Research article

Effect of Drip-Fertigation Intervals and Hand-Watering on Tomato Growth and Yield

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Abstract Irrigation is vital to increase the crop yield or crop productivity. The research was conducted in Royal University of Agriculture (RUA), Phnom Penh, Cambodia, in order to compare the influence of different irrigation intervals and methods on plant development and yield of tomatoes. As replicated three times, the treatments designed in the experiment layout included daily drip irrigation without fertilizer (T_0), daily drip fertigation (T_1), drip fertigation in every two days (T_2), and (T_3) daily hand-watering by applying the same amount of fertilizer before planting. In the study, the quantity of water applied in each treatment was equal to 5.22 m^3, or 20.88 m^3 as a whole. The chemical fertilizers, 46-0-0 and 20-20-15, were only applied for three treatments (T_1, T_2 and T_3), and the total amount of fertilizers used was 7,662 g, or 2,554 g for each treatment, whereas T_0 was not added with any fertilizer. The result illustrates that T_0, T_1, T_2 and T_3 yielded 10.4 t/ha, 42.25 t/ha, 27.45 t/ha and 29.95 t/ha, respectively. The average numbers of tomatoes in each treatment were 8, 22, 18 and 17 fruits per stem for T_0, T_1, T_2 and T_3 respectively. Moreover, the stem growth rate and diameter growth rate was 63.36 cm and 9.38 mm (T_0), 84.81 cm and 12.03 mm (T_1), 75.96 cm and 10.50 mm (T_2) and 79.33 cm and 11.10 mm (T_3). Based on the experiment, it could be concluded that the application of water and nutrients to meet the crop needs without interrupting irrigation, as seen in T_1, had optimal effects on the growth and yield of tomatoes. Therefore, growers should irrigate crops by focusing on the real crop needs for water and nutrient and should choose drip-fertigation methods, which offers multiple benefits such as providing water effectively, reducing erosion and loss of nutrients in the soil, making the ground slower in density, reducing grass, saving time and water and increasing crop growth and yield.

Keywords drip-fertigation, hand-watering, effect, tomatoes, growth, yield, fertilizer

INTRODUCTION

Supplying an adequate amount of water is very important for plant growth; especially, when rainfall is not sufficient, the plants must receive additional water from irrigation. There are various irrigation methods that can be used to supply water to the plants. Each irrigation method has its own advantages and disadvantages, so these should be taken into account when choosing the irrigation method which is best suited to the local circumstances. A simple irrigation method is to bring water from the source of supply, e.g. a well, to each plant with a bucket or a watering can (FAO, 2001). The drip irrigation system is one of the most effective irrigation systems which can controll the water supply to the rootzone of the crops before the water is evaporated or run-off. This irrigation method is able to save water and time, providing a certain amount of water to suit crop requirements. However, water content in the soil must be taken into consideration before supplying the irrigation water as non-uniformity of the soil water content could lead to different crop productions (Hargreaves et al., 1998). Drip irrigation is currently a suitable irrigation method for reducing the impact from drought to the agricultural productivities. It can diversify and maximize crop productions through effective water management (GDA, 2016). Moreover, in the irrigation process, proper irrigation interval is very important to strengthen the effective water use and crop productivities by providing a particular amount of water based on the crop water need (Ismail et al., 2009).

Tomato is one of the most popular vegetable crop which is widely grown in the world. It belongs to the genus *Lycopersicon* which is grown for its edible fruit (Jones, 1990). The fruit contains high levels of vitamin A, B, C, E and nicotinic acid and is therefore an important source of vitamins. On the average, the fruit contains 8% protein, 34% minerals (mainly K+ Ca+ and P), 48% total soluble sugars, 9% citric acid and 0.5% vitamin. Tomato has a higher acreage than any vegetable crop in the world and it requires a high water potential for both optimal vegetative and reproductive development stages (Jones, 1990). The crop tolerates fairly acid soil and liming is unnecessary unless the soil pH is below 5. Well drained sandy loam is preferred by the crop. No horticultural crop has received more attention and detailed study than tomato (Lycopersicon esculentum). Water deficit decreases tomato growth, yield and quality (Byari and Al-Sayed, 1999). Therefore, proper water management is vital for sustainable crop production. In Cambodia, drip irrigation system is mainly used for fruit tree plantations and some vegetable cultivation. Tomato is one of the crops which is suitable for drip irrigation to produce a better yield (Sy, 2004).

OBJECTIVE

The research aims to compare the influence of different drip fertigation intervals and irrigation methods with the diversed application of fertilizers on plant development and yield of tomatoes.

MATERIALS AND METHOD

Study Area: The study was carried out at the Faculty of Agricultural Engineering, Royal University of Agriculture (RUA), which is located at latitude of $11^{0}30'40.91''$ and longitude of $104^{0}54'01.24''$ from January 01, 2016 to April 30, 2016. Soil samples at the study area were taken to the laboratory to determine pH = 7.10, Organic matter (OM) = 0.85%, Ec = 137.00 μS cm^{-1}, Nitrogen (N) = 530.00 mg/kg, Phosphorus (P) = 109.60 mg/kg, and Potassium (K) = 180.00 mg/kg. Flow rate and operating pressure before and after irrigation were measured with flow meters and a pressure gauge. The amount of water and fertilizers were applied equally in all treatments/plots. The total amount of irrigated water was 20.88 m^3, from which each treatment consumed 5.22 m^3. The chemical fertilizers, 46-0-0 and 20-20-15, were only applied for three treatments (T_2, T_3 and T_4), and the total amount of fertilizers used was 7,662 g, or 2,554 g for each treatment, whereas the control treatment (T_0) was not tested with any fertilizer.

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

Experimental Design: A Randomized Complete Block Design (RCBD) was applied. There were 12 plots and each plot size was 1 x 2.8 m. There were two rows in each plot with plant spacing of 0.4 x 0.8 m and plant population per plot was 16 plants. The experimental plots were divided into 4 treatments as the following:

- Treatment T_0 = Drip irrigation with no application of fertilizer (Control treatment)
- Treatment T_1 = Drip irrigation with daily application of fertilizers
- Treatment T_2 = Drip irrigation with every two days application of fertilizers
- Treatment T_3 = Daily hand-watering with application of fertilizer at the land preparation

All treatments were irrigated in the morning and evening when the irrigation schedules were required.

Sample Collection: Some parameters selected to analyze plant development/growth and yield were collected during the experiment such as blooming period, stem diameter, stem height, and yield including good and bad yields of the fruits.

Statistical Analysis: Analysis of Variance (ANOVA) was conducted on the data using XLSTAT statistical package. The means were compared by applying Least Significant Difference (LSD) at test 5% probability level.

RESULTS AND DISCUSSION

Blooming 50% and 100% of Tomatoes

The duration of 50% blooming was counted when the 6 plants per plot flowered and the period of 100% blooming was also counted when all plants reached full flowering..

Table 1 Effect of irrigation method on blooming period of tomatoes

Treatment	50% Blooming	100% Blooming
Treatment T_0	56.33a	63.66a
Treatment T_1	47.33b	50.66b
Treatment T_2	53.66ab	58.33ab
Treatment T_3	50.00ab	54.33ab
F-test probability	0.03	0.03
CV (%)	3.50	2.70

Note: Different used alphabets indicate measurement is significantly different ($p<0.05$) from each otherNote: Different used alphabets indicate measurement is significantly different ($p < 0.05$) from each other

Table 1 shows that the average blooming period of tomato plants in each treatment was significantly different. For the number of 50% blooming days, T_1 could produce the flowers within 47 days, which was faster compared to the other treatments. Meanwhile, T_2 and T_3 took 52 days, whereas 56-day flowering period was recorded in T_0, and this period was the longest and differed significantly with T_1. Aside from these, the tomato plants took 51-64 days in order to produce 100% blooming period. Based on the observation, the 100% blooming period were the same as the 50% blooming period did. The different irrigation system could affect the blooming period of the tomatoes. T_1 had quick flowering, but T_2 had slower flowering, 6 days for 50% flowering and 7 days for 100% flowering. Similarly, the research conducted by (Sionit, 1977) and (Kramer, 1983) on soybean found that if we retard the water to the plants, it might prolong the blooming period but also cause more flower drop.

Stem Diameter and Height

Figures 1 and 2 illustrate the stem growth rate (stem height) and diameter growth rate (stem diameter) of all treatments: T_0, T_1, T_2 and T_3 which there were 63.36 cm and 9.38 mm, 84.81 cm and 12.03 mm, 75.96 cm and 10.50 mm and 79.33 cm and 11.10 mm, respectively. When the tomato plants were 30-40 days old (5 days after applying fertilizer), each stem diameter and height in all treatments were not much significantly different. However, after 25 days of fertilizer application, the stem diameters and height were steeply increased because it was the development stage of the crop, but the stem diameters and height increased slightly at the age of 70-90 days (flowering stage), which was the mid-season of the crops. Moreover, irrigation systems highly affected the stem diameter and height of tomato crops, as shown in figures below. After 45 days of planting, the stem diameter and height of tomatoes in T_1 were the greatest in comparison to the other treatments. This illustrates that the development of plant diameter is parallel with the increase in stem height if the adequate amount of water and fertilizers are applied regularly. Moreover, the differences in average stem diameter measured in each treatment remained significant until the end of the harvesting time. The stem diameter grew rapidly in the development stage, but from the flowering stage till the end of harvesting time, its growth was retarded.

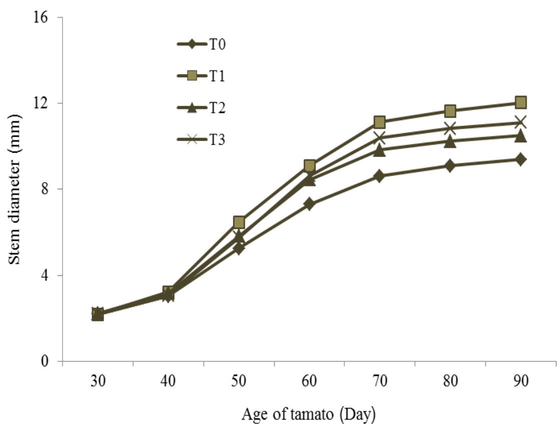

Fig. 1 Effect of irrigation on stem diameter

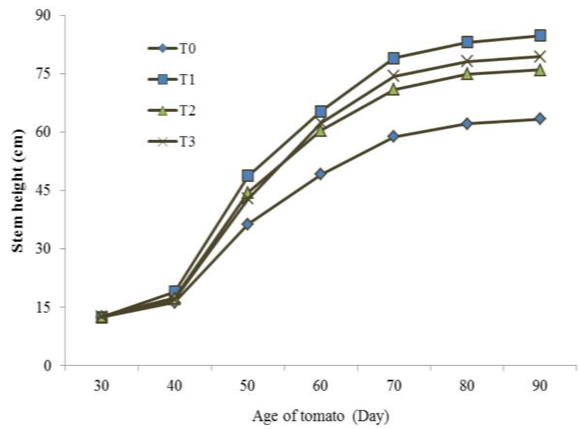

Fig. 2 Effect of irrigation on stem height

Having compared the average stem heights in all treatments, the findings show that T_2 had greater stem height than T_3, but from day 60, the plants grown in T_3 was 2 cm higher than in T_2. Cevik et al., (1996) and Yazar et al., (1991) showed that insufficient irrigation scheduling based on the crop water requirements can reduce partly the development of plant growth. Moreover, Srinivas et al., (1989) carried out the research on plant water relations, canopy temperature, yield and water-use efficiency of water melon Citrullus lanatus indicates that while the plants cannot be able to intake enough water, the moisture at the root zone is reduced, resulting in retardation of the plant development.

Yield of Tomatoes

a. Number of fruits: The count of tomato fruits per stem was done at the harvesting time by counting the numbers of fruits out of 6 tomato stems in each treatment. Each fruit was identified and totaled considerately. The average numbers of tomatoes in each treatment were 8, 22, 18 and 17 fruits per stem for T_0, T_1, T_2 and T_3 respectively. These tomato fruits per stem collected from each treatment were affected by different irrigation as it was indicated in the Fig. 3 that T_1 could yield 22 fruits/stem, compared to other treatments. However, there was no significant difference in tomato fruits per stem between T_2 and T_3, while the T_0 yielded the lowest numbers of fruits which was only 8 fruits/stem and it was significantly different in comparison to the other three Treatments. Candido et al., (1999) studied the effect of irrigation regime on yield and quality of processing tomato cultivars found that inadequate application of water could retard the plant development and fruit size. Moreover, low soil moisture can cause irregularity to plant physics as a result of dropping flowers and producing less flowers. Furthermore, Ponce et al., (1996) indicated that all crops with stress problems may encounter stunted growth, lessening flowers to produce the fruit set.

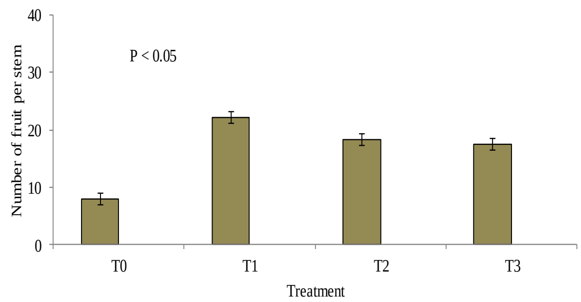

Fig. 3 Effect of irrigation on number of fruits

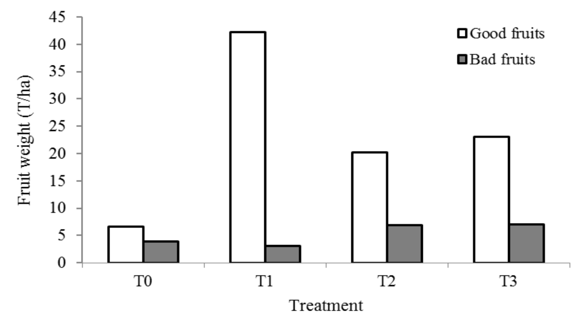

Fig. 4 Effect of irrigation on fruit yields

b. Total tomato yield: Total tomato yield (Fig. 4) included good and bad yields of fruits which were collected from all treatments. The Table 2 below illustrates the total yield of tomatoes during the experiment, and the result indicates that different irrigation methods and irrigation intervals could dramatically affect the yield of tomatoes.

Table 2 Effect of irrigation method and interval on tomato yield (t/ha)

Irrigation method	Tomatoes yield (t/ha)	SE
Treatment T_0	10.40c	0.08
Treatment T_1	42.25a	0.56
Treatment T_2	27.45b	0.31
Treatment T_3	29.95b	0.28
F-test probability	74.59	
CV (%)	1.79	

Note: Different used alphabets indicate measurement is significantly different ($p<0.05$) from each other

The result shows that T_0, T_1, T_2 and T_3 yielded 10.4 t/ha, 42.25 t/ha, 27.45 t/ha and 29.95 t/ha, respectively. The highest yield of tomatoes (42.25 t/ha) obtained from the experiment was the T_1, whereas the lowest yield (10.40 t/ha) obtained was the T_0, while the T_2 could produce the same yield as the T_3. Zhai, et al., (2010) studied the effects of drip irrigation regimes on tomato fruit yield and water use efficiency found that the more the irrigation interval is prolonged or not often irrigated, the lower the yield would be. Moreover, the other research findings of Pasternak, et al., (1995) also indicated that drip irrigation systems with daily fertilizer application provide higher yields, compared to the same drip irrigation method with the application of fertilizer for 2-3 days per time.

CONCLUSION

Based on the experiment, it could be concluded that the drip-fertigation system is an effective irrigation method to promote tomato growth and yield and it is easy to control the amount of fertilizer and water applied to the crops. The application of water and nutrients to the crop needs without interrupting irrigation as in T_1 had optimal effects on growth and yield of tomatoes while it highly affected not only the stem diameter, but also the height of tomatoes which after 45 days of planting, were the greatest in comparison to the T_0, T_2 and T_3. Moreover, the tomato fruits per stem collected from each treatment were also affected by different irrigation methods as T_1 could yield 22 fruits/stem. Furthermore, the highest yield, 45.30 t/ha, could be obtained, if compared to the other Treatments and the average yield of bad fruit was only 3.05 t/ha as the yield of T_3 was 29.95 t/ha and the yield of its bad fruit was 6.9

t/ha. Therefore, growers should irrigate crops by focusing on the real needs of the crop requirement and should choose drip-fertigation methods, which offers multiple benefits such as providing water effectively, reducing erosion and loss of nutrients in the soil, making the ground slower in density, reducing grass, saving time and water and increasing crop growth and yield. Thus, farmers should apply this irrigation technique for their own cultivations and stop using the conventional hand-watering as it may waste water and obtain low yields.

