the transpired amount of soil water during the dry-down experiment

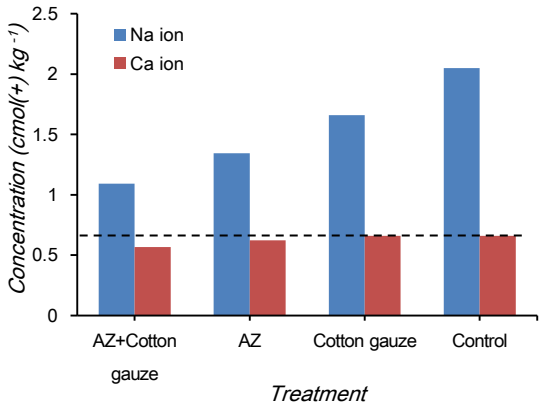

Fig. 18 Variations in the average ion-concentration at surface soil with different treatments

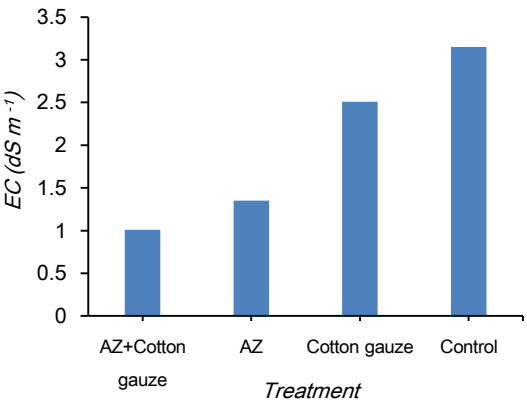

Fig. 19 Variation in the average EC values at surface soil with different treatments

developed country. From the case studies in the study sites, it is not easy to conclude that eco-environmental and natural resource problem(s) are always easier to manage in a specific area because it depends on the facts and the circumstances of each case. As stated in the methodology section, we carried out a number of preparatory experiments to set and to determine the most suitable ratios among the concerned parameters (e.g., soil, water, cotton, coal ash, and vegetation) in our study area, which was the Inner Mongolia region. Some of the study sites as well as other potential resources in this particular region (studies are currently being conducted) are not included in this paper; however, the results and the analyses discussed in this paper outline that the locally available/waste materials, specifically cotton and coal ash in our study, have a great potential to be used as soil improvers that facilitate plant growth and thus combat desertification in a site-specific and sustainable way. To achieve the best results, carrying out outdoor experiments in the study fields and convincing the local people to accept the extension of our technologies would be more effective from the perspective of field-application. Also, follow-ups and feasibility surveys at the initial stage (if accepted by the local people) would be necessary.

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REFERENCES

Bai, Y.F., Han, X.G., Wu, J.G., Chen, Z.Z. and Li, L.H. 2004. Ecosystem stability and compensatory effects in the Inner Mongolia grassland. Nature, 431, 181-184.

Cao, S. 2008. Why large-scale afforestation efforts *in* China have failed to solve the desertification problem. Environmental Science *&* Technology, 42, 1826-1831.

Fan, S. and Zhou, L. 2001. Desertification control in China*:* possible solutions. Ambio, 30 (6), 384-385.

Henmi, T. 1997. Chemical conversion of coal ash into artificial zeolite and its recycling. New Ceramics, 7, 54-62.

Kaneuchi, T., Roy, K., Yamamoto, T. and Inoue, M. 2008. Capture of excessive salt from soil by using artificial zeolite. Proc. of Japanese Society of Irrigation, Drainage and Rural Engineering (JSIDRE) conference held in Akita, Japan, 782-783 (*in Japanese*).

Liu, J. 2014. Forest sustainability in China and implications for a telecoupled world. Asia and the Pacific Policy Studies, 1, 230-250.

Nishimura, T. and Roy, K. 2010. Applicability of artificial zeolite and cotton as water holding materials to the farmlands. Environmental Information Science, 39, 132-133 (*in Japanese*).

Roy, K., Kitani, O. and Wei, Z. 2005. Cotton and coal-ash: their effectiveness while using as locally sourced water holding materials in arid land soil. Proc. of JSIDRE conference held in Gifu, Japan, 320-321 (*in Japanese*).

Sinclair, T.R., Ludlow, M.M. 1986. Influence of soil water supply on the plant water balance of four tropical grain legumes. Australian Journal of Plant Physiology, 13, 329-341.

Tang, Z, Ma, S., Ding, J., Wang, Y, Zheng, S. and Zhai, G. 2013. Current status and prospect of fly ash utilization in China. Proc. of 2013 World of Coal Ash (WOCA) conference held in Lexington, KY, USA, 1-7 (URL: http://www.flyash.info/2013/037-Ding-2013.pdf, access date: August 11, 2014).

Yi, L., Wang, H., Wang, X. and Peng, J. 2012. Research progress of utilizing fly ash as resource of building material. Bulletin of the Chinese Ceramic Society, 31 (2), 88-91.

Zhen, L., Yan, H., Liu, G. Lui, J., Zhang, H., Du, B., Wu, R., Sun, C. and Wang, C. 2014. Herders' willingness to accept versus the public sector's willingness to pay for grassland restoration in the Xilingol League of Inner Mongolia, China. Environmental Research Letters, 9, 1-15.

Research article

Pesticide Distribution in the Namphong River NE Thailand Arising from Land Use and Other Practices

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Abstract Large quantities of pesticides and herbicides are used in the Namphong River catchment, NE Thailand for protection of crops and agro industrial production. The aim of this study was to screen pesticides in waters of the Namphong River from in-situ river aquaculture, surface runoff and agro industrial discharges to identify if pesticide levels pose significant risk to the aquatic ecosystem. A passive sampling technique was used to estimate the level of pesticides in the river water. Pesticides were accumulated on polydimethyl siloxane (PDMS) strip passive samplers during 29 days deployment in January-February 2012, and then sent to Australia for analysis of pesticides at the University of Queensland and Queensland Health Laboratories. The PDMS passive samplers were deployed at 5 sites in the Namphong River from below the Ubonratana Dam, the tributary downstream of the paper mill and vegetable and paddy fields down to the Chi River above the junction of Namphong River. Atrazine, ametryn, chlorpyrifos and oxadiazon were found at all sites at elevated levels associated with vegetable and paddy field areas indicating their extensive application. Terbuthylazine, terbuphos and phosphate tri-n-butyl were found only in the paper mill discharge. Traces of galaxolide were found at all sites but only in significant amounts (30 times higher) just below the paper mill. Comparison of pesticides between the present and an earlier 2005 study of the paddy field ecosystem 50 km N from Khon Kaen show a shift from organochlorine use to low persistence pesticides, particularly chlorpyrifos. The results confirm that a range of pesticides are being used in the Namphong river catchment able to be detected downstream, though at low levels. These data provide a baseline, showing the need exists for more systematic and complex assessment of the catchment to develop a tool for pollution control in the catchment and to identify major sources of contamination and for ongoing environmental risk management.

Keywords pesticides, herbicides, passive sampling, land use practices, environmental risk management

INTRODUCTION

The Namphong River in the NE part of Thailand is within a sub-catchment of the Mekong River (Fig. 1). The Namphong River flows to the Chi River and via the Mun River to the Mekong River. Below Ubolratana Dam, there are extensive agro-industry and farming activities along the Namphong River which use irrigation from dam storage and some supplementary groundwater supply. Pesticides and herbicides from agro-industry activities are identified as potential risks to human health and the environment and as significant pollutants (Somparn et al., 2014). Of all pesticides in use, chlorpyrifos was identified as the highest volume of insecticide importation in Thailand (Department of Agriculture, 2012). The aquatic ecosystem of the Namphong River is a critical aspect for the evaluation of the effects of pesticides dispersed in the environment. Ecotoxicological effects from pesticides on aquatic organisms may be observed via biomonitoring with both individual organisms and ecosystem function and structure. The Namphong River also supports extensive cage aquaculture which may be affected by pesticides. In 2010, 209 cages produced 1536 tonnes of Nile tilapia in Khon Kaen province (Department of Fisheries, 2010).