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Research article

The Importance of Non-timber Forest Products for Rural Livelihoods and Ecosystem Services at Phnom Prich Wildlife Sanctuary, Cambodia

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Abstract This study aims to answer the research questions as follows: What is the current context of Phnom Prich Wildlife Sanctuary (PPWS)? Where are the most accessible sites of Non-timber forest products (NTFPs) over the landscape of PPWS? Who are NTFPs-dependent people? What is the importance of NTFPs for local livelihoods? What is the importance of NTFPs for ecosystem services? Analyzed the NTFPs endowment, the open access simulation model was applied. From the 310 sample households, NTFPs dependency and intensity were analyzed through descriptive statistics. Cross tabulation was applied to identify the main users of NTFPs. The role of NTFPs in local livelihoods and ecosystem services were discussed. The simulation result clearly shows that NTFPs are rich over the landscape, which local people can easily access. Among many types of NTFPs, eight of them are considered as the most importance for rural livelihoods including liquid resin, solid resin, bamboo shoot, bamboo poles, wild honey, orchid flower, fuelwood, and Prich leaf (*Melientha suavis* Pierre). Around 93% of total households collect NTFPs for foods, cash incomes, house construction, and farm equipment. NTFPs are the resources not only for the poor but also to all rural households at PPWS. Some types of NTFPs also contribute to ecosystem services.

Keywords NTFPs, rural livelihoods, ecosystem services, Phnom Prich Wildlife Sanctuary, Cambodia

INTRODUCTION

Policy makers tend to forget the role of Non-timber forest products (NTFPs) because they lack readily information on contribution to the daily life of rural people and environmental services at national or global levels (De Beer and McDermott, 1996). In Cambodia, about 84% of rural people heavily depend on forest resources, especially on NTFPs for domestic consumption and complementary cash income (MoE, 2011). NTFPs are also an intrinsic part of culture and traditions of forest-based and indigenous communities of Cambodia (EC-FAO, 2002). Local people have collected NTFPs traditionally for various purposes without any statistical recording to the national economy, yet the importance of NTFPs are not recognized well by the policy makers (Tola and McKenney, 2003). Cambodia's government has implemented the forest protection and management in various policies, but they do not include NTFPs in their primary development agenda (FA, 2009). At present, the empirical evidence on the importance of NTFPs is not well documented in Cambodia. The role of NTFPs has traditionally measured regarding direct benefits from only selling amounts. This description does not reflect the real benefits of NTFPs to rural society, to the national economy, or to the global ecosystem services. To understand the real importance of NTFPs; first, the uniform category of NTFPs-dependent people must be known because it gives insights who are actually utilizing these resources for livelihoods. Then, the role of NTFPs in ecosystem services enhancement should also be revealed to reflect the real importance.

OBJECTIVE

The objective of this study is to explore the importance of NTFPs in rural livelihoods and ecosystem services at Phnom Prich Wildlife Sanctuary (PPWS). This study addresses the following questions: What is the current context of PPWS? Where are the most accessible sites of NTFPs over the landscape of PPWS? Who are NTFPs-dependent people? What is the importance of NTFPs for local livelihoods? What is the importance of NTFPs for ecosystem services?

METHODOLOGY

Study Site Selection

Phnom Prich Wildlife Sanctuary (PPWS) is located in the west of Mondulkiri province, north-east Cambodia. The whole areas of PPWS are 2,225km^2. PPWS consists a rich intricate mosaic of forest habitats, which consists of a mosaic of deciduous dipterocarp forest (1027 km^2) and wetter semi-evergreen/mixed-deciduous forest (1070 km^2) (WWF, 2016). Whilst PPWS regards as the wealth of ecosystems, and it is also of great importance to local communities who thrive to enhance livelihood through extraction of NTFPs. Currently, there is eight community protected areas (CPAs) have been organized. However, this study selected six communities including Nglaoka, Sre Y, Chi Klab, Poutong-Pouhoung, Toul, and Srae Khtong.

Data Collection and Analysis

Fieldworks took place in September 2015, March and April 2016. Questionnaire testing and adjusting were conducted prior to the survey. Secondary data were mainly gathered to produce the maps of accessibility NTFPs. The secondary data types were the dataset of forest cover 2010, population centers and road locations over the landscape. Participatory rural appraisals (PRA) were conducted in four focus group discussions from four communities protected areas (CPAs) in the different part of PPWS. Two primary tools had been applied including seasonal calendar and NTFPs accessibility stocks. Structural questionnaire interviews were conducted with 310 households, which randomly selected from six communities.

Descriptive statistics were used to describe social characteristics of local people in PPWS, the frequency of forest resources dependency, and frequency of people who involved with NTFPs. Then the people-forest relationships by the seasonal calendar and people's dependence on the forestry resources were indicated. The simulation of "Open Access" model in Arc-GIS software (version 10.1) was run to get the map of NTFPs accessibility stock over the landscape of PPWS. The inputs data for processing were current land use and land cover (LULC) 2010, NTFP harvest products stocks (unique value 0, 0.3, 0.5, 0.7, 1), maximum travel distance to the product, population center, road locations and size and legal accessibility for harvesting. The output by whether NTFP resources are abundant in the area or not and how local people make use those resources for their daily life were interpreted. Crosstabs tabulations were used to analyze the people's dependence on the NTFPs, which vary in different categories of households. The importance of NTFPs to local livelihoods through the types and utilization level of NTFPs was analyzed. Last, the role of NTFPs in ecosystem services by using literature reviews was described.

RESULTS AND DISCUSSION

Current Rural Households in PPWS

Fig. 1 shows the current livelihood activities of local people in PPWS. All agricultural activities including rainfed rice, cash crop, and vegetables are done in rainy season. Livestock, fishing, and small business are done in year-round. People, who were landless or owned small agricultural land, worked for other farmers especially in the sowing and harvesting period of the rice crop. Also, local people collected NTFPs in both seasons upon the types of NTFPs. For illustration, bamboo shoot can be collected in the rainy season, but wild honey and Prich leaf (*Melientha suavis* Pierre*)* are available only dry season. Liquid resin, solid resin, bamboo pole, orchid flower, and fuelwood can be collected in year-round. In dry season, local people often traded liquid resin, solid resin, wild honey, and orchid flower. However, this result indicates that NTFPs play the vital role in livelihoods diversification especially during the off-season, when local people are free from farming.

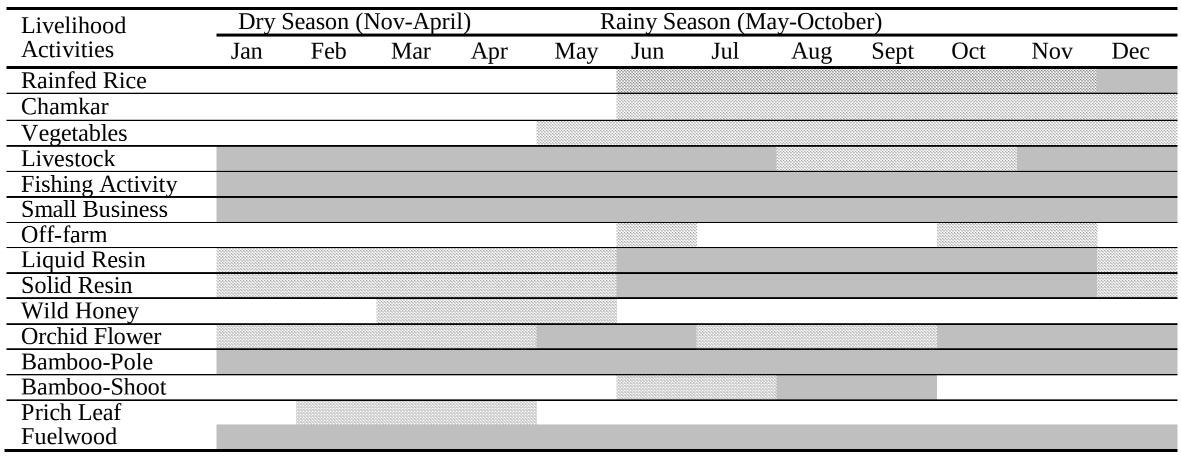

Fig. 1 Seasonal households' livelihood activities

Noted: Blank, light grey and pattern represent no activity, occasionally activity, intensively activity respectively

NTFPs Resources Endowment in Phnom Prich Wildlife Sanctuary

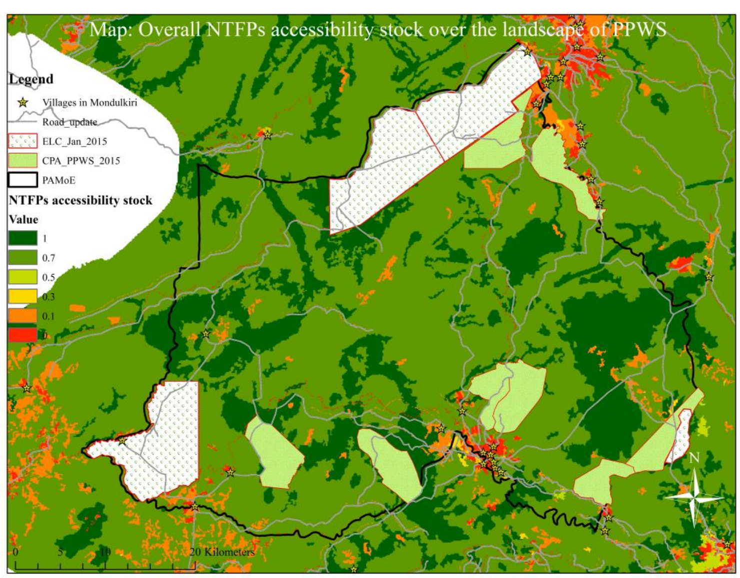

Fig. 2 NTFPs resources endowment in PPWS

Figure 2 shows the result of "Open access" model simulation. Through the NTFPs accessibility map, it clearly shows that NTFPs are abundant over the landscape, according to the identified value of high accessibility - light green (0.7) and dark green (1.0). The value of resources accessibility is likely less in the areas nearby the roads and village zones and city, as indicated by the red, orange, and yellow color. Each NTFP has different characteristics of habitats and capacity to produce. Bamboo, fuel wood, and prich leaf (*Melientha suavis* Pierre*)* are very abundant, so local people easily access nearby the villages. The commercial NTFPs including liquid resin, solid resin, wild honey, and orchid flower are located in further distance, mostly in evergreen and semi-evergreen forests where the distance ranged from 9 km to 14 km from their villages.

NTFPs Dependent People in Phnom Prich Wildlife Sanctuary

Households' characteristics make a crucial distinction between people who rely on NTFPs as the main source or starting point of livelihoods. Fig. 3 shows that indigenous people (Bunong) tend to depend more on NTFPs because it is the traditional activities to sustain their livelihoods. The study also finds that households who had moderate livelihood diversification (3 to 4 occupations per household) seem to collect more NTFPs. Also, low education people were more likely to rely on NTFPs. However, this finding agrees with other studies that native people and low education people are more likely to depend on NTFPs for livelihoods (Shackleton and Pandey, 2014). The claimed from Wunder (2001) that only less income diversification household depend more on NTFPs is rejected because NTFPs are very important for everyone living in the forest sanctuary. Regarding households' production factors, the household group having more members collected NTFPs more than the household who has less, as be shown in Fig. 4. This result indicates that collection NTFPs is labor intensive. Also, households owned a motorcycle for transportation enables to travel further to collect more NTFPs. Moreover, the households owned average agricultural land are likely to collect more NTFPs than the landless or the people owned large land. Despite the claimed from Cavendish (2002) that only local people who limit the land ownership, limit capital, limit labor and less income diversification tend to depend on NTFPs heavily, is rejected.

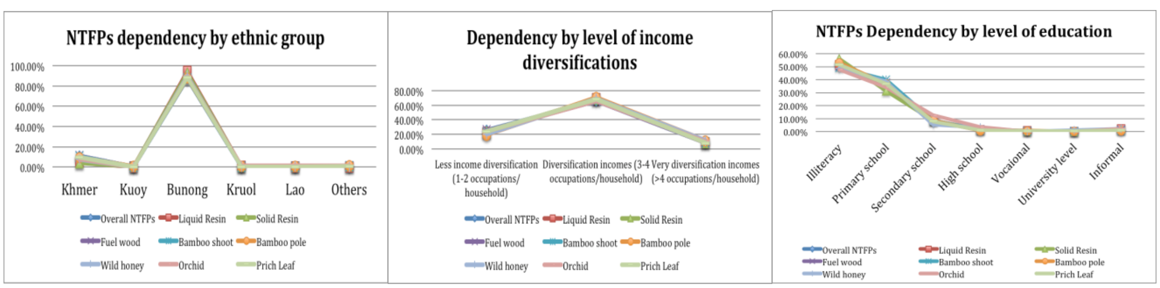

Fig. 3 NTFPs dependency level by households' characteristics

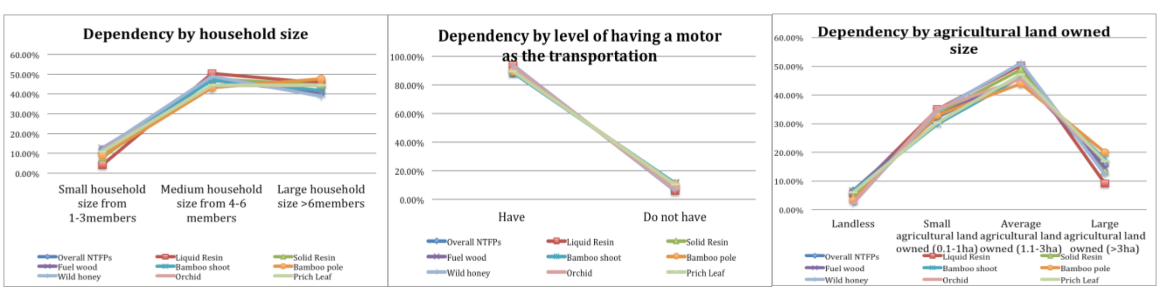

Fig. 4 NTFPs dependency level by households' production factors

Importance of NTFPs for Local Livelihoods

Results from focus group discussions indicated 14 NTFPs which local people have collected the most in PPWS. Among the 14 NTFPs, six NTFPs are considered as the most important NTFPs including fuelwood, bamboo shoot, prich leaf, solid resin, bamboo poles, and liquid resin, which represent 98%, 85%, 83%, 56%, 56%, and 50% respectively. Additionally, wild honey and orchid flower are also considered as the importance NTFPs because they constitute as the sources of households' cash income. Table 1 shows the diversity of NTFPs use and commercialization in PPWS. The most important NTFPs for subsistence uses in PPWS were fuelwood, bamboo shoot, bamboo poles, prich leaf, wild honey, and liquid resin which identified by the signal + and +/- in Table 1. Bamboo shoot and prich leaf were consumed for food during the wet season and the dry season respectively. Fuelwood has ultimately served the local communities for energy sources for cooking. Local people used the bamboo poles for construction, fencing, and furniture. Wild honey was used for traditional medicine and food ingredient. Liquid resin was used as the raw material for small construction. Table 1 shows that liquid resin, solid resin, wild honey, and orchid flower were widely collected for commercialization at PPWS. Wild honey, orchid flower, and solid resin were seasonally collected and sold. Liquid resin was the only NTFP that local people extracted intensively and sold in year-round. In a few cases, bamboo poles and prich leaf were sold to the market. This result is similarly to another study that many NTFPs are the critical subsistence in rural households' economy. People traded NTFPs when only the markets were available at their locations (Cavendish, 2002).

Table 1 Importance of NTFPs to local livelihoods

NTFPs	Key species	Importance to local livelihoods	
		Use	Commercial
Liquid resin (n=143)	*1. Dipterocarpus alatus* *2. Dipterocarps intricatus* Dyer	+/-	+
Solid resin (n=162)	*1. Shorea guiso* *2. Shorea siamensis* 3. And some of *Genera of Dipterocarpaceae (Vatica & Hopea)*	-	+/-
Wild honey (n=89)	*1. Apis dorsata* *2. Apis florae* *3. Apis cerana*	+/-	+/-
Orchid flower (n=91)	*1. Vandopsis gigantea*	-	+/-
Bamboo poles (n=160)	1. *Bambusa sp.* *2. Bambusa bambos*	+/-	-
Bamboo shoot (n=244)	*1. Bambusa sp.* *2. Bambusa bambos*	+/-	-
Prich leaf (n=239)	*1. Melientha suavis* Pierre	+/-	-
Fuelwood (n=281)	Diverse long-lived tree species	+	-

Noted: Frequency of use/sell: - not or little use/sell; +/- sometimes use/sell (moderate amount/seasonally); + often use/sell (regularly in year round)

Source: Author's structured interviews (2016).

Contribution of NTFPs to Ecosystem Services

Although most of the NTFPs do not play a direct role in ecosystem services, they are ones among the final products provided by ecosystem services. However, the trees/forest, which provided NTFPs play a crucial role in ecosystem services as follows.

First, many of the trees providing NTFPs are the long-lived trees, so all parts of the trees play a role in carbon sequestration, (Table 2). The carbon storage function has the social value which equals to the social damage avoided by not releasing the CO_2 into the atmosphere (Nordhaus, 2007). Second, the forest can regulate the runoffs the rainwater. It can reduce flood volumes during torrential rains, and in dry seasons, forest gradually releases the absorbed water that maintains river flow. The value of watershed protection is commonly equal to water treatment costs, water supply or investment costs of reservoir construction (Gaodi et al., 2010). Third, the trees/forest helps to prevent soil erosion and minimize sedimentation in water reservoir or rivers. This service has a value that equal to the cost of sediment removal from rivers and reservoirs (Keeler et al., 2012). Fourth, the honey bee not only provides the honey products but also to crop plants pollinated. They are the pollinators that can increase yield, quality, and stability of fruit and seed crops. Value equals to the investment costs to optimize agriculture and conservation (Breeze et al., 2016). Last, some species, especially wild orchid flower also contribute a role in aesthetic or recreation. The value of recreation equal to the travel costs of tourists to visit the particular site (Gaodi et al., 2010). This finding is consistent with other studies that NTFPs play a direct or indirect role to maintain the value of ecosystem services because extraction activities do not impact critically to the forest or trees (Arnold and Pe´rez, 2001; Neumann and Hirsch, 2000; Ros-Tonen and Wiersum, 2005).

Table 2 Contribution of the NTFPs to environmental services

Primary NTFPs	Ecosystem Services	Description of functioning contributed by NTFPs
Long-lived trees: Liquid resin, Solid resin, Fuelwood, Bamboo, and Prich leaf *(Melientha suavis* Pierre*)*	Carbon storage	Leaves, branches, stems, barks, and roots of the long-lived trees play role in carbon storage
	Watershed protection	Water can be relocated to regulate availability of surface water and runoff through the crown, trunk, undergrowth vegetation and forest littler and soil.
	Soil erosion prevention	Trees/forest help to prevent soil erosion and minimize sedimentation in reservoirs and rivers.
Honey bee	Pollination	A honey bee is the key animal pollinator for crop pollination
Ornament plant: Orchid flower	Aesthetic	Slightly contribute to recreation and eco-tourism (physical wellbeing, learning, and quality of life)

Source: Author's literature reviews (2016).

CONCLUSION

The contribution of NTFPs to rural livelihoods and forest conservation is regarded as very promising. NTFPs are the common natural wealth for all residents, and their importance in rural livelihoods is confirmed because of the strong dependence from most of the local people regardless their different households' characteristics. NTFPs make a significant contribution to the local economy such as food, house construction, fencing, energy, farm equipment, and cash income. Some primary types of NTFPs also contribute simultaneously to ecosystem services through carbon storage, watershed protection, soil erosion prevention, pollination, and aesthetic.

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Research article

Global Overfishing: A Last Call for Our World Natural Resource

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Abstract Global overfishing has been a severe problem for the last 37 years. The research objectives were to 1) study the situation of global overfishing as our common property 2) examine factors influencing global overfishing and 3) explain the global overfishing policy implementation. Secondary data were collected from the database of Food and Agriculture of the United Nations from 1979 to 2016 as well as additional countries. Descriptive statistics were applied as a tool for data analysis. The inferential statistics were an applied econometric model to examine factors affecting global overfishing. Research results found that 1) for the last 37 years, the situation of global overfishing: according to the FAO database (2016), the world has been faced with overfishing for 37 years, with 3 percent underexploited, 20 percent moderately exploited, 52 percent fully exploited, 17 percent overexploited, and 7 percent depleted; 2) factors affecting global overfishing were comprised of the world amount of fish caught, the world quantity of consumption demand, the world fishery product price, the world population and the fishery technology index; 3) for the global overfishing policy and its implementations: in China, they launched a policy called legal regulations on the price of access-rights to fisheries resources in China. Also, they have resource fishery taxes, which are about 1 to 3 percent of the total production value. In Australia, they applied Individual Transferable Quotas (ITQs) of southern bluefin tuna (SBT) as policy implementation resulting in about 67 percent by average. ITQs reduced the amount of SBT caught. As common property, global overfishing has been, and still is, one of our world problems that everyone in the world should pay attention to. It is a last call for this world natural resource.

Keywords global overfishing, world natural resource

INTRODUCTION

Overfishing is a form of overexploitation where fish stocks are reduced to below acceptable levels. Overfishing can occur in water bodies of any size, such as ponds, rivers, lakes or oceans, and can result in resource depletion, reduced biological growth rates, and low biomass levels. Sustained overfishing can lead to critical dispensation, where the fish population is no longer able to sustain itself. Some forms of overfishing, for example the overfishing of sharks, have led to the imbalance of entire marine ecosystems (Scales, H.2007). The ability of a fishery to recover from overfishing depends on whether the ecosystem's conditions are suitable for the recovery. Dramatic changes in species composition can result in an ecosystem shift, where other equilibrium energy flows involve species compositions different from those that had been present before the depletion of the original fish stock. For example, once trout have been overfished, carp might take over in a way that makes it impossible for the trout to re-establish a breeding population (Gaia Vince, 2016).

Overfishing occurs when more fish are caught than the population can replace through natural reproduction. Gathering as many fish as possible may seem like a profitable practice, but overfishing has serious consequences. The results not only affect the balance of life in the oceans, but also the social and economic well-being of the coastal communities who depend on fish for their way of life (Gaia Vince, 2016). Overfishing has significantly affected many fisheries around the world. As much as 85% of the world's fisheries may be over-exploited, depleted, fully exploited or in recovery from exploitation (Gaia Vince, 2016). Significant overfishing was also observed in pre-industrial times. In particular, the overfishing of the western Atlantic Ocean from the earliest days of European colonization of the Americas has been well documented (Bolster, W. Jeffery, 2012).

Following World War Two, industrial fishing rapidly expanded with rapid increases in worldwide fishing catches. However, many fisheries have either collapsed or degraded to a point where increased catches are no longer possible. Examples of overfishing exist in areas such as the North Sea, the Grand Banks of Newfoundland, and the East China (Sea Lu Hui, ed, 2006*).*

According to a 2008 UN report, the world's fishing fleets are losing US$50 billion each year through depleted stocks and poor fisheries management. The report, produced jointly by the World Bank and the UN Food and Agriculture Organization (FAO), asserts that half the world's fishing fleets could be scrapped with no change in catch. In addition, the biomass of global fish stocks have been allowed to run down to the point where it is no longer possible to catch the amount of fish that used to be caught (Black, R, 2008).

There are three recognized types of biological overfishing: growth overfishing, recruit overfishing, and ecosystem overfishing (Fish recruitment, 2013). Economic or bio-economic overfishing additionally considers the cost of fishing when determining acceptable catches. Under this framework, a fishery is considered to be overfished when catches exceed maximum economic yield where resource rent is at its maximum. Fish are being removed from the fishery so quickly that the profitability of the fishery is sub-optimal. A more dynamic definition of economic overfishing also considers the present value of the fishery using a relevant discount rate to maximize the flow of resource rent over all future catches. Overfishing occurs when more fish are caught than the population can replace through natural reproduction. Gathering as many fish as possible may seem like a profitable practice, but overfishing has serious consequences. The results not only affect the balance of life in the oceans, but also the social and economic well-being of the coastal communities who depend on fish for their way of life (Pauly, D.1989).

Billions of people rely on fish for protein, and fishing is the principal livelihood for millions of people around the world. For centuries, our seas and oceans have been considered a limitless bounty of food. However, increasing fishing efforts over the last 50 years, as well as unsustainable fishing practices, are pushing many fish stocks to the point of collapse. More than 85 percent of the world's fisheries have been pushed to or beyond their biological limits, and are in need of strict management plans to restore them. Several important commercial fish populations such as Atlantic Bluefin tuna have declined to the point where their survival as a species is threatened. Target fishing of top predators, such as tuna and groupers, is changing marine communities, which leads to an abundance of smaller marine species, such as sardines and anchovies. Many fishermen are aware of the need to safeguard fish populations and the marine environment; however, illegal fishing and other regulatory problems still exist. The World Wildlife Fund works with stakeholders to reform fishery management globally, focusing on sustainable practices that conserve ecosystems, but also sustain livelihoods and ensure food security (https://www.worldwildlife.org/initiatives).

In this research, the researcher tries to explain the situation of global overfishing, examine factors affecting global overfishing, and explain the global overfishing policy implementation in China and Australia, which present both sides of the policy implementation—negative and positive impacts.

OBJECTIVES

In this research, the research objectives were to

1. study the situation of global overfishing as our common property

2. examine factors influencing global overfishing
3. explain the global overfishing policy implementation

METHODOLOGY

Secondary data were collected from the database of Food and Agriculture (FAO) of the United Nations from 1979 to 2016 as well as additional countries. Statistical methodology was applied multiple regression analysis in order to construct a global overfishing model to estimate the factors affecting global overfishing. Statistical methodology was applied as the tool for data analysis with T-test, F-test, Coefficient of Determination (R^2), Durbin Watson (DW).

RESULTS AND DISCUSSION

Following research objectives, the research results would be expressed into 3 parts as below:

1. The Situation of Global Overfishing: According to the FAO database (2016), the world has faced with overfishing for 37 years, with 3 percent underexploited, 20 percent moderately exploited, 52 percent fully exploited, 17 percent overexploited, and 7 percent depletion (Table 1, and Fig 1). Obviously, there are more than 50 percent of global fisheries faced with the fully exploited, which potentially led to global overfishing.

Table1 World fishing situation

Global Fishing Situation	Percentage
Underexploited	3
Moderately exploited	20
Fully exploited	52
Overfished	17
Depleted	7

Source: Food and Agriculture Organization of the United Nations (FAO), 2016

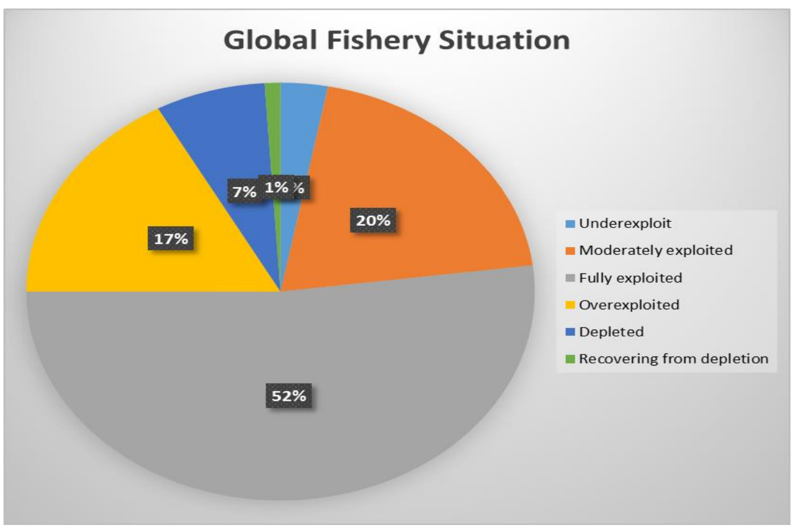

Fig. 1 The Global Fishery Situation

Source: Food and Agriculture Organization of the United Nations (FAO), 2016

2. Factors Affecting Global Overfishing, could be expressed as the econometric model below:

GOF = -227.750 + 0.025(MFC) + 0.003*(QCD) + 0.0026*(NWP) + 0.124*(FTI) + error term*
*t-value (275.421)** (186.592)** (127.643)*** (89.643)** (212.146)***

R^2	.996
F	226.378**
D.W	1.96

** Statistical Significance at 99 percent level, the estimated parameters were estimated by stepwise regression

Where: GOP = Global Overfishing (%)
MFC = The World Amount of Fish Caught (%)
QCD = The World Quantity of Consumption Demand (%)
FPP = The World Fishery Product Price (%)
NWP = World Population (%)
FTI = Fishery Technology Index (%)

According to the above equation, it revealed that factors affecting global overfishing were the world amount of fish caught, the world quantity consumption demand, the world fishery product price, the world population, and the fishery technology index. The results expressed that when the world amount of fish caught increased by 1 percent, it would increase global overfishing by 0.025 percent. When the world quantity consumption demand increased by 1 percent, it made global overfishing increase by 0.003 percent. And an increase in world population by 1 percent made global overfishing increase by 0.0026 percent. Also, the fishery technology index was one of factors affecting global overfishing, it obviously expressed that the increase in 1 percent of the fishery technology index raised global overfishing by 0.124 percent. From the research results, it was clear that the fishery technology index had the biggest impact on global overfishing.

3 The Global Overfishing Policy and Its Implementation: The Food and Agriculture Organization (FAO) of the United Nations encourages the member countries to buy back fishing vessels older than 20 years. In this research, the researcher presented 2 different countries—China and Australia.

China is one fishery that produces and trades in the world market. There is a Marine Fishery policy in China called the Fishing License System. By using this, fishermen can apply for a fishing license issued by the minister of agriculture of China. They also launched the policy called Legal Regulations on the Price of Access-rights to Fisheries Resources in China. Moreover, they have resource fishery taxes which are about 1 to 3 percent of the total production value. A fishing moratorium on catches both inland and to a 200 nautical mile extent was initiated for fishing resources from late 1970. The impact of the resource tax or tax per value of fisheries in China led the Chinese government to collect the taxes as revenues. In contrast, the number of new entrants in the fishing industry increased more than 50 percent. The size of fleet grew along with advanced technology (compared with the old vessels.) The increased size of the fleet in the Chinese fishery industry forced Chinese fishermen to operate beyond 200 nautical miles. Nowadays, China has the biggest size fleet in the world and is the biggest producer.

Australia is one of the countries that applied Individual Transferable Quotas (ITQs) of southern bluefin tuna as a policy implementation. By 1983, the southern bluefin tuna (SBT) fishery was in a severe state of decline. Catch rate and the recruitment to parent stock were going down. A group of biologists from the major bluefin tuna fishing nations concluded that the total SBT catch should not exceed its estimated 1980 level, which was 21,000 tons. In 1983, the Australian government responded to biologists' recommendations by implementation of a total allowable catch limit of 21,000 tons in the Australian SBT fishery. In 1984, the Australian government reduced the total allowable catch from 21,000 tons to 16,000 tons. In 1985, the ITQs were introduced with a catch quota of 14,500 tons. ITQs caused a 50 percent reduction in fleet size because of the reduction in allowable catch limits. Australian fishermen can sell their quotas and exit the industry, or buy quotas from others, which led to a majority (over 50 percent) of Australian fishermen selling their quotas and leaving the industry. Fishermen who bought up quotas from others improved their technology and fishing capacity by about 67 percent on average. ITQs reduced the amount of SBT caught and the efficiency of the fishery increased as older boats left, and also because fishermen increased the technology of the remaining boats. It required 10 years, from 1984 to 1994, for the parent stock to recover and stabilize. Nowadays, ITQs of 11,750 tons of SBT are issued for Japanese, Australian, and New Zealand fleets. In sum, the impact of ITQs of SBT in Australia brought about 1) reduction in the size of fleet and number of fishermen, 2) increased and improved fishing technology (it was about 67 percent on average), 3) the total amount of ITQs dropped the annual catch by almost 50 percent from the pre-quota level, and 4) it took almost 10 years for the parental stock of southern bluefin tuna to recover.

CONCLUSION

Global overfishing is the now a severe problem for our world natural resource. Obviously, 17 percent of our world fishery is overexploited with 7 percent already depleted. According to the data, 52 percent is now fully exploited—this means that there is a high chance of increasing to overfishing. Over the last 37 years, global fishing has increased year by year. Factors affecting global overfishing were the world amount of fish caught, the world quantity consumption demand, the world fishery product price, the world population, and the fishery technology index which had the biggest impact on global overfishing. In order to relieve global overfishing, we should reduce all factors that affect all global overfishing, especially the fishery technology index. Moreover, it should be our function to provide relief for our world fishery natural resource to keep it with us. Nowadays, the FAO still encourages all country members to apply a fishery policy to relieve global overfishing and protect us from its return. Some countries have been successful with policy implementation, but others have not. Furthermore, it has brought up other problems. Global overfishing could be declared as our world natural resource problem, and we should save our world natural resource. Food Agriculture Organization of the United Nations as a key global organization would have concrete policy and its implementation to restrain global overfishing. Moreover; everyone in the world would have attention and cooperation with global overfishing in order to restrain our would severe problem since it is our world common property.