Key questions are: (i) what are the effects of pesticides in the Namphong River?; and (ii) their relationships to other water quality parameters associated with agro-industry and farming activities. The prevailing tropical wet and dry seasons cause variation in river flow. The addition, of particulate and organic matter from soil transferred directly to river water can absorb pesticides. Potential effects are therefore possible from pesticides added to river water during the annual cycle that may arise from agricultural, aquaculture and other urban discharges from Khon Kaen city.

OBJECTIVE

This study aims to identify if pesticides and herbicides from multiple agro-based activities comprising agro-industry and small-scale farming activities along the Namphong River, are environmental and health risks, causing any impact to the Namphong River water body at different sample locations, and compares data from the 2012 dry season with existing data and criteria.

METHODOLOGY

Pesticides and herbicides were accumulated on polydimethylsiloxane (PDMS) strip passive samplers during 19 January-23 February 2012 at 5 sites at the Namphong River from below the Ubonratana Dam, the tributary downstream of the paper mill and vegetable and paddy fields down to the Chi River above the junction of Namphong River (Fig. 1). Site C is on a small tributary less than a few km to the Namphong River from the pulp and paper mill (Fig. 1C). Prior to application each PDMS sampler (strips 2.5 cm x 92 cm and thickness about 400 μm) was cleaned on a horizontal shaker in fresh redistilled hexane for three consecutive 24 h periods at the pesticide analytical laboratory followed by drying under high purity nitrogen gas steam, wrapping in acetone rinsed aluminium foil and stored in the refrigerator until dispatched to Khon Kaen. The PDMS samplers were placed under water at a depth of 0.50 m and left in place for 29 days. Following collection, the PDMS samplers were placed in pre-cleaned acetone rinsed aluminium foil envelopes and kept refrigerated until dispatched with quarantine clearance details from Khon Kaen to Australia for sample processing and analysis using the routine procedures of Queensland Health Organic Chemistry Laboratory. Prior to PDMS extraction in hexane and following instrumental analysis each of them was cleaned by scrubbing with water, dipping in redistilled hexane for 30 seconds and 0.5M HCL for 20 seconds followed by rinsing with acetone and isopropanol. Water quality measured using standard techniques described (Komarova et al., 2012, 2013).

Passive samplers using polydimethylsiloxane are low cost and have an improved affinity for

polar compounds relative to other samplers (Rusina et al., 2007). Comparative studies (Shaw et al., 2010) showed that PDMS samplers accumulated a larger number of compounds with log Kow 2.9 to 6.4 dissolved in water. At log Kow of 4.7 (chlorpyrifos) and 4.27 (trifluralin) the mass captured was 6 times higher in PDMS compared with other samplers with the same surface area.

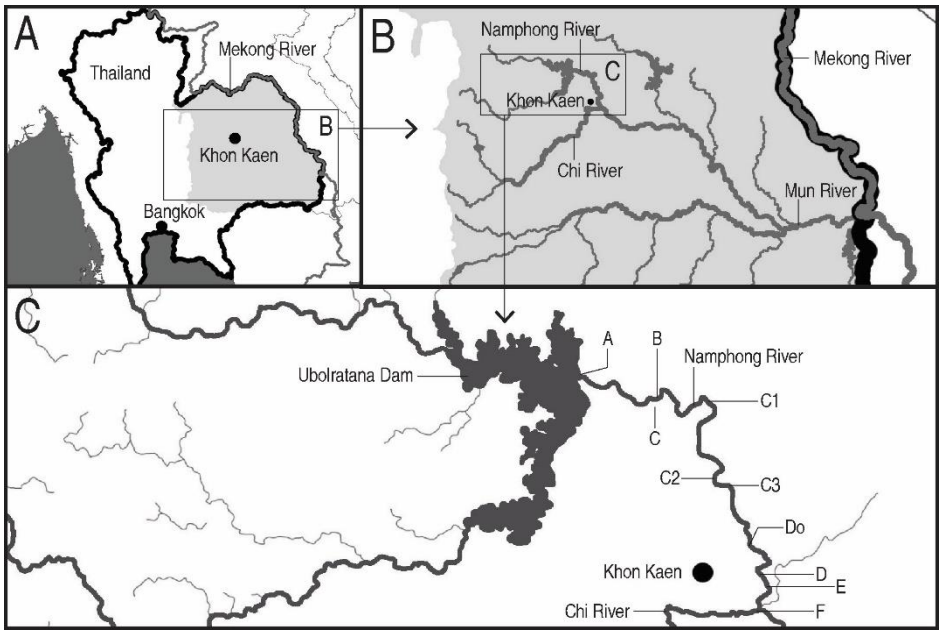

Fig. 1 Location of study site in the Mekong River basin NE Thailand (Maps A and B) and sampling sites along the Namphong River (Map C)

[*Sites A – Ubolratana Dam; B – fish cage (in-river cage aquaculture for Tilapia production); C – pulp/paper industrial plant (discharge via small tributary to main river); sugar industrial plant; C2 cucumber culture; C3 corn culture; Do vegetables culture; D vegetable culture and paddy fields; E vegetables culture; and F – vegetables culture, residential discharge to Chi River just upstream from confluence with Namphong River*]

Well developed and validated procedures are used at all steps of PDMS passive sampler application (Shaw, 2005). The mass of contaminants accumulated in a PDMS sampler are converted to their concentrations in water (Cw, ng/L) using a sampling rate (Rs in Ld^{-1}) that is estimated for different pesticides at different environmental conditions in laboratory calibration study (Huckins et al., 2002) by Eq. 1.

$$C_w = M_{PDMS} / Rs\ t \quad (1)$$

where M_{PDMS} is the mass of a pesticide found in the PDMS sampler after deployment (ng) and t is the deployment time in days. Method detection limits are calculated from the lowest mass per sampler detected on analytical equipment (LCMS, GCMS) and the respective compound sampling rate (e.g. <50 ng/mL for the extracted volume in the laboratory and 0.001 ng/L for chlorpyrifos in PDMS samplers for 29 day deployment). These detection limits are an order of magnitude lower than reported for pesticide concentrations using grab sampling techniques (Shaw, 2005). The linearity of the relationship between log K_{ow} and sampler to water partition coefficients has been demonstrated over a wide range of compounds for PDMS (Yates et al., 2007).

Following preparation, extraction of samples and extensive clean-up procedures using size exclusion chromatography, pesticide and herbicide are analysed by different instrumental analytical methods: these are gas chromatography (GC), high performance liquid chromatography (HPLC), GC/MS and LC/MS-MS undertaken in the Queensland Health NATA accredited laboratory (according to ISO 17025) and based on USEPA Method EPA 503/6-90-004. All standards (3 external standards) and samples are spiked with an internal standard just prior to analysis.

RESULTS AND DISCUSSION

Table 1 gives the pesticide and herbicide concentrations that have the highest inputs for effluent at Site C (Paper Mill) when compared with Table 2. Galaxolide, terbuthylazine, phosphate tri-n-butyl, tonalid and terbutryn are added in paper mill effluent (Table 1) but only galaxolide remains detectable at much lower concentration (1:35) showing dilution down to Site F at the Chi River; tonalid is diluted 1:10 at Site C3 (Fig. 1C) but is then undetectable downstream.