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Research article

Comparative Study of Methane Emission and Structural Development of Rice Plants from SRI and non-SRI Methods in a Lysimeter Experiment

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Abstract Mitigating greenhouse gas (GHG) emission is a challenging issue in context of coping with the ongoing climate change. Rice farming is considered as the major emitter of CH_4 along with gaseous N_2O. There are several methods of irrigation management that reduces the amount of CH_4 and N_2O gases produced, such as intermittent irrigation and mid-season drainage. SRI (system of rice intensification) is one of the new methods known to increase the yield while mitigating GHGs by applying one of key elements intermittent irrigation, and is a method which is now disseminating in tropical countries. This study was conducted to measure the effectiveness of SRI method by measuring plant development, yield component, and methane emission using a lysimeter facility. The transplanted nursery was *koshihikari*, a Japanese rice variety. The study compared between two plots with different water treatments. The results showed that a plant growth characteristics were better in a continuous plot than in a intermittent plot, while grain yield was not significantly different. Methane gas was almost 50% less in the intermittent plot than in the continuous plot. Total global warming potential from methane emission for intermittent plot and continuous plot were 50.41 g CO_2/m^2 and 100.53 g CO_2/m^2, respectively. The results suggest that SRI methodology could be an effective method for mitigating methane emission without reducing the grain yield.

Keywords Methane, water management, system of rice intensification, climatic variability

INTRODUCTION

Mitigating greenhouse gases is a challenging issue in the present world. Exponential growth in world population against a linear growth of food supply, coupled with a decrease in agricultural land, are major problems for the world. To overcome the problems, several technologies are being applied to increase food supply to support the growing population. The development of rice technology is beneficial for both the environment and rice production. In rice production, technologies like SRI (system of rice intensification), and an irrigation management method called intermittent (alternative wetting and drying) irrigation, are being practiced in areas with limited resources to adapt to the ongoing climate changes. SRI originated in Madagascar in 1983, developed by Father Henri de Laulanı´e and later disseminated by Cornel University to more than 50 countries. SRI is broadly defined as an agro-ecological methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water, and nutrients (Cornell International Institute for Food, Agriculture and Development, CIIFAD). Moreover, SRI method is a single transplanting method that reduces seed requirement by 90%, increases yield by 20-100%, and saves water by 50%, according to the CIIFAD report. However, several issues are also known in implementation of SRI within local farming practices from region to region, because the rice production largely depends on the topography, climate conditions, and soil nutrients. Nonetheless, SRI method has shown positive synergies. Sato et al., (2005) reported that it is a method that saves water and costs, while also producing high yields in Indonesia. SRI method in India resulted in higher yields by almost 67% than a conventional method (Singh and Talati, 2006). Similarly, SRI method can save up to 25-50% water compared to conventional practices in Japanese rice farming (Chapagain and Yamaji, 2010). A study of the rice plant development in China (Defeng et al., 2002) under a wider space transplanting method resulted in a higher root number than a close transplanting method. SRI method itself is a single transplanting method of baby nursery with wider spacing. Chapagain et al., (2011) showed that the SRI method results in a higher development of roots, where root number was greater by 30% and tillering and early flowering increased by 25% during the paddy field experiment in Japan. Similarly, an experiment in India with the SRI method observed a significantly higher development in terms of physiological and plant development characteristics (Thakur et al., 2009).

Yet there are still a lack of reports for SRI adoption, particularly in Japan, since there are challenges that needs to be overcome against local methods. Therefore, a comparative study of SRI and non-SRI methods was conducted with a lysimeter facility of the University of Tokyo in Kashiwa, Chiba, Japan. The objectives of the study were to examine the structural development of rice plant and methane emission by two methods: the SRI method (intermittent irrigation) and non-SRI method (continuous flooding). The hypothesis was that the SRI method would perform better in comparison to the non-SRI method. In particular, the SRI method was expected to result in higher grain yield, biomass, and longer roots elongation, as reported in other countries. The experiment was conducted in the lysimeter with transplantation of single seedling in two plots, where the intermittent plot was irrigated by intermittent irrigation, and non-SRI method plot by continuous flooding. how high yields are achieved through SRI's key principles through a range of environmental factors and agronomic management practices including variety selection.

METHODOLOGY

1) Study Area and Experimental Set Up

The experiment was conducted on the lysimeter situated in the University of Tokyo in Chiba Prefecture during the rice growing season, from May to the end of October, in 2014. The lysimeter area was 500 x 160 cm, soil depth 25 cm, was equipped with a drainage system on the right border and irrigation tap on the left border (Fig. 1). The soil was puddled homogeneously at the time of soil preparation. 800 g of organic fertilizer was applied homogeneously. The composition of fertilizer was 1.3% nitrogen, 0.6% phosphorus, and 1.8% potassium, with C/N ratio of 22. The lysimeter was divided into two plots by along the center by a plastic sheet. Plot A was named intermittent plot and plot B was named continuous plot. Two water tubes of 25 cm length and 13.5 cm diameter were installed to monitor the ponding depth of the plots. The water tubes featured a fixed measuring scale made of aluminum to observe the water level in the lysimeter. 12 days-old single nursery of Japanese rice variety (koshihikari) was transplanted. The nurseries were prepared by the local farmers under our request. 32 nurseries were transplanted on May 23,. The space between each hill was (30 x 30) cm. The Soil Eh (ORP) sensors were set up for both plots at 5 cm and 10 cm depths. Soil Eh data were recorded by EH-120 (Fujiwara Scientific Co. Ltd., Tokyo, Japan).

2. Management Method

Two types of water management were applied in the experiment. One was intermittent irrigation for the intermittent plot, and the other was continuous flooding for the continuous plot. For the first two weeks after the transplantation, shallow ponding condition was maintained in both plots until the young rice nurseries became stronger. Intermittent plot was then managed by intermittent irrigation method (Fig. 2). Water was drained by a pumping tube in case of excess rainfall. Continuous plot was ponded continuously during the vegetative phase. The first weed was removed from both plots three weeks after the transplantation. The plots were maintained by periodical weeding thereafter. The weeds removed from the plots were buried under the soil as practiced by the SRI method. The first flowering of the rice plant was observed on August 9th. The lysimeter was covered by a net on August 29th to prevent damage by birds. The rice was harvested on October 3, 2014. Lysimeter was kept dry for the last two weeks to prepare for the harvest.

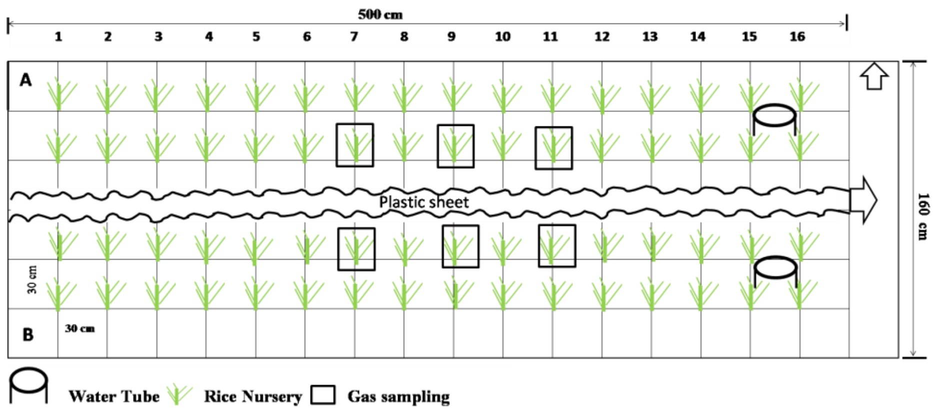

Fig. 1 Layout of lysimeter

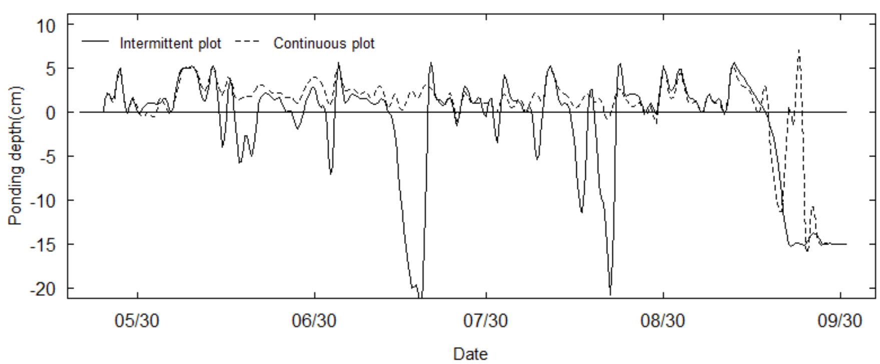

Fig. 2 Ponding condition in Lysimeter

RESULTS AND DISCUSSION

1) Rice Plant Development

The rice plant development in this study is divided into three phases. The day from the transplantation to panicle formation is the vegetative phase. From panicle formation to the fertilization is the reproductive phase. The final phase is the ripening phase which includes maturity of rice grains. During the vegetative phase, rice plant height was similar in growth (Fig. 3a). After the vegetative phase, plant height grew significantly higher in the continuous plot, suggesting that plant height grows more favorably without water stress. The development of rice tillers during the first three weeks after the transplantation was similar. Afterwards, a significant increase in the number of tillers was observed in the continuous plot (p<0.01). Higher number of tillers was observed in continuous plot DAT (days after transplant) 49 and 56. Intermittent plot showed a higher number of tillers in DAT 70 (Fig. 3c). After DAT 70, tiller number decreased as the lower parts of small tillers decayed in both plots, which was not included in counting. Higher number of leaves was observed in DAT 70 in both plots (Fig. 3b). Average number of leaves for the intermittent plot and continuous plot were 51.90 and 66.06, respectively. In the reproductive phase, similar cases of descending number of leaves were observed after the dry leaves were excluded from the count. The first panicle was counted on DAT 78. Lower number of panicles was recorded in intermittent plot because of lower tiller number compared to the continuous plot. The number of panicles and tillers were same at the time of harvest (Fig. 3d).

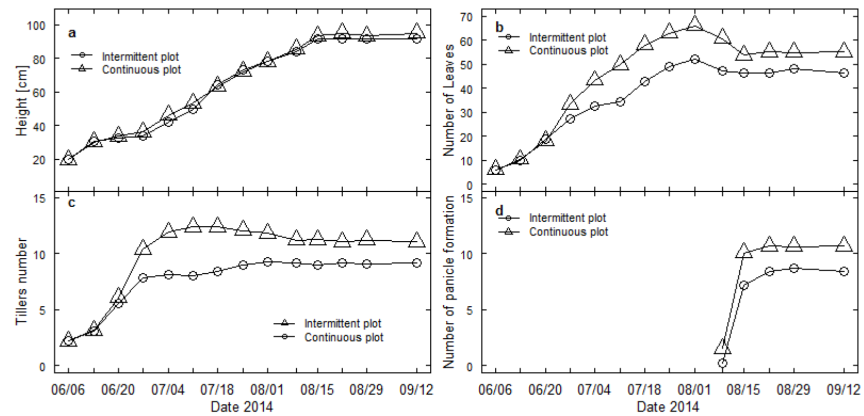

Fig. 3 Rice plant development: (a) plant height, (b) number of leaves, (c) number of tillers, and (d) number of flowerings

2. Rice Yield and Root Development

Table 1 Comparisons between number of grain, branch, rice root, and methane

Measurement indicators	Significant level	Intermittent plot		Continuous plot	
		Mean	SD†	Mean	SD†
Number of grains	-	1086.10	395.49	1198.30	383.15
Grain weight (gram)	-	21.03	6.82	21.97	5.95
Panicle branches (number)	**	95.50	36.08	117.30	39.19
Panicle weight without grain (gram)	*	1.09	0.41	1.34	0.49
Root length (centimeter)	-	19.20	2.53	20.60	2.63
Dry root weight (gram)	***	5.07	2.21	7.62	3.23
Methane flux (mg/m^2/hr.)	**	0.82	0.73	1.77	1.70

***** Significant level at 0.1**, **** Significant level at 0.05**, ***** Significant level at 0.01**, -:** Not Significant
†Standard deviation

To study the yield component, 10 rice plants were selected from both plots. The rice plants were selected from both sides of the plot borders in order to make the sampling process uniform. Larger panicles were observed in rice plants from borders than from the middle of the plot. The number of grains, panicle branches, and roots were measured from the same rice plant samples. Every measurement indicators are an average of 10 plants from each plot. The average grains number and weight were higher in the continuous plot, but without significant difference compared to the intermittent plot. A significant difference was observed in panicle branches. Higher number of panicle branches were found in the continuous plot than in the intermittent plot (Table 1). In terms of root dry weight, continuous plot had a higher weight of total root than the intermittent plot, but there was no difference between root lengths. Thakur et al., (2009) reported a higher elongation and better distribution of root system by SRI method, and several other studies from outside Japan has also reported of high yield and water savings by SRI. In this study, however, no significant difference was observed in terms of the yield and number of grains.

3. Methane Emission

The methane gas emission from the intermittent plot was typically lower than the continuous plot. The methane gas reduction process by intermittent irrigation is already known by many researchers (Hadi et al., 2010; Kudo et al., 2014). The pattern of methane emission in both plots were increasing during the vegetative phase and decreasing during the reproductive phase. The rapid development of rice plants during the vegetative phase and longer application of irrigation caused the higher emission of methane. Soil Eh was measured as an indicator of methane gas emission from both plots. A significantly positive correlation between methane flux and soil water content was found in the lysimeter experiment in 2013 (Pun et al., 2013).

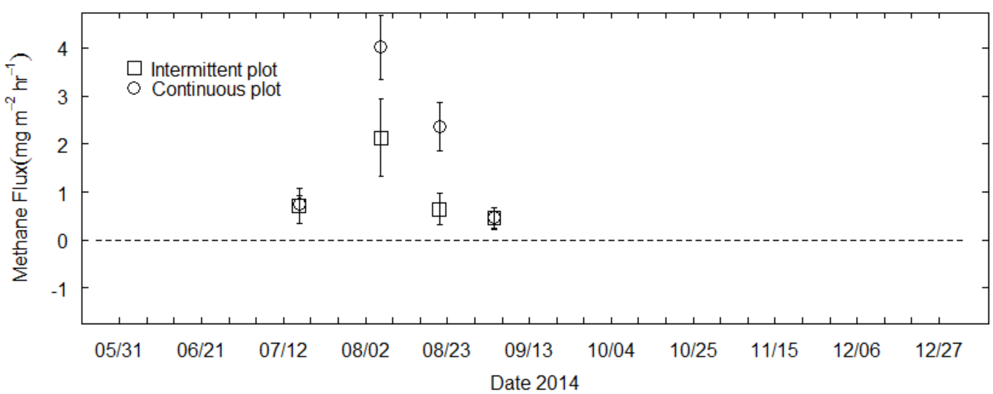

Fig. 4 Methane gas emission in intermittent plot and continuous plot

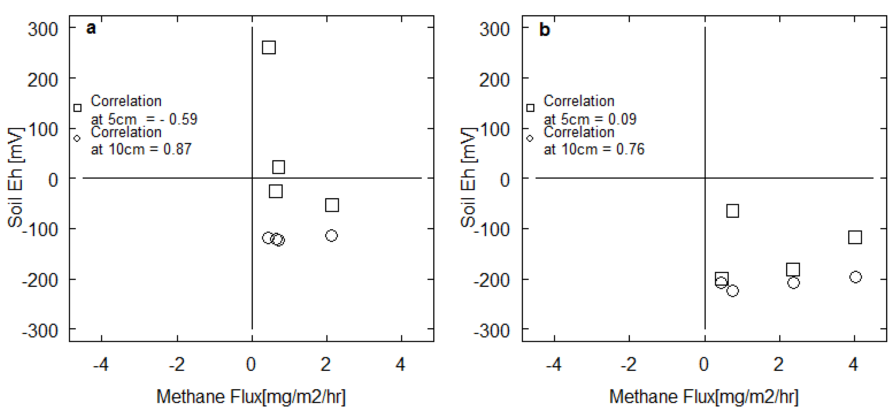

Fig. 5 Relation between methane flux and soil Eh

Moreover, to understand the mechanism of methane gas flux with soil layer condition, depth-wise measurements of soil Eh were taken. Both plots at 10 cm depth showed a positive correlation between methane flux and soil Eh in Figs. 5a and 5b. However, intermittent plot showed a negative correlation at 5 cm depth in Figure 5a. In the intermittent plot, the soil surface was alternatively kept wet and dry by intermitttent irrigation, resulting in a soil Eh fluctuation and low level of methane formation. The aerobic condition of the soils kept the emission low in the intermittent plot. In case of the continuous plot with continuous water ponding, soil Eh was lower at both 5 cm and 10 cm depths with higher methane flux. During the continuous flooding, the soil was under a reducing condition and thus emitted the methane gas. Cumulative methane flux during the rice growing season was reduced by nearly 50% in the intermittent plot compared to the continuous plot. Total methane flux emitted from the intermittent plot and the continuous plot were 50.41 g CO_2/m^2 and 100.53 g CO_2/m^2 per rice growing season, respectively. Another anthropogenic gas, N_2O emission, occurred when the flooding water disappeared from paddy field and fertilizer was applied (Cai et al., 1997).

CONCLUSION

The experiment was conducted to measure methane emission and the structural development of rice plant by SRI and non-SRI methods. The structural development of rice plant in the continuous plot was significantly greater than the intermittent plot. Young single seedlings were used in both plots, and there was no difference in grain yield. Dry root weight was greater in the continuous plot but no difference was observed for root length. The methane flux in intermittent plot was significantly lower than the continuous plot, with almost 50% reduction in emission. The methane flux peak was mainly observed during the vegetative and pre-reproductive phases. If the water could be managed without stress to the plant, then SRI method can be the appropriate method for reducing global warming potential. The higher correlation between soil Eh and methane flux were found at 10 cm depth in both plots. The experiment was conducted on concrete made lysimeter, and the heat from the concrete may have affected the measurements for soil temperature and Eh. To clearly understand soil Eh in relation to depth, tests in real paddy fields are needed. SRI method itself is a new environment-friendly method, and while several researchers produced higher yields than a conventional rice cultivation method, the results from this study was different. The dissemination of SRI method is still a work in progress, where key basic elements are being identified by particular local areas, since different areas have different climate conditions and resource availability. The difference in result was because the same number of rice seedling was transplanted in both plots. In other to further understand the structural development in SRI and non-SRI methods, an experiment is needed to test by seedling densities.

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Research article

Development of Portable Artificial Rainfall Simulator for Evaluating Sustainable Farming in Kenya

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Abstract Artificial rainfall simulation is an important aspect to investigate soil erosion process and surface runoff through application of rainfall simulator. On the other hand portable artificial rainfall simulator can be utilized in remote areas to solve some of the challenges that may be posed by heavy and expensive factory-made rainfall simulators at the same time maintaining the effectiveness and efficiency of the equipment. Drop size, kinetic energy, surface runoff and sediment yield were obtained from experiments conducted using artificial portable rainfall simulator developed in the lab of land and water use engineering for testing on actual fields with different vegetation cover in Kenya. Average kinetic energy and drop size calculated from 24 outlet needles of the rainfall simulator was found to be approximately 1.6 x 10^{-5} J and 3.42 mm respectively. Using calibrated cylinder, intensity was measured randomly along the simulator needle outlets and average intensity calculated as 40 mm hr^{-1}. Water pressure was generated through elevated Marriote bottle. Experiments were conducted in research site in Mombasa Kenya. Drop size and kinetic energy for actual rainfall in Kenya were also determined. Evaluation of soil erosion using portable artificial rainfall simulator is therefore important in establishment of proper and effective soil erosion control strategy for achieving sustainable farming in Kenya.

Keywords rainfall simulator, soil erosion, sustainable farming, portable, Mombasa Kenya

INTRODUCTION

Kenya is located in Eastern part of Africa and It lies between latitudes 5°N and 5°S, and longitudes 34° and 42°E and its total area is 582,650 km^2. It borders five countries (Tanzania, Uganda, Sudan, Ethiopia and Somali) and Indian Ocean on south eastern part. Agriculture in Kenya faces various challenges like water shortage, soil erosion, inadequate technical farming knowledge etc.

Research on soil erosion through application of portable rainfall simulator is among the basic steps necessary in improving sustainable agriculture. Although water is considered as the most critical resource for sustainable agricultural development worldwide (Konstantinos et al., 2015), soil erosion control is also one of the factors considered in enhancing sustainable agriculture.

Rainfall aggressiveness has always been a prominent environmental threat in the course of human history, especially affecting the agricultural sector (Nazzareno et al., 2010). Rainfall intensity, drop size, drop fall velocity and kinetic energy are considered in determination of rainfall effect on the soil whereas together with other factors like vegetation cover, land slope, soil erodibility and support practice can be applied to estimate amount of soil loss.

Rainfall simulators have been developed and used extensively for runoff, infiltration and erosion data collection for several years (Roberto et al., 2013). Approximately, for the last 75 years rainfall simulators have been developed and used throughout to conduct research on infiltration, surface water runoff and soil erosion (Humphry et al., 2002). Weight, efficiency, cost and portability are among the major factors considered in development of rainfall simulators. They have produced raindrops either through nozzles or tubing tips like hollow needles. In this research, more emphasis is put on simulators that utilize hollow needles and require lower pressure as compared to those that use nozzles. Development of portable rainfall simulator can be achieved through utilization of readily available materials and a Marriott bottle for evenly distributed water pressure generation.

Many of the existing rainfall simulators are laboratory tools suited for working with disturbed soil samples in shallow trays (Abudi, 2011). Data from the actual fields can yield better analytical results as compared to prepared laboratory plots and provides more actual conditions for further research. Simple design of portable rainfall simulator facilitates extensive research to be done in many fields. In this study more emphasis is put on how to develop portable artificial rainfall simulator and evaluate soil erosion through application of portable artificial rainfall in different fields and appropriate soil erosion control measures to improve environmental factors and also promote economic factors leading to increased farm output.

OBJECTIVE

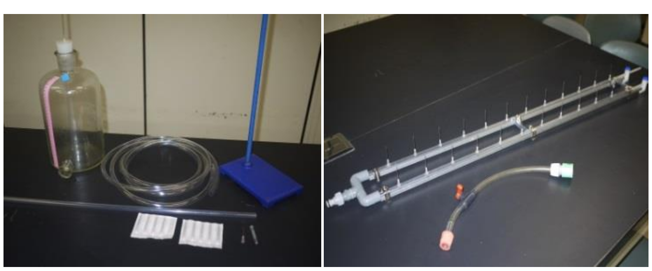
To develop portable artificial rainfall simulator with Marriott bottle and to evaluate soil erosion on agriculture field through observing soil loss in different fields condition under a portable artificial rainfall simulator for sustainable farming practices in Kenya.

METHODOLOGY

Rainfall simulators are commonly used instruments to study sheet erosion, since they can be set to predefined values such as rainfall duration and quantity (Schindler et al., 2012). Development of affordable portable artificial rainfall simulator can therefore be utilized in solving some of the challenges that may be posed by heavy and expensive factory made rainfall simulators at the same time maintaining the effectiveness and efficiency of the equipment.

Materials: Locally available materials were used to develop portable artificial rainfall simulator which includes; 2 pieces of PVC pipes 1 meter long each and 8 mm internal diameter, outlet needles 0.83 mm internal diameter, connecting plastic pipes with control valves, Marriott bottle and metallic stand.

Twelve holes were drilled 8 cm apart on each pipe and outlet needles 0.83 mm internal diameter fixed tightly to allow evenly distributed water drops. Marriott bottle was attached for constant pressure head as shown in Fig. 1.



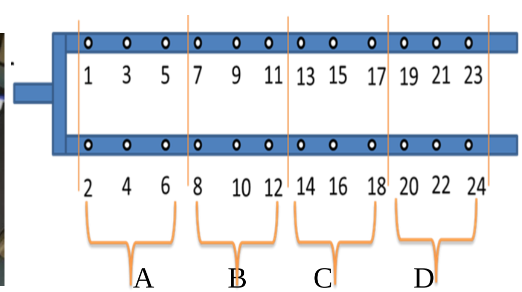


Fig. 1 Materials for artificial potable rainfall simulator **Fig. 2 Needles numbering and grouping**

Using simple metallic stands, developed rainfall simulator was suspended horizontally and firmly at a height of 73 cm from the base and Marriott bottle connected approximately 83 cm from the base to generate equal and evenly distributed pressure and maintain a constant head of water.

Experiments were conducted in laboratory to determine intensity, drop size, drop velocity and kinetic energy of the raindrop simulated. Filter paper method was used to determine drop size, whereas camera method was used to determine drop velocity. Kinetic energy is calculated by mathematical relationship of drop mass and velocity. Drops from all 24 needles were collected and considered individually.

Intensity of the raindrops from simulator developed were also measured since it is crucial in the relationship between rainfall intensity and kinetic energy and its variations in time and space is important for erosion prediction (Van Dijk 2002).

Raindrop Size Measurement: Using a filter paper, drops were collected individually and approximate diameter of each circle formed by the rain drop measured and the average diameter calculated using equation 1. To determine mass of the rain drop, its volume was calculated and multiplied with water density.

$$d = 0.141d' + 0.888 \text{ (m)} \tag{1}$$

$$Vol = \pi/6d^3 \text{ (m}^3\text{)} \tag{2}$$

$$M = Vol * D = Vol * 1000 \ (kg) \tag{3}$$

Where: d = Assumed diameter of spherical drop (m), d'= Diameter of the drop on the filter paper (m), M = Mass of the drop (kg), D = Density of water (1000 kg/m^3).

Raindrop Velocity: Rain drop velocity was calculated using the camera method and applying equation 4. Distance travelled refers to height covered by a falling raindrop represented by image captured by camera at a known camera shutter speed.

$$\text{Velocity} \left(\frac{\text{m}}{\text{s}}\right) = \frac{\text{Distance (m)}}{\text{Time(s)}} \tag{4}$$

Time represents the camera shutter speed which is set as 1/100 seconds of camera shutter and distance in meters represents the height captured by camera shutter covered by the falling drop.

Raindrop Kinetic energy: Raindrop kinetic energy was determined from product of mass and raindrop velocity.

$$KE_D = \frac{1}{2} M_D {V_D}^2 \tag{5}$$

Where: KE_D = Kinetic energy (J), M_D = Raindrop mass (kg), V_D = Drop velocity (m/s).

Pressure Generated by Marriott Bottle: For production of desired intensity over a period of time, it is important to supply equal water pressure which can be achieved by maintaining constant water head

$$\text{Pressure} = h \times \varrho \times g \quad \text{(Pa)} \tag{6}$$

Where: h = head difference (m), ϱ = density of liquid (kg/m^3), g = gravitational force (m/s^2).

Actual Rain Drop Observation in Kenya

Drop size determination by filter paper method and drop velocity determination by camera method were also applied in actual rainfall in Kenya for comparison with simulated drop characteristics. Several other methods which are more complicated and expensive but more precise are applied to determine the size of the raindrop and drop velocity. The simple filter paper and camera methods were applied for easy and quick comparison with simulated raindrop.

Evaluation of Soil erosion through Application of Developed Simulator in the Field

Runoff plots were designed by isolating an area in the field of 1.1 m long by 0.2 m wide and sheet metal inserted around to a depth of approximately 0.2 m below the ground. After leaving the place wet overnight, surface runoff was collected at an interval of five minutes. Six samples from each of the four different field conditions were collected and each sample was measured and recorded. Soil lose was also determined by oven drying surface runoff collected.

RESULTS AND DISCUSSION

Raindrop Diameter and Kinetic Energy

Size of raindrop is defined by its diameter assuming that the raindrop is spherical. Size and kinetic energy of each of the twenty four needles was calculated and graphically represented as shown in Fig. 5. Average kinetic energy was calculated as 1.6 x10^{-5} J and raindrop size approximately 3.42 mm. Actual raindrops have different sizes but in average according to many researchers, they ranges between 0.5 mm to 5 mm. Simulated raindrop is therefore within this range.

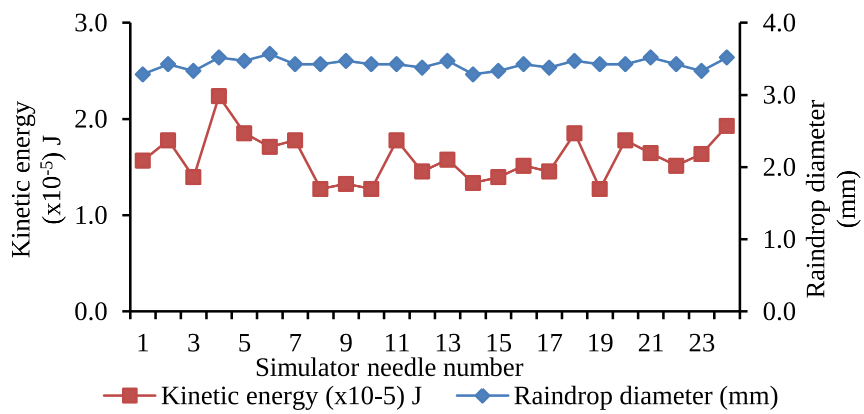


Fig. 5 Kinetic Energy and raindrop diameter

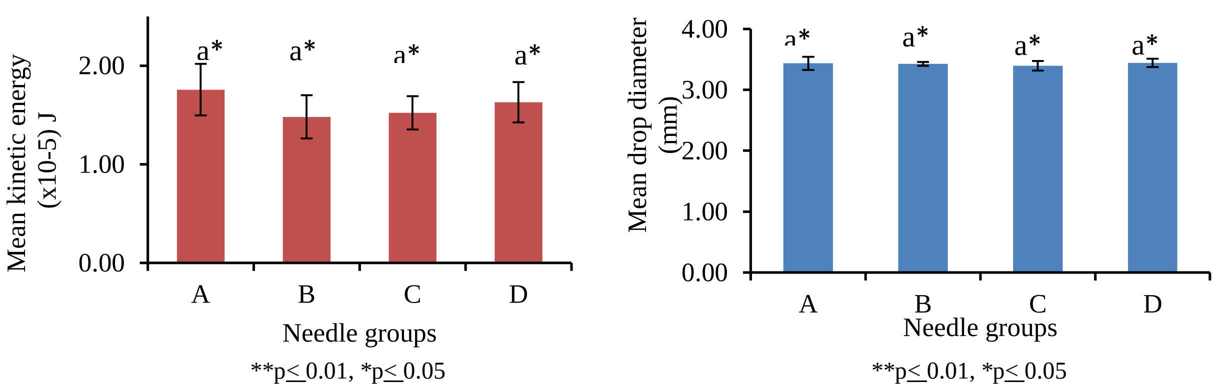


Fig. 6 Mean kinetic energy and mean drop diameter statistical analysis

In Fig.6 according to needle grouping A, B, C and D, there was no statistical difference among the means for both drop size and kinetic energy. This indicates that pressure calculated as 981 Pa was uniformly distributed among all the needles and the drops impact on the ground is fairly uniform.

Intensity: Using a measuring container, intensity was measured directly from four sections of the rainfall simulator and average intensity was calculated as 40 mm/hour. Actual rainfall intensity has a wide range depending on the amount of rain per specific time. Raindrop from this developed simulator utilizes gravity and its own weight to fall. Similarly homogeneous pressure generated through Marriott bottle is due to gravity.

Actual Rainfall Drop in Kenya and Simulated Drop Characteristics

Actual raindrops differ with the simulated drops since it's hard to maintain same drop velocity, shape and size throughout the experiment as compared to simulated ones. Therefore, application of camera method and filter paper to determine drop velocity and drop size respectively for actual rainfall was applied purposely to obtain an estimate of these characteristics range and for comparison purposes. After sampling 22 actual raindrops and determining their drop velocity, average velocity was calculated as 1.38 m/s compared to average simulated raindrop velocity of 1.23 m/s. To determine actual rainfall drop size, 58 raindrops were sampled and average drop size calculated as 3.94 mm which is slightly higher than average of simulated raindrop which was calculated as 3.42 mm.

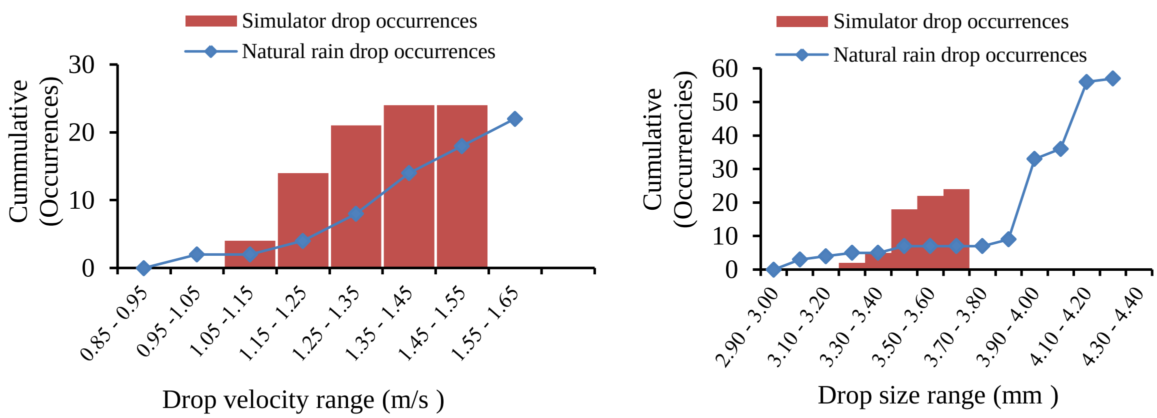


Fig. 7 Natural rain drop and simulator drop relation on drop velocity and drop size

From Fig. 7, drop size, drop velocity and kinetic energy were found to be within the range although actual rain drop size varied greatly. Portable artificial rainfall simulator can therefore be applied in the field to simulate rainfall which is comparable to actual rain for evaluation of soil erosion.