Table 1 Pesticide and herbicide concentrations for 19-23 January 2012 showing Site C (Paper Mill) effluent with highest input (average of 2 PDMSs per site)

Sampling site	Galaxolide[a]	Terbuthylazine	Terbuphos	Phosphate Tri-n-Butyl	Tonalid	Terbutryn
A. Ubolratana (ng/L)	0.201	<0.001	<0.001	<0.001	<0.001	0.069
C. Pulp mill (ng/L)	26.8	3.1	1.1	0.18	0.17	0.34
C3. Corn (ng/L)	0.68	<0.001	<0.001	<0.001	0.017	<0.001
D. Vegetable/ paddy field (ng/L)	0.81	<0.001	<0.001	<0.001	<0.001	<0.001
F. Vegetable (ng/L)	0.89	<0.001	<0.001	<0.001	<0.001	<0.001
Guideline or acute toxicity						
Algae, protozoa LC50 (ng/L) (WHO, 1991)	-	-	-	3.2-100 x 10^6	-	-
Fish LC50 (ng/L) (PAN, 2014)	-	0.16-90 x 10^6	2340 – 20000	-	-	0.8 – 10.0 x 10^6
Fish LC50 (ng/L) (PFW Aroma Chemicals, 2007)	-	-	-	-	0.318 x 10^6	-

Note: a. Not toxic to aquatic species, with low toxicity to terrestrial species [Rat Acute: >5000 mg/kg rat (Spectrum, 2009)]

Table 2 gives the pesticide and herbicide concentrations for all sites upstream or lower downstream; i.e. below Site C2. Ametryn, oxadiazon, chlorpyrifos, prometryn and atrazine are all found at measureable concentrations at Site A below Ubonratana Dam (Fig. 1C) indicating that application of these pesticides and herbicides has occurred in the upper Namphong River catchment above Ubonratana dam and contribute to the downstream river load. Fig. 1 shows that about 60% of the Namphong River catchment is associated with the two branches above Ubonratana dam. At Site C3 (Fig. 1C), ametryn, oxadiazon, chlorpyrifos, prometryn and atrazine all show increased or similar concentrations indicating extensive insect and weed control from agricultural activities in the upper Namphong catchment. The trend continues at Sites D and F with significant (2-7 times) increases in concentrations of ametryn, oxadiazon, chlorpyrifos, prometryn and atrazine in river water (Table 2) where the observed levels of pesticides and herbicides are associated with vegetable and paddy field areas indicating their extensive application. At Site D (Fig. 1C) the application of trifluralin is observed, indicating a particular crop application, but was then undetectable at Site F (Table 2).

The comparison of measured concentrations of pesticides and herbicides for all sites in Tables 1 and 2 with compiled details of guidelines and LC50 values for fish and other freshwater species shows that all compounds are well below concentrations that will induce a toxic response. While all compounds excepting chlorpyrifos are present at exceedingly low concentrations, chlorpyrifos is only 10-20 times lower than the validated Australian aquatic guideline (Table 2 – note no Thai guideline available). The application of chlorpyrifos is associated with insect control of vegetable and paddy field areas in line with the highest volume of insecticide importation in Thailand cited above (Department of Agriculture, 2012). The pesticides and herbicides that were detected at the sampling sites of the Namphong River in January 2012 are all low persistent compounds and indicate recent applications. Comparison of the observed pesticides and herbicides identified in this study with an earlier 2005 study of paddy fields, horticulture and vegetable farming in the

Namphong River basin sediment, water samples and PDMS samplers (Boonthai-Iwai et al., 2007) showed that the pesticides and herbicides in use at that time included atrazine, oxadiazon and the organochlorines dicofol and endosulfan; comparison with Tables 1 and 2 levels shows there was no detection of organochlorines in 2012 but that chlorpyrifos is used extensively together with a range of herbicides. If the application rate of chlorpyrifos increases, the level in Namphong River may increase and exceed the threshold of toxicity for fish and be a threat to cage aquaculture. Thus there needs to be a more systematic and complex assessment of chlorpyrifos in the Namphong River basin to develop a tool for its control and environmental risk management.

Table 2 Pesticide and herbicide concentrations for 19-23 January 2012 showing inputs at all sites upstream or below site C downstream (average of 2 PDMSs per site)

Sampling site	Ametryn	Oxadiazon	Chlorpyrifos	Prometryn	Atrazine	Trifluralin
A. Ubolratana (ng/L)	2.6	0.46	0.061	0.23	0.10	<0.001
C. Pulp mill (ng/L)	0.12	0.75	0.24	<0.001	0.10	<0.001
C3. Corn (ng/L)	1.7	1.0	0.45	0.14	0.29	<0.001
D. Vegetable/ paddy field (ng/L)	2.7	6.7	0.79	0.30	0.40	0.062
F. Vegetable (ng/L)	2.6	7.2	0.88	0.28	0.40	0.18
Guideline or acute toxicity						
95% protection aquatic freshwater species (ANZECC/ARMCANZ, 2000) (ng/L)	-	-	10	-	13000	4400
Nile tilapia LC50 (ng/L) (PAN, 2014)	-	60000	-	-	-	-
Fish LC50 (ng/L) (EXTOXNET, 2014a,b)	3.2 – 8.8 x 10^6	-	-	2.5 – 10.0 x 10^6	-	-

CONCLUSION

This paper identified that the Namphong River basin can absorb current inputs of pesticides and herbicides that arise from the agro-based activities and is not causing any impact to the water quality in the Namphong River itself. Measured pesticides and herbicides except chlorpyrifos were present at exceedingly low concentrations in Namphong river water. However chlorpyrifos is only 10-20 times lower than the Australian aquatic guideline (noting no Thai guideline) for protection of aquatic species and was identified as the highest volume of insecticide importation in Thailand. If the application rate of chlorpyrifos is increased, the level in Namphong River may increase and exceed the threshold of toxicity for fish and other species and be a threat to cage aquaculture. Although there does not appear to be a current contamination problem there is a potential issue with chlorpyrifos in water which is identified as having higher risk and requiring further data and information. Thus there needs to be a more systematic and complex assessment of chlorpyrifos in the Namphong River basin to develop a tool for its control and environmental risk management.

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REFERENCES

ANZECC/ARMCANZ. 2000. Australian water quality guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Boonthai-Iwai, C., Sujiya, H., Somparn, A., Komarova, T., Mueller, M. and Noller, B. 2007. Monitoring pesticides in the paddy field ecosystem of North-eastern Thailand for environmental and health risks. Chapter 16 in Rational Environment Management of Agrochemicals Risk Assessment, Monitoring, and Remedial Action. First Edition Eds. Kennedy, I.R., Solomon, K., Gee, S., Crosnan, A. and Wang, S. ACS Symposium Series 966. American Chemical Society, Washington, D.C, pp 259-273, USA.

Department of Agriculture. 2012. Report of volume of insecticide importation in 2012. Ministry of Agriculture and Cooperative, Thailand.

Department of Fisheries. 2010. Aquaculture production report in Thailand. Khon Kaen in Land Fisheries Research and Development Center, Khon Kaen, Thailand.

EXTOXNET. 2014a. Ametryn. EXTOXNET, The extension toxicology network. University of California, Davis, Oregon State University, Michigan State University, Cornell University, New York. Publication Date: Sep. 1995 (available at http://pmep.cce.cornell.edu/profiles/extoxnet/24d-captan/ametryn-ext.html Accessed: 31, Dec. 2014.)

EXTOXNET. 2014b. Prometryn. EXTOXNET, The extension toxicology network. University of California, Davis, Oregon State University, Michigan State University, Cornell University, New York. Publication Date: June 1996 (available at http://extoxnet.orst.edu/pips/prometry.htm. Accessed: 31, Dec. 2014.)

Huckins, J.N., Petty, J.D., Prest, H.F., Clark, R.C., Alvarez, D.A., Orazio, C.E., Lebo, J.A. Cranor, W.L. and Johnson, B.T. 2002. A guide for the use of semi-permeable membrane devices (SPMDS) as sampler of waterborne hydrophobic organic contaminants. API Publication 4690 Columbia Environmental Research Center. US Geological Survey. USDI, USA.

Komarova, T., Boonthai Iwai, C., Somparn, A., Tokhun, N. and Noller, B. 2013. Passive sampling approach to identify contaminants in a tropical freshwater river system. Int. J. Environ. Rural Development., 4 (2), 154-159.

Komarova, T., Olszowy, H., Noller, B. and Golding, G. 2012. The diffusive gradients in thin films technique (DGT) for trace metals versus active sampling. Int. J. Environ. Rural Devt., 3 (1), 169-174.