Evaluation of Soil erosion through Application of Developed Simulator in the Field

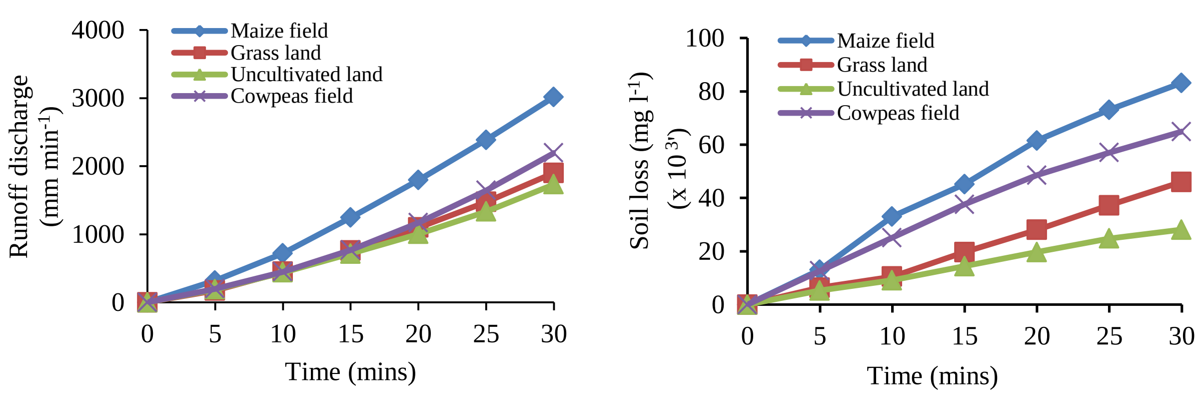


Fig. 8 Runoff discharge and soil loss graphs for different soil field types

Surface runoff was collected at an interval of 5 minutes on 1.2 m by 0.2 m plot on undisturbed soil. According to Fig. 8, developed portable rainfall simulator was applied to evaluate soil erosion in four different fields. Quantitative surface runoff and soil loss was calculated. Highest soil loss and highest surface runoff was observed at maize field since the soil was looser due to frequent cultivation as compared to uncultivated field and probably due to less vegetation cover as compared to other fields. This indicates that better soil conservation measures are necessary to reduce soil erosion for sustainable farming practices in Kenya, depending on soil erosion rate, type of soil, water availability, different fields' vegetation cover and amount of rainfall among other related factors.

CONCLUSION

Portability of the rainfall simulator allows the researcher to work in remote areas in Mombasa County and Simple installation can be an added advantage in performing timely, effective and efficient research. Development of affordable and simple but effective artificial rainfall simulator encourages more research on soil erosion to be conducted in different fields which would otherwise been difficult especially in developing countries.

Calibration through experiment indicated that portable artificial rainfall simulator connected to Marriott bottle for pressure generation produces simulated rain drop of approximately 3.42 mm and kinetic energy of approximately 1.6 $x10^{-5}$ J for soil erosion impact study. Through statistical analysis the simulated drops had no statistical difference both for the drop size and drop kinetic energy. Moreover, characteristics of the simulated drops were within the range of the actual rain drops in Kenya. This implies that the developed rainfall simulator can be effectively applied in field experiments.

Evaluation of soil erosion using portable artificial rainfall simulator is important since soil erosion is among the leading challenges faced by farmers. Soil with less cover and more cultivated are easily eroded, therefore proper and effective soil erosion control strategy establishment is important for achieving sustainable farming in Kenya. Since terraces are common practice of soil erosion control but less effective, better strategies like thick vegetation cover and trees are recommended to reduce direct contact of raindrops with the soil.

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Research article

Event-Based Rainfall-Runoff Forecasting in Pampanga River Basin, Philippines using Artificial Neural Networks (ANN)

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Abstract This study developed a series of rainfall-runoff forecasting models that can be used in the designing of flood warning system around Pampanga River Basin. The data regarding rainfall and water level of the river was obtained from the Hydrometeorological Division (HMD) of Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). Data were collected from 2014 and 2015 hourly water level reading and rainfall reading. Feedforward Backpropagation Model, a variant of the Artificial Neural Network (ANN), was used in the study and Gradient Descent with Adaptive Learning Rate Algorithm was used as a learning technique for the network. MATLAB R2009b was used to train and design the networks. A total of 45 networks were trained. Results of the training gave reasonable predictions for most of the stations with a minimum accuracy of 96%. Result inaccuracy of training in some stations were attributed to the inconsistency in the data and other factors.

Keywords Artificial Neural Networks, river basin, event-based forecasting, Feedforward Backpropagation, rainfall-runoff model

INTRODUCTION

Flooding has been one of the most destructive phenomena in the Philippines. Flood causes loss of lives, damage to personal assets and real properties, and adverse economic, environment and agricultural impacts (Chen and Graham, 2005). In 2014, it was reported that 153 out of 324 natural disasters that occurred in the country were hydrological disasters (Guha-Sapir et al., 2015) and in the last decade, the country experienced frequent flooding due to continuous raining and typhoons brought about by its archipelagic characteristic.

In Central Luzon, Philippines, one of the regions that have been affected by recent disastrous events including Typhoon Nona (*Typhoon Melor*) and Lando (*Typhoon Koppu*), there situates the second largest river in Luzon Island, the Pampanga River. It traverses the provinces of Pampanga, Nueva Ecija, Tarlac and Bulacan. Pampanga-Agno river basin serves as the catch basin for Tarlac, Nueva Ecija, Pampanga and Bulacan provinces. Severe flooding of this river can swallow the whole province of Pampanga and the neighboring provinces of the region. Pampanga River Basin is continuously being monitored by Philippine Atmospheric Geophysical, Astronomical Services Administration (PAGASA) since it is one of the major land reservoir that affects the region.

The use of conventional deterministic models in this case requires extensive data and costs since it considers various physical factors that are not only tedious to collect but also are complex in nature. Hence, the use of Artificial Neural Networks (ANN) attracted many researchers because of its simple yet powerful architecture to deal with complex nature of problems without sacrificing the results. The black-box nature of this model needs no requirement to fully understand the system in the aggregate (Brath and Toth, 2002). The model, given sufficient data, can be used as a reliable forecasting tool especially in forecasting the flood in Pampanga River Basin.

The use of ANN models as a rainfall-runoff model proves to produce qualitative forecasts (Lekkas et al., 2005); and the rainfall level and actual stream flow (water level) can be actually used as parameters for the development of the model (Elsafi, 2014). This study focuses on the application of ANN as a rainfall-runoff model in Pampanga River Basin with rainfall level and streamflow level (water level) as its parameters.

OBJECTIVE

The objective of this research is to forecast the flooding of the Pampanga River basin. This will help develop a warning signal that will inform the residents living near the area ahead when to evacuate. In this way, a network will be to determine the network that will give the reasonable relationship between the water levels and rainfall in Pampanga River Basin specifically on how the rainfall level can forecast stream flow (water level) downstream.

METHODOLOGY

Study Site

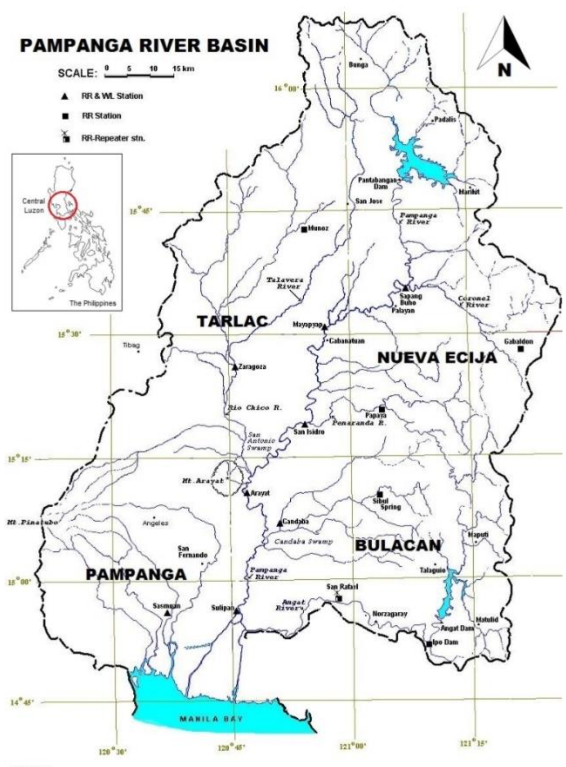

Fig. 1 Hydrological map of Pampanga river basin, Philippines

The Pampanga River Basin (Fig. 1), the 4th largest basin in the Philippines, has an aggregate area of 10,434 km^2. About ninety five percent (95%) of the basin transcends the bounds of four provinces, namely Nueva Ecija, Tarlac, Pampanga and Bulacan. The remaining five percent is part of provinces including Aurora, Zambales, Rizal, Quezon, Pangasinan, Bataan and Nueva Vizcaya.

Data Preparation

Rainfall and water level data of the Pampanga River Basin for the years 2014 and 2015 were gathered from the Hydrometeorological Division (HMD) in Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). An hourly data from January 2014 to October 2015 of the water level and rainfall reading was provided by the office. Since this study focuses on event-based modelling, cumulative 24-hour rainfall level of the wet season of Philippines including June 2014 – Dec 2014 and from June 2015 – October 2015 were considered.

In the data given, there were seventeen rainfall reading stations, but only thirteen stations were considered since the data from other stations have problems in it including incomplete or erroneous data and the rainfall data from these stations will serve as input data for the model. Nevertheless, for the water level reading stations, there are ten of them but only nine stations were considered. These nine stations will represent the nine sets of models which will serve as basis for the clustering of the data set. Data from these nine stations will represent the output/target data for the model. The input data is, then, normalized using the normalization formula intrinsic in the use of the MATLAB Neural Network Toolbox given in Eq. (1).

$$p' = 2\frac{p - \min(p)}{\max(p) - \min(p)} - 1 \tag{1}$$

In Eq. (1), *p* represents the original data before normalization, *p'* represents the normalized data and; min(*p)* and max(*p)* represents the minimum and the maximum data in the set, respectively. The data was split into two computational components: the training set and the validation set which will be used as calibration for the model developed. Using MATLAB Neural Network Toolbox, the input data can be randomly classified into seventy percent (70%) for the training set and the thirty percent (30%) for the validation set.

Model Development and Implementation

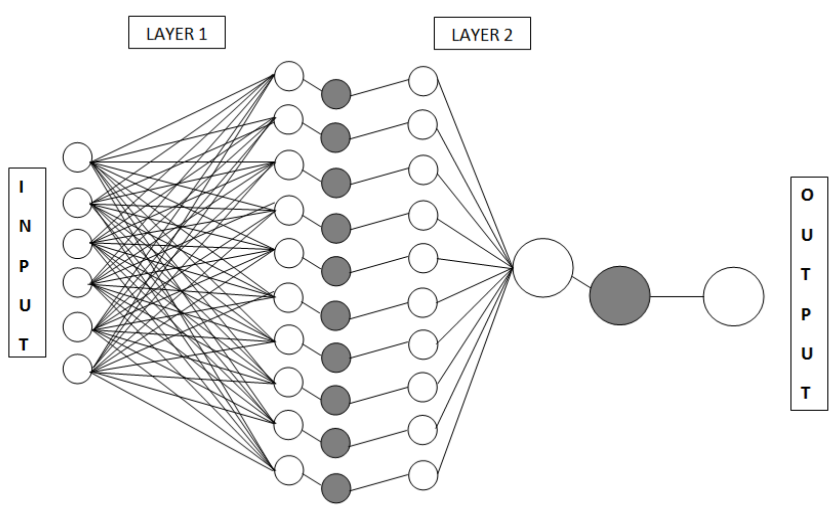

Fig. 2 Network visualization of the architecture of ANN

ANN's are designed to mimic the behavior of a neuron inside a human brain while it sends information (Sarkar and Kumar, 2012; Gershenson, 2003; Zhang and Govindaru, 2000; Chakraborty et al., 1992). It requires inputs (like neuron synapses) which are multiplied by numerical weights (strength of respective signals), and mathematical functions that determine the activation of the neuron. In the end, a function computes for the total output of an artificial neuron. In this study, a *Feedforward Backpropagation* ANN Model was used with fixed network structure consisting of two hidden layers and ten nodes each as shown in Fig. 2.

A hyperbolic tangent sigmoid (*tansig*) function is used in the problem for all the transfer (or activation) functions in the model. The *tansig* function is given by Eq. (2).

$$\text{tansig}(n) = \frac{2}{1+e^{-2n}} - 1 \tag{2}$$

Before the training process starts, several parameters were set. These values will be used in the process and is important to achieve the best possible model using the Mean Square Error (MSE) criterion. Parameters (Table 1) are set accordingly before training the model.

Table 1 Values of the model parameters before the model training

Parameters	Values assigned
Maximum number of epochs to train	1000.00
Maximum validation failures	1000.00
Initial learning rate	0.01
Learning rate increase factor	1.05
Learning rate decrease factor	0.70
Maximum performance increase	1.04
Momentum	0.90
Minimum performance gradient	10^{-10}
Epochs between displays	25.00

Values shown were the pre-set of MATLAB Neural Network Toolbox.

RESULTS AND DISCUSSION

Network Model Assessment

Forty-five (45) models using the set architecture of ten neurons in the first later and a single node in the last layer for the output were developed after the training process. For each area cluster, there are five models that were developed – each forecasting from three hours water level advance up to seven hours water level advance. In general, most of the models showed good fit in its regression analysis in terms of their forecasting capability and validity. Using the Mean Square Error (MSE) criterion, it measured the average squares of errors or deviation from the predicted water level data to the actual recorded water level data and the Pearson Correlation (R) that defines the strength of linear fit for the ANN trained.

The other four to seven-hour models follow the same behavior as the initial three-hour model for each area cluster. The average square of deviation of all the model combined ranges from 0.0007 to 0.7624 which is relatively low compared to the actual predicted data. Most of the models showed very strong linear relationship (R between values 0.8 to 1) for the predicted data except for the set of Sasmuan area cluster with weak linear relationship (R between values 0.4 to 0.6).

Table 2 MSE and R of the three-hour model for each of the nine (9) area clusters

Clustered Station	Mean Square Error (MSE)	Pearson Correlation (R)
Arayat	0.5832	0.9916
Candaba	0.0060	0.9991
Mexico	0.0019	0.9922
Penaranda	0.0090	0.9962
San Isidro	0.0295	0.9979
Sapang Buho	0.0473	0.9926
Sasmuan	0.0246	0.5448
Sulipan	0.2000	0.9889
Zaragoza	0.0135	0.9948

Data Plots

The actual plot of area model with the highest value of R (three-hour model in Candaba station) shows a clear visual captivity of behavior of the actual recorded water level versus the predicted data in Candaba station of water level as shown in Fig. 3.

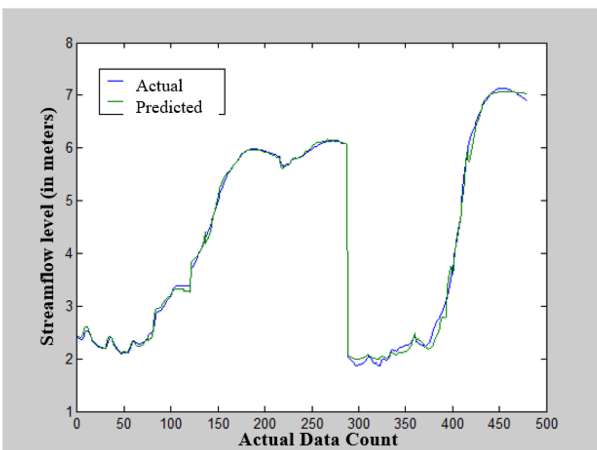

Fig. 3 Plot of target data vs predicted data for three-hour ahead forecasting in Candaba station

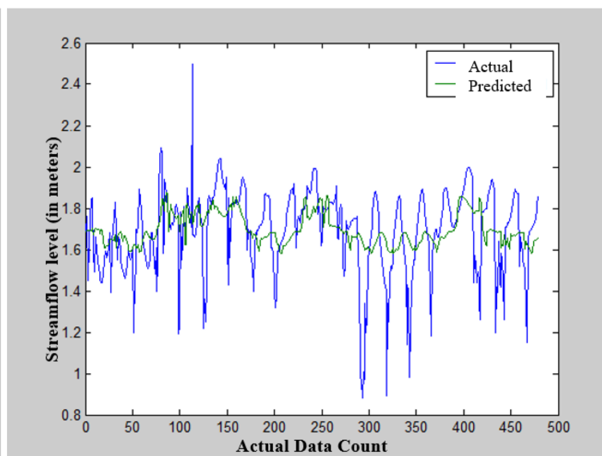

Fig. 4 Plot of target data vs predicted data for five-hour ahead forecasting in Sasmuan station

On the contrary, the model with the lowest value of R (five-hour model in Sasmuan station) showed weak captivity of behavior of the actual water level data (Fig.4). The model cannot linearly capture the trend of the actual data and the actual data shows periodic up and down of plot. This may be attributed to the nonlinear relationship of the rainfall and water level in the area and to the other physical phenomena or factors not considered in this study.

CONCLUSION

The application of Artificial Neural Networks (ANN) to the hydrology in Philippine setting has been explored by creating forty-five (45) forecasting models under nine (9) area clusters in Pampanga river basin. The training of the model resulted in good-fitted models except for the case of the Sasmuan station. Inaccuracy of the model in Sasmuan station may be attributed to the other factors not considered in this study and hence can be further investigated and studied so that the model can be recalibrated. Furthermore, the use of ANN is not governed by theoretical rules nor any rule-of-thumb suggestions that will result in a global optimal model. This side of the ANN can be further explored in its application to hydrology. In addition to this, ANN is a data-dependent method and reasonable amount of data must be used in order to build a much reliable network model.

ACKNOWLEDGEMENTS

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Research article

The Effects of Land Restoration on Soil Fertility in Tsunami-inundated Farmlands of Miyagi Prefecture in Japan

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Abstract In previous studies, a series of samples were analyzed to measure the salinity status of agricultural lands in Miyagi prefecture, where the extent of the seawater damage was the most severe among the tsunami-affected area in Northeast Japan following the Great East Japan earthquake in 2011**.** Since then, various restoration projects have been implemented according to a massive plan introduced by concerned agencies of the central and local governments. In the agricultural lands damaged by the earthquake and flooded with tsunami water, most of the technical tasks, such as the removal of debris and salts and the repair of irrigation and drainage infrastructures, were in the final stages of completion in 2016, and the efforts seems to have achieved their primary objectives. However, soil productivity in the restored farmlands remains a big issue for the local farmers. The present study was carried out in different farmlands in two adjacent towns in Miyagi Prefecture, Watari-cho and Yamamoto-cho. The major physicochemical and biological properties of soil were investigated, and the results show that the soil dressing used as topsoil in the restored farmlands had a low average cation exchange capacity (CEC) of <6 cmol(+)kg^{-1}, which ultimately contributed to lower average CEC values overall (<9 cmol(+)kg^{-1}). Moreover, carbon-to-nitrogen (C:N) ratios in the soil dressings and the restored lands showed a wider range (5 to 19), making the soil inconsistent in nutrient supply i.e., less fertile, compared to those in the farmlands where there was no top-dressing and in the farmlands at nearby inland sites. The study also suggests that issues concerned with rebuilding soil fertility and improving soil productivity in tsunami-inundated agricultural lands should be resolved through sustainable, soil-friendly methods and practices.

Keywords tsunami, farmland, soil salinity, soil fertility, soil dressing, land restoration

INTRODUCTION

The Great East Japan earthquake and tsunami disaster of 2011 caused massive damages to the coastal area. The earthquake damaged irrigation and drainage infrastructures severely, while the tsunami waves inundated large areas of agricultural land, causing excessive saline in the soil. A lot of restoration efforts and studies have been carried out in the disaster-affected areas to measure salinity levels as well as the effectiveness of remedial measures. Most notably, the central government of Japan announced a comprehensive recovery plan in the devastated area (Government of Japan, 2012), and accordingly, all concerned ministries, agencies, prefecture administrations, and non-governmental organizations (NGOs) started restoration projects in different sectors. In agricultural lands, salinity was a very big issue soon after the tsunami, especially in Miyagi prefecture, as this region accounted for nearly two-thirds of the tsunami-inundated agricultural lands (23,600ha) in northeast Japan (MAFF, 2011). The different stages and the order of execution related to the restoration, remedial, and reclamation works in agricultural lands consisted of mostly removing debris, puddling and leaching with freshwater and flushing away salts from the topsoil, and cutting away the top layer and dressing it with new soil carried from a nearby mountain area along with the rejuvenation of irrigation/drainage infrastructures. Roy et al. (2014, 2015) monitored the spatiotemporal changes in soil salinity in the tsunami-inundated agricultural lands in Miyagi prefecture from 2013 to 2015 and concluded that the salinity varied because of several physical factors, such as topography, soil texture, and water stagnation due to damage to drainage infrastructure. Research studies carried out by Tomomasa et al. (2013) and Toyama and Tajima (2014) specified the damage to underground infrastructures (i.e., buried drainage pipes) as an important factor responsible for water-logging, poor infiltration, and high salinity. As the restoration works progressed and reached the final stages of completion in 2016, salinity levels in most areas had returned to pre-tsunami levels (electrical conductivity<1 dS m^{-1}). In addition, the area had enough precipitation (approximately 1,200mm/year) to help to mitigate the salinity level even in non-restored lands (NARO, 2013; Roy et al., 2015). However, when crops were cultivated, farmers started to face new problems related to soil productivity in the restored lands.

Soil productivity refers to the capacity of the soil in its normal environment to support plant growth, while soil fertility refers to the ability of the soil to provide nutrients in proper quantities for the growth of plants (Gruhn et al., 2000). Therefore, to better understand the potential productivity of soil in the restored area, it is important to examine key soil characteristics and indicators—such as soil texture, depth, pH, organic matter content, and fertility—that might be affected through human activities, such as the use of a soil dressing in restoration works, or by natural processes, such as the accumulation of salt due to seawater intrusion. A report published by the Miyagi Prefecture Furukawa Agriculture Resaerch Station (2013) showed that the parts of restored paddy fields with a soil dressing had a reduced average production (361 kg/10a) compared to that of non-restored lands (563 kg/10a). During prior field surveys from 2013 to 2015, restoration works and farming activities were observed, and local farmers were interviewed at random about these issues. It is not difficult to understand that, in the case of any sudden replacement of the topsoil with a new soil (soil dressing), the fertility of the new soil is a big factor that ultimately affects soil productivity. No reports were published to date indicating that any prior investigations or analyses were completed regarding the fertility status of the new soil used as the soil dressing in the restored lands in the studied area. This promted further study to determine the existing soil productivity in terms of the soil fertility in the area. In particular, field samples were collected from different farmlands in two adjacent towns, Watari-cho and Yamamoto-cho, in Miyagi prefecture, where samples were also collected from 2012 to 2014. Soil samples were collected from restored farmlands with topsoil dressing (“dressed land”); farmlands with no soil dressing (“undressed land”); new/mountain soil used in topsoil dressing (“soil dressing”); and inland farmlands (“inland”) and analyzed for soil fertility.

The aim of this study is to determine the soil fertility in tsunami-inundated farmlands in Miyagi prefecture, where restoration works have already been completed, as well as to investigate sustainable, soil-friendly methods for agricultural lands where salinity and soil recovery are big issues.

METHODOLOGY

Study Sites and Methods of Sampling

Two adjacent towns, Watari-cho and Yamamoto-cho, both of which accounted for the largest inundated areas in Miyagi prefecture, were selected as study areas for sampling, although the post-disaster statuses and recovery plans were different in these two sites (Watari-cho, 2015; Yamamoto - cho, 2015). Field samples were collected and interview surveys were conducted five times from

December 2014 to December 2015. Fig. 1 presents the sampling sites and sampling points (farmlands) in the study area. The location of each sampling point were traced by a portable GPS receiver (Garmin eTrex). It is notable that, in some cases, the land use of the surveyed farmlands (paddy fields/uplands) as shown in Table 1, differed before and after the tsunami. The sampling points of dressed and undressed lands were randomly selected based on the information gathered during interviews with the local farmers. Samples of soil dressing were collected with permission from construction workers at the study sites. In addition, soil samples were collected from inland farmlands within a distance of 1 km from the inundated zone (sampling point) to represent the pre-tsunami soil characteristics of the inundated farmlands. A total of 48 samples were collected from different farmlands in the two sampling sites: 17 from dressed lands (paddy fields:14, upland:3), 13 from undressed lands (paddy fields:4, upland:9), 6 from soil dressing, and 12 from inlands (paddy fields:6, upland:6). All soil samples were collected from the top layer of disturbed soil (upto a depth of 10 cm) by a diagonal sampling method, packed in polyethylene sacks, and brought back to the laboratory for analysis. Other related data about land use (paddy, upland, or mountain), land condition (dressed or undressed lands), plant growth, fertilizer uses, and yields were recorded during interviews with farmers.

A visual outlook of two adjacent farmlands, one a restored land with soil dressing and the other with no soil dressing, as presented in Fig. 2, points a clear difference in growth between the two farmlands.

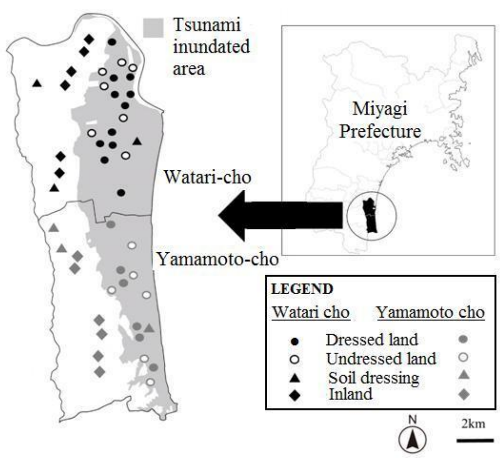


Fig. 1 Study sites with sampling locations Miyagi Prefecture, Japan

(Picture taken on June 22, 2015)

Fig. 2 Plant growth in two adjacent paddy fields in at Yamamoto-cho in Miyagi Prefecture

Analysis of Soil Samples

All of the soil samples were processed and analyzed in the laboratories of the College of Bioresource Sciences at Nihon University. The collected soil samples were air-dried and sieved through a 2 mm mesh, and then select parameters representing key indicators related to soil quality and productivity were measured. The parameters selected to represent the chemical properties were pH, electrical conductivity (EC), cation exchange capacity (CEC), and exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, Na^+). The pH (H_2O) and the EC of the soil were measured with a pH meter (Twin pH B-212, Horiba, Japan) and an EC meter (B-173, Horiba, Japan), respectively. The ratio of soil to deionized water was 1:2.5 for pH, and 1:5 for EC. The CEC, estimated from soil cations (Ca^{2+}, Mg^{2+}, K^+, Na^+), was determined by ammonium acetate method (soil extracted in 1 mol L^{-1} ammonium acetate (NH_4OAc) at a pH 7) and measured with an atomic absorption spectrophotometer (AA-6680, Shimadzu, Japan). The concentrations of exchangeable cations, as well as the total exchangeable bases, were then expressed in terms of centi-mol per kg (cmol(+)kg^{-1}). Moreover, basic cation ratios—e.g., calcium-to-magnesium ratio (Ca:Mg), magnesium-to-potassium ratio (Mg:K)—and the percent base saturation were also calculated from the amounts of exchangeable cations analyzed. On the other hand, the selected physical properties were mainly particle size distribution and soil texture. In addition, gravel content (weight percentage) was also determined since the local farmers were worried about an excess of gravel in the soil dressing. The particle size distribution of the soil was measured using with the pipette method based on Stoke's theorem, and the soil textural classes were determined according to the IUSS (International Union of Soil Sciences) method. Gravel contents were calculated based on the remnants after sieving the air-dried soil through a 2 mm mesh. For biological properties, total carbon (TC), total nitrogen (TN), carbon-to-nitrogen (C:N) ratio, and organic matter content (OMC) were measured. The C:N ratio, TC, and TN of the soil were determined using an NC analyzer (Sumigraph NC-220F, Sumika Chemical Analysis, Japan), while the OMC of the soil was estimated using with the loss-on-ignition method and a muffle furnace (KBF-748, Koyo Thermos, Japan). All measured and calculated data regarding soil properties are listed in Table 1.

Statistical Analyses

Descriptive statistics, correlation analyses, and one-way analyses of variance (ANOVA) among the physicochemical and biological parameters in this study were executed using a Microsoft Office Excel 2013 add-in application.

RESULTS AND DISCUSSION

Chemical Properties of Soil

As presented in Table 1, the average soil CEC values in dressed lands were 8.7 cmol(+)kg^{-1} and 7.8 cmol(+)kg^{-1} in Watari-cho and Yamamoto-cho, respectively, whereas those values in undressed lands were 17.5 cmol(+)kg^{-1} and 14.9 cmol(+)kg^{-1}, respectively. The inland soil at these two sites had similar average CEC values at 18.4 cmol(+)kg^{-1} in Watari-cho and 16.7 cmol(+)kg^{-1} in Yamamoto-cho. However, average CEC values were much lower for soil dressings at these two sites—5.9 cmol(+)kg^{-1} and 5.5 cmol(+)kg^{-1} in Watari-cho and Yamamoto-cho, respectively. Soil from several dressed lands at both sites (sample numbers 14 to 18 and 34 to 36 in Table 1) showed comparatively lower pH values (4.5 to 5.6) and percent base saturation (17% to 55.4%). However, $EC_{1:5}$ values in the respective lands were comparatively higher than in other farmlands. Although CEC and percent base saturation are essential indicators of soil fertility, the overall balance in exchangeable ions that can be estimated from the nutrient ratios is more important for the nutrient supply to the plants. Fig. 3 and Fig. 4 present the basic cation ratios (Ca:Mg, Mg:K) in the studied farmlands. The suitable values as recommended by MAFF (2007) are 2 to 6 for Ca:Mg and 2 to 4 for Mg:K. The nutrient ratios from different farmlands, as presented in Table 1 and graphed in Fig. 2 and Fig.3, indicate that, while most of the farmlands' soils were within the MAFF-recommended limits, some soil samples collected from the dressed lands (sample 8 and 13 through 18 for Watari-cho, and samples 35, 36, and 39 for Yamamoto-cho in Table 1) had either higher or lower values than the recommended ranges. Such a situation indicates an imbalance in nutrition supply in the dressed lands at both Watari-cho and Yamamoto-cho.

Physical Properties of Soil

As presented in Table 1, most of the soil samples (42 out of 48 samples), including each type of lands in both of the studied areas, were sandy (sandy loam (SL), sand (S), or loamy sand (LS)). The textural class of 31 soil samples (of 48) was sandy loam (SL), according to the IUSS classification system. Therefore, the texture of the soil in the study area was generally sandy by nature, regardless of

Table 1 Surveyed and analyzed data of soil samples collected from farmlands located in Watari-cho and Yamamoto-cho in Miyagi Prefecture