PAN. 2014. Pesticide Action Network website. (http://www.pesticideinfo.org/Detail_Chemical.jsp?Rec_Id =PC34542 , Accessed 31, Dec. 2014).

PFW Aroma Chemicals. 2007. Safety data sheet TONALID® II. Test data PFW Aroma Chemicals B.V. and Research Institute for Fragrance Materials (RIFM). PFW Aroma Chemicals B.V. Veemweg 29-31 3771 MT Barneveld The Netherlands.

Rusina, T.P., Smedes, F., Klanova, L., Booij, K. and Holoubek, I. 2007. Polymer selection for passive sampling: A comparison of critical properties. Chemosphere, 68, 1344-1351.

Shaw, M. 2005. Pesticides on the Great Barrier Reef: Monitoring tools. PhD Thesis. National Research Centre for Environmental Toxicology. The University of Queensland, Brisbane. Australia.

Shaw, M., Furnas, M.J., Fabricius, K., Haynes, D., Carter, S., Eaglesham, G. and Mueller, J.F. 2010. Monitoring pesticides in the Great Barrier Reef Mar. Pollut. Bull. 60 (1), 113-122.

Somparn, A., Boonthai Iwai, C. and Noller, B. 2014. Comparison definition of tropical and temperate conditions with difference of organic matter content and pH on acute toxicity of chlorpyrifos and cadmium to *Chironomus javanus*, Kieffer in freshwater sediment. International Journal of Research in Chemistry and Environment, 4, 199-207.

Spectrum. 2009. Material safety data sheet Galaxolide 50% solution in Diethyl Phthalate. Spectrum Laboratory Products Inc. 14422 S. San Pedro Street Gardenia, CA 90248, USA.

WHO. 1991. Tri-n-butyl phosphate. Environmental Health Criteria 112 World Health Organisation, Geneva.

Yates, K., Davies, I., Webster, L., Pollard, P., Lawton, L. and Moffat, C. 2007. Passive sampling: partition coefficients for a silicone rubber reference phase. J.Environ. Monit., 9, 1116-1121.

Research article

Non-uniform Distribution of Soil Salinity Along a Transect of an Irrigation Field in an Arid Region

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Abstract We assessed soil salinity at field scale and suggested appropriate water and salt management practices for an arid region. Specifically, we focused on non-uniform salinity distribution along a transect in a research field. We also examined factors affecting the distribution of salt, including irrigation, drainage and salt movement. The non-uniform salinity distribution across the field was probably formed by irrigation management and distance from main drainage channel, while the effect of soil physical properties and groundwater was limited. The main drainage channel functioned well during the past irrigation period when abundant *Karez* water was available for leaching irrigation, and this contributed to the present non-uniform salinity distribution. Currently, farmers use less irrigation water, which does not promote desalinization. Vertical movement of soluble salts near the soil surface was dominated by irrigation management. Border irrigation promotes desalinization but drip irrigation enhances salt accumulation, with salinity increasing after irrigation because of high evaporation rates in the hyperarid climate. Based on these results, we explained the following points to local farmers in non-technical language: 1) a drainage channel is important for desalinization but the current channel is no longer sufficient to discharge salt from the field; 2) drip irrigation is effective for deficit irrigation but it enhances salt accumulation; 3) border irrigation has a positive effect on salt leaching from surface layers but the leached salt returns to the surface after irrigation ceases; and 4) there are high salinity layers below 60 cm soil depth, distributed widely across the fields.

Keywords drainage, hyperarid region, irrigation, non-uniform distribution, soil salinity

INTRODUCTION

It is estimated that saline soil covers 3.1% (397 mega hectares) of the total land area of the earth (FAO, 2005), which is 1.2 times larger than the land area of India. The total area of secondary saline soil induced by anthropogenic activity such as agriculture is approximately 76.6 Mha (Oldeman et al., 1991), almost twice of the land area of Japan. There are no data to suggest that the amount of saline soil is decreasing; on the contrary, Rengasamy (2008) expects that the prevalence of saline soil will increase because of climate change and increasing human population.

Salinization is one of the biggest problems affecting agricultural activities, especially in arid regions. Salinity studies have been conducted since the 1950s. Soil electrical conductivity (EC) has long been used as an index of salinity in the laboratory (US Salinity Laboratory Staff, 1954), though electromagnetic induction (McNeill, 1980; Rhodes and Corwin, 1981) and satellite remote

sensing (Metternicht, 2003; Metternicht and Zinck, 2008) are now widely applied to assess the extent and severity of saline areas. Free numerical modeling software (e.g., Šimůnek et al., 2013) is available for simulating the movement of water and salt in soil layers.

In irrigated agricultural fields, non-uniform distribution of soil salinity is caused by inappropriate application of water and salt management practices such as irrigation, drainage and salt leaching (Kume et al., 2004; Nishimura et al., 2012). This leads to loss of irrigation water and decreasing crop production. Knowledge of the structure of the non-uniform distribution, and available technical solutions, is crucial to effective management of water and salt in arid regions. However, field conditions and irrigation techniques differ from one place to another, and so a site-specific approach is needed to help farmers to understand their current situation and to suggest ways of developing saline soil in an appropriate way.

OBJECTIVE

We assessed soil salinity at field scale and suggested appropriate water and salt management practices for an arid region. Specifically, we focused on non-uniform salinity distribution along a transect in a research field. We also examined factors affecting the distribution of salt, including irrigation, drainage and salt movement.

METHODOLOGY

Research Field

The research field is situated in Paran Karez village near the city of Torpan, in the Xinjiang Uygur Autonomous Region of China (Fig. 1). The average temperature at Torpan is 14.0 °C. Maximum and minimum temperatures are 40 °C and −14.5 °C, respectively. Annual precipitation is 16.6 mm. Torpan is classified as a hyperarid region.

Fig. 1 Location of Torpan in the Xinjiang Uygur Autonomous Region, China

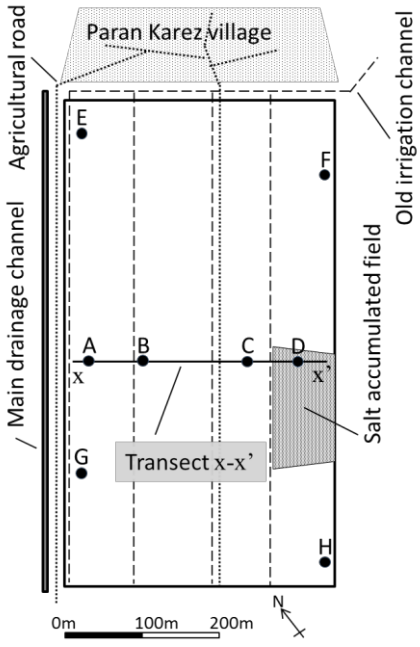

Fig. 2 Map of investigation area, showing transect x-x', soil profile sampling points (A-D), and reference soil sampling points (E-H)

The village of Paran Karez has been developed using water from Paran Karez over the last 300 years. The term *Karez* means a horizontal series of vertically dug wells that are then linked by underground water canals. Unfortunately, Paran Karez dried up in 2010. Farmers irrigated their fields with Paran Karez groundwater 20 years ago and now they pump up groundwater from wells for irrigation. The main crops grown are cotton, maize, wheat and cumin. The most common irrigation methods are basin irrigation and border irrigation; drip irrigation has been introduced in some areas beginning in 2013.

Materials and Methods

We defined a transect, x-x', in the irrigated field (Fig. 2) to reveal horizontal soil salinity distribution and took soil samples at 10 meter intervals in June 2013, October 2013, May 2014 and November 2014. Soil samples were taken from 0–5 cm and 5–15 cm below the soil surface. Soil electrical conductivity was measured in a soil-water extract (soil:water = 1:5, $EC_{1:5}$). To examine the topography of the transect, we conducted a level survey at 50 meter intervals in May 2014. To examine the vertical profiles of soil salinity and soil physical properties, we also took soil samples at four points, A, B, C and D on the transect at six soil depths from each profile wall: 0–5, 5–15, 15–30, 30–60, 60–90 and 90–120 cm below the soil surface. The same sampling and measurement regime was used at four reference points, E, F, G and H, some distance away from the transect.

RESULTS AND DISCUSSION

Soil Physical Properties

Soil physical properties affect water and salt movement in soils. Therefore, soil physical properties were examined to understand non-uniform distributions of soil salinity in irrigated fields. The soil texture was classified as International Society of Soil Science at the four points along the transect (A to D) was silty loam (SL) as shown in Table 1. The soil was mainly composed of silt and it contained less than 10% clay. The same silty loam texture was seen at the reference points (E to H). Soil bulk density showed that the soils were somewhat compacted, and soil permeability was reduced, ranging from 10^{-5} to 10^{-6} cm/s^{-1}. Particle density ranged from 2.64 to 2.76 g/cm^{-3}, indicating low organic matter content. From these results, we expect that the differences of soil physical properties were not so large that it did not affect non-uniform distribution of the soil EC.

Table 1 Average values of physical properties of soil from 0-1.2 m soil depth at points A-D along the transect x-x'

Point	Soil texture	Soil bulk density (g/cm^3)	Particle density (g/cm^3)	Soil permeability (cm/s)
A	SL	1.27	2.64	1.8×10^{-5}
B	SL	1.31	2.76	1.8×10^{-6}
C	SL	1.35	2.74	1.8×10^{-6}
D	SL	1.27	2.76	3.6×10^{-6}

Effect of Irrigation Methods on Surface Soil Salinity

Irrigation practices affect water and salt movement, especially salt leaching at the soil surface. As shown in Table 2, the average value of $EC_{1:5}$ for all data including non-irrigated fields, and $EC_{1:5}$ excluding non-irrigated fields ranged from 4.8 to 7.6 dS/m and from 2.2 to 3.5 dS/m, respectively. The highest $EC_{1:5}$ values were observed in non-irrigated fields 280-300 m away from the main drainage channel along the transect (Fig. 2), whereas the lowest $EC_{1:5}$ values were obtained near the main drainage channel. $EC_{1:5}$ was high in the non-irrigated fields because of the lack of salt leaching without irrigation, and salt accumulation from the vicinity by lateral water flow. It is clear that irrigation and drainage management affects surface soil salinity.

Changes in average $EC_{1:5}$ during the research period (Table 2) can be interpreted in the light of irrigation management practices and salt movement. First, border irrigation leached surface salt to the deeper soil layers (June 2013), and the leached salt was returned to the soil surface by evaporation (October 2013). Second, drip irrigation induced intense capillary rise and promoted salt movement from deeper layers to the surface (May 2014) (Zhang et al., 2014). Finally, salt continuously rose to the soil surface by evaporation and showed the highest $EC_{1:5}$ at the end of the research period (November 2014). This shows that border irrigation promotes leaching of salt to deeper soil layers, while drip irrigation enhances salt mobility from deeper soil layers to the surface.

Table 2 Descriptive statistics for $EC_{1:5}$ at four measurement times

Data used for statistical analysis	Sampling date (Month/Year)	Irrigation	Soil $EC_{1:5}$ (dS/m)			
			Mean	Max	Min	Standard deviation
N=31 (0-300 m) (Including data from salt accumulate fields, 280-300 m from drainage channel)	06/2013	Border irrigation	4.8	47.8	0.5	9.3
	10/2013	-	5.8	59.6	0.2	11.5
	05/2014	Drip irrigation	7.6	84.5	1.5	15.0
	11/2014	-	6.9	41.2	0.4	9.4
N=28 (0-270 m) (Irrigated fields only)	06/2013	Border irrigation	2.2	5.4	0.5	1.1
	10/2013	-	2.7	6.3	0.2	1.6
	05/2014	Drip irrigation	3.4	8.5	1.5	1.7
	11 2014	-	3.5	8.9	0.4	1.9

Relationship Between Soil Salinity and Distance from Main Drainage Channel

The salt distribution before agricultural development of the research field was not known. However, conventional desalinization using techniques such as leaching irrigation has been employed since the 1970s, so it is unsurprising that soil salinity increases with increasing distance from the main drainage channel (Fig. 3). The only exception was seen in May 2014. Regression analysis showed a positive correlation between $EC_{1:5}$ and distance from main drainage channel (Fig. 3). The highest coefficient of determination (R^2), 0.71, was obtained in October 2013 and the lowest, 0.22, was seen in May 2014. Similar results were obtained across the irrigated field, from 0 to 270 m from the drainage channel along the transect x-x'. This relationship was not seen in May 2014 and the R^2 value at that time was just 0.02 (data not shown). Conventional desalinization management with abundant *Karez* water in the past promoted leaching and salt drainage from soil layers. This is consistent with the $EC_{1:5}$ data from May 2014, which showed that drip irrigation temporarily caused a uniform salinity distribution through intense capillary rise in the irrigated field.

The topographic level survey showed that the elevation became higher with increasing distance from the main drainage channel (Fig. 3). Non-irrigated salt accumulated fields, which were located 280–300 m away from the drainage channel, were higher than the irrigated fields. This implies that salt accumulated fields have not been received enough leaching water because of their higher elevation, and that dissolved salt moved from nearby fields. The same results were seen by Kume et al., (2004) and Nishimura et al., (2012).

Distribution of Salinity Profile

Desalinization practice involves a series of leaching and draining salt from soil layers to the drainage channel. We assessed the salinity profile in the root zone and below to develop an effective desalinization strategy. Results showed two types of salinity profile as shown in Fig. 4. At point A, which was the nearest point to the drainage channel, soil salinity was observed to increase with depth. In contrast, at points B, C and D, salinity decreased with depth below the soil surface. Salinity of soil from 0 to 40 cm deep increased with distance from the drainage channel, this trend was similar to the results shown in Fig. 3.

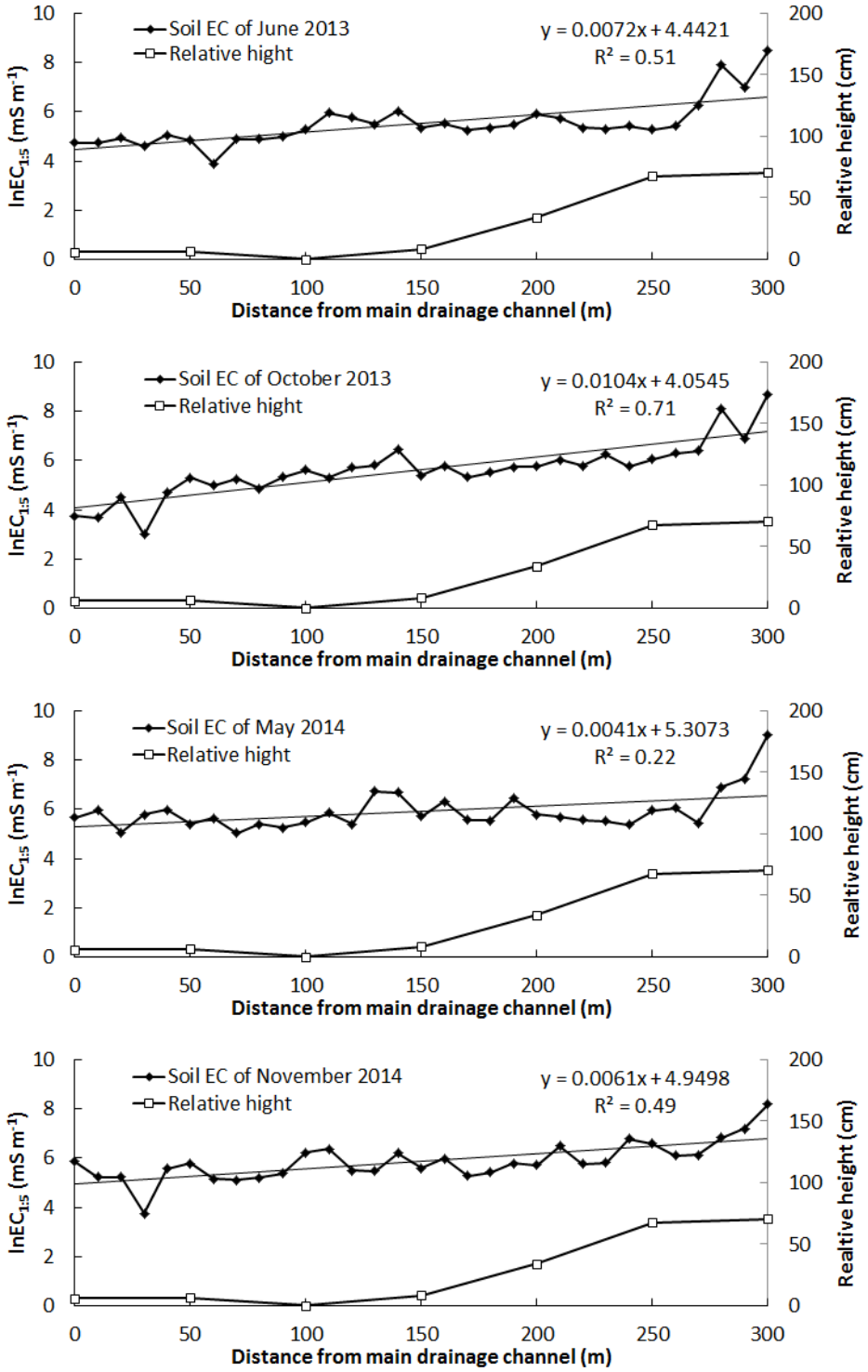

Fig. 3 Changes in spatial distribution of $EC_{1:5}$ along the transect x-x' at four measurement times and relative height of the transect

High salinity layers (2.0–2.5 dS/m) were found at around 60 cm soil depth at points A, B and C (and also at E, F, G and H, reference points (data not shown)). This indicates that high salinity layers below 60 cm soil depth are widely distributed across the fields. Based on our field survey, it was confirmed that groundwater depth was at least 4.0 m below the soil surface, so the effect of groundwater on the salinity profile was negligible during the observation period.

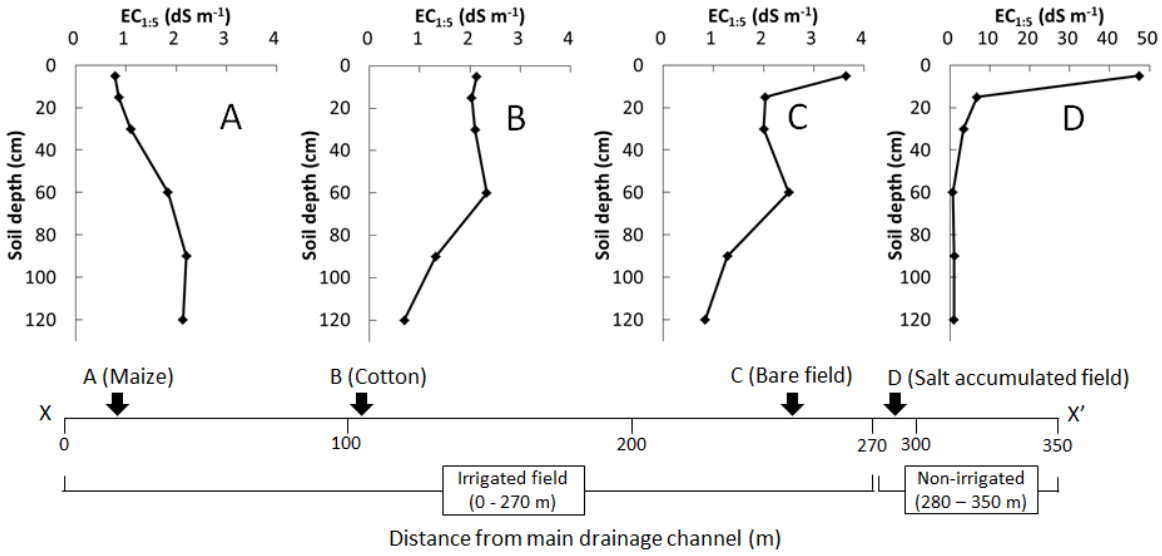

Fig. 4 $EC_{1:5}$ of soil vertical profiles at points A to D along the transect and distribution of crops cultivated in June 2013

Structure of Non-Uniform Salinity Distribution of the Field

The non-uniform salinity distribution across the field was probably formed by irrigation management and distance from main drainage channel, while the effect of soil physical properties and groundwater was quite limited. The main drainage channel functioned well during the past irrigation period when abundant *Karez* water was available for leaching irrigation, and this contributed to the present non-uniform salinity distribution. Currently, farmers use less irrigation water, which does not promote desalinization. Vertical movement of soluble salts near the soil surface was dominated by irrigation management. Border irrigation promotes desalinization but drip irrigation enhances salt accumulation, with salinity increasing after irrigation because of high evaporation rates in the hyperarid climate.

CONCLUSION

In this study, we identified the primary factors affecting structure of non-uniform salinity distribution in terms of irrigation and drainage management. Based on these results, we will explain the following points to local farmers in non-technical language: 1) a drainage channel is important for desalinization but the current channel is no longer sufficient to discharge salt from the field; 2) drip irrigation is effective for deficit irrigation but it enhances salt accumulation; 3) border irrigation has a positive effect on salt leaching from surface layers but the leached salt returns to the surface after irrigation ceases; and 4) there are high salinity layers below 60 cm soil depth, distributed widely across the fields.

Two-dimensional profiles of salt and water distribution and their movement within and between soil layers are required to manage agricultural activity in the research area. We plan to simulate salt and water balance using a numerical model assuming installation of various types of drainage channels and adoption of different irrigation managements to develop a practical strategy for irrigation and drainage management for local farmers to employ in the research field.

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REFERENCES

FAO. 2005. Global network on integrated soil management for sustainable use of salt-affected soils. Rome, Italy: FAO Land and Plant Nutrition Management Service.

Kume, T., Nagano, T., Watanabe, T. and Mitsuno, T. 2004. Analysis of heterogeneous soil salinity distribution in poor drainage Field. Trans. of JSIDRE, 234, 19-26. (In Japanese with English abstract)

McNeill, J.D. 1980. Electromagnetic terrain conductivity measurement at low induction numbers. Mississauga, Ontario, Canada, Geonics Limited, Technical Note TN-6.

Metternicht, G.I. 2003. Categorical fuzziness: A comparison between crisp and fuzzy class boundary modeling for mapping salt-affected soils using Landsat TM data and a classification based on anion ratios. Ecological Modelling, 168, 371-389.

Metternicht, G.I. and Zinck, A. 2008. Remote sensing of soil salinization: Impact on land management. CRC Press.

Nishimura, T., Ishiyama, Y., Seki K., Imoto, H., Mizoguchi, M. and Miyazaki, T. 2012. Salt accumulation above shallow ground water table at Songnen Plain, Heilongjian, China. IDRE Journal, 279, 35-44. (In Japanese with English abstract)

Oldeman, L.R., van Engelen, V.W.P. and Pulles, J.H.M. 1991. The extent of human-induced soil degradation. World map of the status of human-induced soil degradation: An explanatory note. Wageningen: International Soil Reference and Information Center, 27-33.

Rengasamy, P. 2008. Salinity in the landscape: A growing problem in Australia. Geotimes, 53, 34-9.

Rhodes, J.D. and Corwin, D.L. 1981. Determining soil electrical conductivity-depth relations using an Inductive electromagnetic soil conductivity meter. SSSAJ, 45, 255-260.

Šimůnek, J., Šejna, M., Saito, H., Sakai, M. and M. Th. van Genuchten. 2013. The Hydrus-1D software package for simulating the movement of water, heat, and multiple solutes in variably saturated media, Version 4.17, HYDRUS Software Series 3. Department of Environmental Sciences, University of California Riverside, Riverside, California, USA.

US Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook, No. 60, Washington, D.C, US Government Printing Office, USA.

Zhi, Z., Hongchang, H., Fuqiang, T., Heping, H., Xinhua, Y. and Ruisen, Z. 2014. Soil salt distribution under mulched drip irrigation in an arid area of northwestern China. Journal of Arid Environments, 104, 23-33.

Research article

Golden Apple Snail as Source of Protein Diets of Fattened Mud Crab (*Scylla serrata* Forskal) in Cellular Bamboo Cages

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Abstract To identify feed alternative in the fattening of mud crab (*Scylla serrata* Forskal), three diets were tested using a modified cellular cages. Mixed sex crabs were fed with trash fish, golden apple snail and combination of trash fish and golden apple snail at 10% body weight. Growth, survival, moulting and picked meat yield and quality were evaluated. Specific growth rate and survival were highest in crabs fed with golden apple snail and combination. Moulting was significantly affected by diet types. There was no significant difference in the yield of picked meat and overall acceptability scores. Golden apple snail could be a potential dietary substitute for trash fish.

Keywords mudcrab fattening, specific growth rate, bamboo cages, feed types

INTRODUCTION

Mud crab (*Scylla serrata* Forskal) locally known as "alimango" is considered as the biggest, fastest growing and the most desirable aquaculture mud crab species in the country. For the past decades aquaculture of mud crab has been intensively studied because of the high market demand of the commodity and dwindling wild stocks. Hatchery technology was developed and adopted to answer the problem in seed supply which was considered as the major limitation of mud crab farming in its early stages (Keenan, 1999). Feeding management in grow out, perceived as the main bottleneck in the advancement of mud crab aquaculture, has been carefully studied through development of formulated diets and experimental feeding (Catacutan et al., 2003; Christensen et al., 2004). Research has demonstrated the high feasibility and profitability of this aquaculture endeavour.

According to Keenan (1999), there are two basic forms of mud crab aquaculture, fattening of crabs with low flesh content and rearing of juveniles from the wild or hatcheries to market size. Both of these approaches are usually pond based with or without mangroves. Fattening employs intensive feeding while the later could be done without supplemental feeding that involves low stocking in large mangrove silviculture ponds. In particular, mud crab fattening refers to the rearing of empty crabs identified at harvest from the wild or from farm stocks for a brief period of time until weight is gained and ready to market (FAO, 2011). Empty crab also called as thin crab, water crab or soft shell crab refers to a crab after moulting having thin and soft carapace with little flesh for male and little ovary tissue for female. Various structures can be used to fatten mud crab for relatively short period of time around 15-30 days that include cages, ponds or tanks. Fattening can be held at fairly high densities provided that water quality is optimum, feeding is regular and the rearing environment is free from diseases. Several studies demonstrated that mud crab fattening is a profitable aquaculture activity (Trino and Rodriguez, 2001).

In the country crab fattening has been widely practiced but varies widely in the different regions due to limited baseline research studies. Trino and Rodriguez (2001) studied crab fattening in ponds and found out that it is economically feasible and production could be very high. Technology verification done by Southeast Asian Fisheries Development Center (SEAFDEC) and a few private individuals using bamboo cages with individual cells or compartments that held one crab per cell resulted to high survival and better weight gain. Nonetheless, the experiments only

focused on the structures for rearing but not on feeding management which is also a very important aspect to achieve maximum economic benefit. Fattened crabs are usually fed with a mixed diet of trash fish and mollusk at a ration ranging from 6-10% body weight (SEAFDEC, 2011). Studies using cheaper feed alternatives in crab fattening are limited. This study will evaluate the feasibility of golden apple snail or locally known as "kuhol" as a substitute of the usual diet of mud crab.

OBJECTIVE

The main objective of the study was to determine the effect of experimental fattening of mud crab (*Scylla serrata* Forskal) using different feed types (trash fish, golden apple snail and combination of trash fish and golden apple snail) on the following indices:

a. growth in terms of absolute growth rate, total carapace length and width
b. survival and moulting incidence
c. yield and quality of picked meat

METHODOLOGY

Location and Cage Design

The experiment was conducted in BISU Calape-Calunasan Brackishwater Station. A cellular system cage design adapted from SEAFDEC was used. The modified bamboo cage had a dimension 2 m x 0.9 m x 0.3 m and divided into 15 compartments, covered with plastic screen for feeding and sampling convenience. The cage was firmly fixed by its corners to the substrate using bamboo stakes to prevent it from being washed away in high weather. The cage was placed in the pond canal with ¾ of its body submerged during the lowest low tide. The set up is ideal for mudcrab culture as water exchange takes place naturally through tidal fluctuations.

Procurement of Stocks and Stocking

Mixed sex crabs with similar sizes weighing 50-100 g were purchased from local fishermen in Calape at PhP 100.00 per kilogram. The crabs were weighed (77.78 g) and carapace length (72.47 mm) and width (50.87 mm) were measured individually. Crabs were individually held in the compartment or "cell" in the cage. A total of 15 crabs were stocked for each treatment corresponding to the different feed types. Stocking was done late in the afternoon.

Rearing

The crabs were reared for 15 days. Water quality parameters such as salinity, temperature and pH were monitored daily. The cages were cleaned daily by removing excess feeds and waste. Drifted debris that clings in the cage was removed to prevent damage in the cage and to easily facilitate water circulation. Six crabs from each treatment were weighed and carapace length and width were measured every three days as basis for the feed ration.

Diet Preparation and Feeding

The feeds used in the experiment were trash fish, golden apple snail and combination of trash fish and golden snail. Trash fish was bought from the local market, washed with clean water and stored in freezer. Golden apple snails were collected in the nearby rice fields and were purged by soaking in clean water for 24 hours. Frozen trash fish was thawed in running water and meat of the golden apple snail was separated by breaking the shells individually and weighed based on the exact feed ration. A feeding rate of 10% body weight was employed (SEAFDEC, 2011). Feeding ration was increased based on the body weight of the crabs measured every three days. Feeding was done twice a day, 7 am and 4 pm.

Sampling and Harvesting

At an interval of 5 days, all mudcrab in each cage were netted, weighted and recorded for analysis of growth and survival. Measurements were done using a calibrated weighing scale recorded in grams. After days, survival was assessed by counting remaining stocks in the cage. Final body weight, carapace length and width were measured. Survival rate, absolute growth rate, specific growth rate and feed conversation ratio were computed.

Picking and Sensory Evaluation

All the harvested crabs were steamed. The meat was then carefully separated from the shell and weighed. After weighing, nine panellists evaluated the sensorial attributes in terms of aroma, texture and taste using the using the simple 9-point Hedonic Scale (9-extremely like, 8-like very much, 7-like moderately 6-like slightly, 5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely).

Statistical Tools and Analysis

Data were statistically analyzed using descriptive statistics particularly; mean, standard, and percentage. Mean of treatments were compared by Analysis of Variance (ANOVA) at 0.50 confidence level.

RESULTS AND DISCUSSION

Water Quality

The ranges of the water quality parameters (salinity: 25-35 parts per thousand (ppt); temperature: 25-30 ^{o}C; pH: 7.5-8.7) recorded during the experiment are within the suitable levels and the culture period (15 days) is within the duration being practiced for mud crab fattening (Cholik and Hanafi, 1992). Placing the cages in the pond canal was ideal because water was continuously flowing maintaining optimum water quality conditions. The preliminary experiment conducted inside the pond resulted to poor growth and survival that could be attributed to poor water quality as water exchange was limited.

Growth, Survival and Moulting Incidence

The mean final weight of the crabs after 15 days of fattening ranged from 90 g to 100 g in all treatments (Table 1). Crabs fed with a combination of trash fish and golden apple snail had the highest mean final body weight at 100.20 g with a total weight gain of 21.93 g. Begum et al (2009) reported relatively lower weight gain at 10-16 g in mud crab with initial weight of 200 g fattened in ponds for 16 days fed with tilapia. In the experimental fattening of mud crab in ponds using trash fish by Trino and Rodriguez (2001), weight gain was relatively higher ranging from 150-200 g with initial weight of stocks at 260-280 g. The lower weight gain observed in the current experiment could be attributed to the use of small stocks and possibly the thinness of the muscle of the crabs initially used (Liong, 1993).

Specific growth rate was highest in mud crab fed with golden apple snails and combination of trash fish and golden apple snails (Fig. 4) at both 1.54% day^{-1}. Specific growth rate of mud crab in all the treatments were comparable to that of mixed sex mud crab reared in ponds fed with trash fish for 20 days with specific growth rate of 0.8$\pm$ 0.12% day^{-1} (Trino and Rodriguez, 2001).

Table 1 Mean initial and final body weight, weight gain and carapace width and length of crabs after 15 days of fattening using different feed types

Treatment	Initial wt (g)	Final wt (g)	Wt gain (g)	Carapace width (mm)	Carapace length (mm)
Trash fish	77.73	90.71	12.98	50.93	72.29
Golden apple snail	77.33	97.53	20.20	51.07	70.87
Trash fish+Golden apple snail	78.27	100.20	21.93	52.07	74.53

Survival was highest in crabs fed with golden apple snail and combination of trash fish and golden apple snail at 100% (Table 2). The result was relatively higher compared to that of Begum et al. (2009) wherein survival rate of crabs reared in cages was only 93.75%. High survival was attributed to the use of cellular cage system. Crabs were held individually to prevent cannibalism and as well as to provide optimal environment for growth.

Another primary use of the cellular cage is the production of soft-shell crabs or newly moulted crabs (FAO, 2011). In this kind of system, small mud crabs are reared in isolation a few weeks until they moult. Soft-shell crabs command higher price and farmers have focused on soft-shell production to maximize profit. In the present study, moulting incidence was observed as an effect of the dietary treatment. It was found out that moulting was significantly affected by diet types; 20% of the crabs fed with golden apple snail and combination of trash fish and golden apple snail moulted during the experiment while none of the crabs moulted in the group fed only with trash fish. The use of golden apple snail could have accelerated moulting incidence. High calcium content of the diet (from the shells of the golden apple snail) could possibly induced moulting of stocks but this needs to be further investigated.

Table 2 Survival, occurrence of moulting and production of mud crab using different feed types

Treatment	Survival (%)	Moulting (%)
Trash fish	93	0
Golden apple snail	100	20
Trash fish+Golden apple snail	100	20

Economic Analysis

As to stocking density, the present study following the stocking density suggested by SEAFDEC (SEAFDEC, 2011) and still yielded a comparable survival rate of >90%. Tables 3 and 4 provides an overview on the economic analysis of different fed types for mudrab in cellular cages. Mudcrab fed with golden apple snail constitute the high return of investment compared to the other treatments as indicated that low expenses incurred during the conduct of the study because feeds are readily available.

Meat Yield and Quality

There was no significant difference in the yield of picked meat (Table 5) and overall acceptability scores in terms of taste, texture, aroma and color among the three treatments (Table 5). The mean score among the three treatments was 8 which is equivalent to like very much in the Hedonic Scale. The results suggested that sensory attributes of mud crab fed with golden apple snail were comparable to that of mud crab fed with trash fish.

Table 3 Return-on-investment of the 3 units 2 m x 0.9 m x 0.3 m cellular cages at different fed types

ROI Parameters	Unit				Input					Income
		T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Total harvest(-ind)	pcs	15	15	15						
AWG	g	12.98	20.20	21.93						
Total biomass	kg	0.195	0.303	0.329						
Gross income								48.75	75.75	82.75
Less: Total expenses					40.00	70.00	75.00			
Net income								8.75	5.75	7.75
ROI								21.88%	8.21%	10.33%

**the Php 250.00-300.00 per kg was based on the actual market price of mudcrab at Calape Public Market*

Table 4 Weight of the picked meat and carapace and the corresponding yield

	Picked Meat (g)	Carapace Weight (g)	Total (g)	% Yield
Trash Fish	31.51	9.46	40.97	76.97
Golden Apple Snail	41.22	8.85	50.07	82.07
Trash Fish+Golden Apple Snail	37.74	7.10	44.83	84.09

Table 5 Sensory evaluation scores of the panellist in terms of overall acceptability

Panelists	Trash fish	Golden apple snail	Trash fish+Golden apple snail
1	8	9	7
2	8	9	7
3	8	9	7
4	8	8	8
5	8	8	8
6	8	7	8
7	7	8	9
8	8	7	9
9	7	9	8
Mean	**8**	**8**	**8**

CONCLUSION

The growth, survival and picked meat yield and quality of mud crab fed with golden apple snails were comparable to that of mud crab fed with trash fish. The results indicate that golden apple snail collected from nearby rice fields could be a potential dietary substitute for trash fish in mud crab fattening.

RECOMMENDATION

The same experiment could be conducted using bigger stocks weighing 200 g. It is interesting to evaluate if there is a significant difference between the growth of male and female individuals. Other fattening duration could be tried using the same dietary treatments. Changes in the proximate composition of the mud crab before and after fattening is also very essential to determine the effects on the nutritional state of the organism.

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REFERENCES

Begum, M., Shah, M.M.R., Mamun, A. and Alam, M.J. 2009. Comparative study of mud crab *Scylla serrata* fattening practices between two different systems in Bangladesh. J. Bangladesh Agril. Univ., 7(1), 151-156.

Catacutan, M.R., Eusebio, P.S. and Shin-ichi, T. 2003. Apparent digestibility of selected feedstuffs by mud crab *Scylla serrata*. Aquaculture, 216, 253-261.

Christensen, S.M., Macintosh, D.J. and Phuong, N.T. 2004. Pond preparation of mud crabs *Scylla paramamosain* (Estampador) and *S. olivacea* (Herbst) in the Mekong Delta, Vietnam, using two different supplementary diets. Aquaculture Research, 35, 1013-1024.

Cholik, F. and Hanafi, A. 1992. A review of the status of the mud crab *(Scylla serrata)* fishery and culture in Indonesia. BOBP/REP, 51, 13.

FAO. 2011. Mud crab aquaculture: a practical manual. FAO Fisheries and Aquaculture Technical Paper No. 567. Rome, p.50-51.

Keenan, C.P. 1999. Aquaculture of mud crab, genus *Scylla* - past, present and future. In: Keenan, C.P., Blackshaw, A. Mud Crab Aquaculture and Biology. Australia. ACIAR Proceedings, p. 9-13.

Liong, P.C. 1993. The culture and fattening of mud crabs. Infofish Int. 3:46.

Southeast Asian Fisheries Development Center (SEAFDEC). 2011. Crab fattening in cages and pen culture of crabs in mangroves. 2011 August 11. (website; www.seafdec.org.)

Trino, A.T. and Rodriquez, E.M. 2001. Mud crab fattening in ponds. ASJ, 14, 211.

International Society of Environmental and Rural Development

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Recently, in developing countries, subsistence agriculture is being converted to export-oriented mono-culture, and the amounts of agricultural chemicals applied to the farmland are increasing every year. The applied chemicals in farmland cause serious environmental problems downstream such as eutrophication, unusual growth of aquatic plants, decrease in dissolved oxygen and accumulation of bottom mud in water resources. Also, there seem to be many cases in which people apply agricultural chemicals without understanding its impact to health and food safety. Therefore, it is necessary to promote and enhance understanding of sustainable rural development among local stakeholders including farmers.

Sustainable rural development aims to meet human needs while preserving the natural environment. As it should cover not only social and economic development but also natural environment conservation, no single organization can achieve sufficiently the aspirations of sustainable rural development. Collaboration among international, governmental and non-governmental organizations, together with the academe and scientific sector, is indispensable.

The knowledge and intelligence accumulated in universities and research institutions are also expected to make the programs facilitated by the international, governmental and non-governmental organizations more adequately implemented and meaningful to societal development. However, these cases especially those implemented locally have been scattered without having been summarized well or recorded in annals academic or scientific societies.

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