Study site	Sample	Land condition	Land use	Location		Elevation	pH	$EC_{1:5}$	CEC	Exchangeable bases (cmol(+)kg⁻¹)			Base saturation	TC	TN	C:N ratio	Soil texture	Particle size distribution (%)			Gravel content
				Latitude	Longitude	(m)	(H_2O)	(dSm^{-1})	($cmol(+)kg^{-1}$)	CaO	MgO	K_2O	(%)	(%)	(%)			Sand	Silt	Clay	(%)
	1	Undressed	Paddy	38°04'06.8"N	140°54'08.6"E	0.3	6.5	0.08	16.94	9.59	3.50	1.68	87.22	1.69	0.15	11.32	SL	66.3	25.0	8.7	2.5
	2	Undressed	Upland	38°04'15.9"N	140°54'01.9"E	1	6.8	0.11	23.11	10.85	3.51	1.74	69.69	2.68	0.22	12.16	CL	57.4	22.1	20.5	2.2
	3	Undressed	Upland	38°02'23.8"N	140°54'01.1"E	1.5	7.4	0.07	17.60	10.54	2.50	1.10	80.37	2.38	0.23	10.48	SL	81.7	11.9	8.4	2.0
	4	Undressed	Upland	38°01'44.4"N	140°52'57.9"E	1.2	6.6	0.09	13.53	8.16	2.28	0.74	82.57	1.09	0.10	11.42	LS	87.0	6.5	6.5	3.4
	5	Undressed	Upland	38°01'13.1"N	140°53'48.6"E	0.3	6.8	0.09	12.40	7.35	2.49	0.69	84.90	1.25	0.12	10.49	SL	76.2	16.2	7.6	2.9
	6	Undressed	Paddy	38°03'53.3"N	140°53'09.7"E	1	6.0	0.12	17.80	6.44	3.12	0.97	59.15	2.00	0.16	12.52	SL	73.1	18.8	8.0	2.4
	7	Undressed	Upland	38°03'36.6"N	140°53'11.1"E	0.7	6.1	0.13	21.42	7.46	3.52	1.11	56.42	1.76	0.16	10.99	CL	47.0	37.0	16.0	3.1
	8	Dressed	Upland	38°04'33.9"N	140°53'31.7"E	1	7.9	0.11	8.33	7.10	1.75	0.30	109.91	0.79	0.05	15.17	SL	73.9	20.0	6.1	4.6
	9	Dressed	Paddy	38°03'44.4"N	140°54'06.2"E	-0.1	6.8	0.11	7.30	3.78	1.37	0.37	75.59	0.58	0.05	11.84	LS	87.7	7.2	5.1	7.4
	10	Dressed	Paddy	38°03'43.1"N	140°53'38.1"E	-0.1	6.8	0.11	8.31	4.25	1.77	1.23	87.25	0.95	0.08	12.01	LS	88.2	6.7	5.1	5.2
	11	Dressed	Paddy	38°03'21.6"N	140°53'40.6"E	-0.3	7.2	0.12	7.32	4.49	1.11	0.37	81.58	0.92	0.07	13.53	LS	90.5	3.1	6.4	7.7
	12	Dressed	Paddy	38°03'21.7"N	140°54'07.4"E	-0.1	6.8	0.09	9.41	3.76	1.80	1.24	72.35	1.01	0.09	11.21	SL	82.6	13.7	3.7	9.7
Watari-cho	13	Dressed	Paddy	38°02'59.1"N	140°54'00.1"E	-0.3	6.6	0.13	9.38	4.42	2.04	0.34	72.47	1.04	0.09	11.95	SL	80.8	11.2	8.0	11.3
	14	Dressed	Paddy	38°01'47.0"N	140°53'20.2"E	-0.3	5.3	0.47	10.60	1.27	0.89	0.10	21.33	1.49	0.10	14.91	SL	79.4	15.5	5.2	9.0
	15	Dressed	Paddy	38°01'29.1"N	140°53'17.5"E	-0.3	5.5	0.46	10.50	0.97	0.75	0.08	17.02	1.50	0.09	17.45	SL	82.1	11.3	6.6	6.7
	16	Dressed	Paddy	38°01'30.1"N	140°53'04.5"E	-0.2	5.6	0.46	9.71	1.43	1.05	0.16	27.21	1.47	0.09	16.16	SL	82.9	9.6	7.5	9.3
	17	Dressed	Paddy	38°01'05.2"N	140°53'04.4"E	-0.1	4.5	0.59	7.16	0.52	0.53	0.07	15.67	1.57	0.09	18.42	S	89.2	6.1	4.6	9.0
	18	Dressed	Paddy	38°00'15.0"N	140°53'41.4"E	0.6	5.3	0.40	7.31	1.18	1.17	0.18	34.53	1.22	0.07	17.36	LS	86.3	5.8	7.9	5.8
	19	Soil dressing	Mountain	38°03'23.1"N	140°50'34.3"E	26.9	6.8	0.05	4.14	2.48	0.78	0.23	84.42	0.34	0.09	10.63	SL	77.3	16.9	5.8	14.1
	20	Soil dressing	Mountain	38°01'32.8"N	140°54'09.7"E	-0.1	6.0	0.06	8.35	2.74	2.03	0.56	63.96	0.95	0.11	5.67	SL	74.3	21.0	4.7	16.9
	21	Soil dressing	Mountain	38°00'06.0"N	140°51'01.5"E	44.7	6.0	0.06	5.24	1.22	0.73	0.19	40.80	0.53	0.10	6.40	S	89.2	9.2	1.5	12.7
	22	Inland	Paddy	38°04'56.5"N	140°52'41.8"E	2.3	6.2	0.10	23.31	12.74	3.88	1.07	75.85	2.82	0.28	10.07	L	58.2	26.9	14.9	2.1
	23	Inland	Upland	38°04'39.2"N	140°52'44.4"E	3.8	6.3	0.09	19.13	7.87	3.43	0.98	64.18	2.42	0.23	10.67	L	54.7	31.6	13.6	2.0
	24	Inland	Paddy	38°03'23.7"N	140°51'36.3"E	3	6.2	0.12	16.76	9.52	2.93	0.85	79.35	2.70	0.22	12.29	SL	68.1	22.8	9.0	1.5
	25	Inland	Upland	38°03'30.5"N	140°51'07.2"E	1.9	6.4	0.13	21.42	10.54	4.05	1.11	73.30	2.31	0.19	12.15	CL	47.0	37.0	16.0	1.4
	26	Inland	Paddy	38°01'25.0"N	140°51'43.6"E	3.6	6.3	0.07	15.54	6.88	3.06	0.99	70.32	2.42	0.15	15.80	L	60.1	31.0	8.9	1.9
	27	Inland	Upland	38°01'04.8"N	140°51'29.5"E	2.3	6.7	0.08	14.52	7.24	3.01	0.96	77.25	1.51	0.12	12.20	SL	79.6	15.2	7.2	1.8
	28	Undressed	Upland	37°58'34.5"N	140°54'08.7"E	1.2	6.4	0.10	12.38	6.10	1.88	0.54	68.72	1.36	0.10	14.31	SL	82.4	10.4	7.2	6.4
	29	Undressed	Upland	37°57'31.0"N	140°54'19.6"E	1.3	6.8	0.11	13.42	7.86	2.39	0.77	82.07	1.41	0.12	11.72	SL	82.3	9.4	8.3	3.6
	30	Undressed	Paddy	37°57'40.1"N	140°53'51.5"E	1.4	5.9	0.13	15.57	4.99	3.07	0.97	58.01	1.89	0.17	11.34	SL	78.1	14.2	7.7	5.6
	31	Undressed	Paddy	37°57'25.2"N	140°53'23.2"E	2.4	7.4	0.14	14.43	10.27	2.26	0.93	93.25	1.79	0.18	10.04	SL	84.5	8.3	7.2	5.9
	32	Undressed	Upland	37°55'22.6"N	140°54'32.2"E	1.9	7.2	0.17	12.40	9.57	2.59	1.03	106.50	1.73	0.11	15.74	SL	75.2	17.6	7.2	4.2
	33	Undressed	Upland	37°54'44.0"N	140°54'48.9"E	7.6	7.0	0.14	21.17	12.47	3.75	1.67	84.49	2.75	0.19	14.19	SL	58.3	26.7	15.0	6.3
	34	Dressed	Upland	37°59'24.3"N	140°53'14.6"E	1.3	6.2	0.32	7.30	2.64	1.82	0.66	70.18	0.97	0.09	10.63	LS	85.3	8.8	5.9	13.2
	35	Dressed	Paddy	37°57'48.6"N	140°53'40.6"E	1.3	5.2	0.49	6.21	0.89	0.72	1.12	43.99	0.63	0.11	5.67	S	89.5	7.3	3.1	20.2
	36	Dressed	Paddy	37°57'39.6"N	140°53'48.5"E	1.3	5.4	0.48	8.29	1.87	1.23	1.51	55.49	0.61	0.10	6.40	S	90.3	5.6	4.2	21.1
	37	Dressed	Upland	37°56'18.7"N	140°54'30.6"E	1.4	7.1	0.10	7.32	5.09	1.55	0.46	97.09	0.65	0.06	10.88	SL	78.5	16.8	4.7	16.8
Yamamoto-cho	38	Dressed	Paddy	37°56'01.3"N	140°54'30.5"E	1.1	6.8	0.13	7.31	3.39	1.02	0.41	65.97	0.79	0.06	12.33	SL	77.3	16.9	5.8	16.4
	39	Dressed	Paddy	37°55'18.3"N	140°54'47.2"E	0.9	6.4	0.16	10.41	3.26	1.36	1.97	63.32	0.94	0.06	15.23	SL	82.4	10.5	7.1	16.2
	40	Soil dressing	Mountain	37°59'01.4"N	140°51'21.4"E	52.3	7.4	0.03	4.02	2.77	0.62	0.25	90.66	0.43	0.03	14.90	S	88.5	8.5	3.0	16.7
	41	Soil dressing	Mountain	37°56'12.6"N	140°54'41.5"E	1.6	7.3	0.04	6.25	4.49	1.06	0.31	93.78	0.44	0.05	9.59	SL	84.6	12.7	2.6	19.9
	42	Soil dressing	Mountain	37°58'22.8"N	140°52'04.0"E	27.7	7.3	0.04	6.22	4.35	1.16	0.35	94.20	0.51	0.07	7.75	SL	85.3	10.3	4.4	25.8
	43	Inland	Paddy	37°58'14.8"N	140°52'14.2"E	11.9	6.9	0.04	16.69	8.44	2.59	1.10	72.69	1.55	0.15	10.12	SL	65.7	22.1	12.2	3.4
	44	Inland	Upland	37°58'08.2"N	140°52'05.6"E	17.3	6.4	0.02	16.76	8.41	3.50	1.02	77.13	1.60	0.15	10.82	SL	67.7	22.6	9.7	1.9
	45	Inland	Paddy	37°56'07.7"N	140°52'47.5"E	19.4	6.5	0.03	23.13	9.62	3.39	1.10	61.03	2.52	0.24	10.72	SL	68.2	18.3	13.5	1.3
	46	Inland	Upland	37°56'09.8"N	140°52'55.2"E	16.6	6.6	0.02	17.70	9.52	3.57	1.11	80.18	2.10	0.18	11.86	SL	77.8	14.5	8.7	1.6
	47	Inland	Paddy	37°55'07.0"N	140°53'08.9"E	13.6	6.5	0.04	13.60	6.82	2.87	1.14	79.62	2.02	0.19	10.82	SL	75.2	17.4	7.4	1.9
	48	Inland	Upland	37°55'10.6"N	140°53'04.0"E	14.4	6.5	0.04	12.52	6.58	2.75	1.02	82.76	1.85	0.18	10.22	SL	65.7	24.3	10.0	1.8

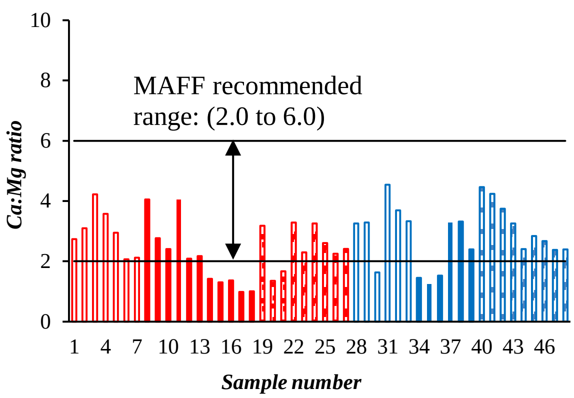
the presence or absence of top dressing. However, the average particle size distribution showed a tendency toward fewer fine fractions (silt and clay) in dressed lands than that in undressed and inland lands because of the abundant gravel contents in the soil dressing—averages of 14.6% and 20.8% in Watari-cho and Yamamoto-cho, respectively (Fig. 5).

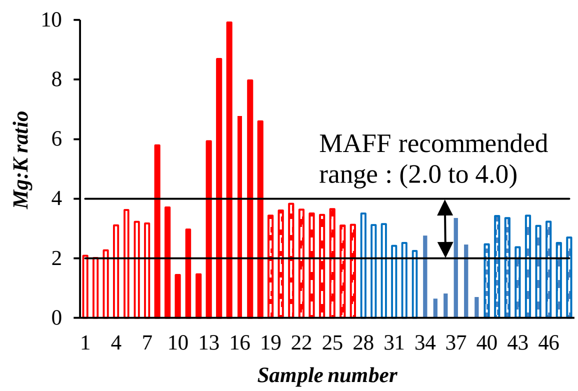
Biological Properties of Soil

Fig. 6 presents the total C:N ratio of soil, a determinant of organic matter content and an important indicator for plants' nutrient availability, at different farmlands in the studied sites. Dividing the C:N ratios into four groups (Fig. 6) shows that most of the soil samples were within the range of $10<C:N<20$. The C:N ratio in most agriculture soils remains more or less constant; Cleveland (2007) found a global tendency for the C:N ratio of overall soil to be 14.3 ± 0.5. A soil with a C:N ratio greater than 20 indicates N-deficiency because of microbial growth (JSSSPN, 1998). Although none of the soil samples in this study had poor C:N values, however, the individual C:N values from the soil dressing and the dressed lands were highly irregular and scattered across a wider range (5.7 to 18.4) compared to those in the undressed (10.5 to 15.7) and inland soils (10.1 to 15.8). Moreover, the TC and TN values were also lower in soil dressings and dressed lands than that in undressed and inland soils. The average values for organic matter content (ignition loss) in the samples of the field soils (dressed, undressed and inland) ranged within 3.9% to 4.9%, whether the same in the soil dressings showed lower values of 2% and 2.1% in the two study sites.

Soil Properties and Their Correlations

Table 2 presents the correlations between the measured properties of the soil samples collected from different farmlands in Miyagi prefecture. The correlation matrix also includes the grain-yield factor as recorded during interviews with farmers at 15 paddy fields with different land conditions. From the table, the grain yield was found to have strongly correlated (positively and negatively) with soil CEC ($r=0.794$), clay content ($r=0.813$), and gravel content ($r=-0.87$). Moreover, significant correlations existed between the pH and the base saturation ($r=0.889$) and EC ($r=-0.743$); between the $EC_{1:5}$ and the base saturation ($r=0.739$); and between the CEC and the TN($r=0.884$), clay ($r=0.882$), and gravel contents ($r=-0.970$). Except for the C:N ratio, most of the measured parameters of the soil samples that represent the productivity and fertility of the agricultural lands were found to have significantly correlated to one another ($p<0.001$, $p<0.01$, or $p<0.05$), as presented in the correlation matrix table.





Notes: 1) MAFF: Ministry of Agriculture, Forestry and Fisheries, 2007
2) Sample number: 1 to 27 denote Watari-cho, 28 to 48 denote Yamamoto-cho
3) Land use and condition: As presented in Table 1

Fig. 3 Soil Ca:Mg ratios at different farmlands in Miyagi Prefecture

Fig. 4 Soil Mg:K ratios at different farmlands in Miyagi Prefecture

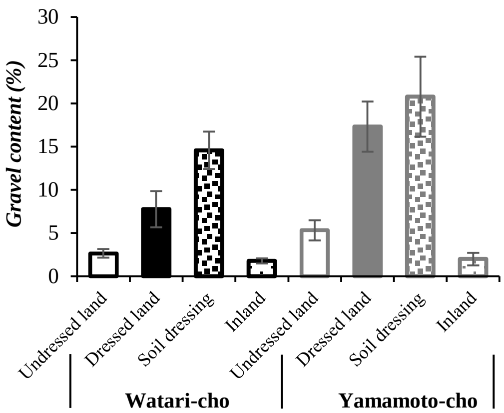


Fig. 5 Gravel contents in soils from different farmlands in Miyagi Prefecture

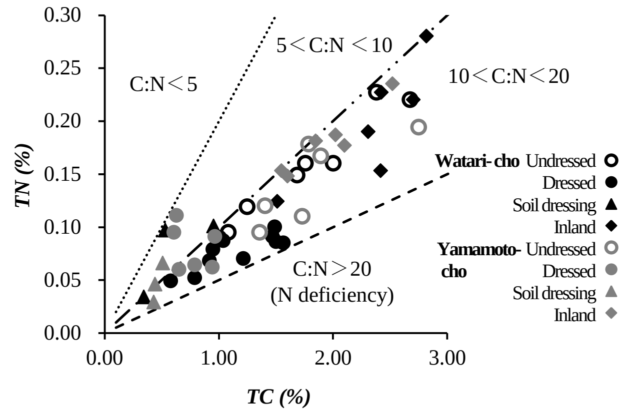


Fig. 6 Total C:N ratios of soils from different farmlands in Miyagi Prefecture

Status of Soil Fertility and Productivity in Restored Lands

While the data and analyses presented above give an idea of soil properties, Fig. 7 shows the yield at different farmlands in our study sites. As seen in the soil properties, the lands that were restored with soil dressing (dressed lands) are relatively imbalanced nutritionally and, therefore, less fertile compared to the undressed and inland fields, which ultimately negatively affects grain yields at paddy fields with soil dressing in both Watari-cho and Yamamoto-cho, as shown in Fig. 7. Although fertility does not always guarantee the productivity of soil, it (fertility) represents the productivity of agricultural lands. Data from Table 1 show that the soils' CEC and percent base saturation values were lower overall in dressed lands than in undressed lands, and the extent of variation widens when comparing the values from dressed lands with the inlands. The use of soil dressings with a low CEC (4.02 cmol(+)kg^{-1} to 8.35 cmol(+)kg^{-1}) in the restored lands can be said to be responsible for that. Because pH and base saturation are generally closely related to soil CEC (Turner and Clark, 1966; Huvlin et al., 2011), even a soil with a high CEC does not guarantee productivity if the pH is low. In the current study, comparatively lower pH values (4.5 to 5.3) and percent base saturations (15.67% to 55.49%) were observed in parts of the dressed lands at both study sites (5 lands out of 11 in Watari-cho, and 2 lands out of 6 in Yamamoto-cho), although the EC were comparatively higher (0.32 dS m^{-1} to 0.59 dS m^{-1}) in the respective areas. In such case, while soil pH needs to be rectified

Table 2 Correlation matrix between soil properties in Miyagi prefecture

	Grain yield (Paddy)	pH(H_2O)	$EC_{1:5}$	CEC	Exchangeable cations			Base saturation	TC	TN	C:N ratio	Sand	Silt	Clay	Silt+Clay	Gravel content
					CaO	MgO	K_2O									
Grain yield	1.0															
pH(H_2O)	0.275	1.0														
$EC_{1:5}$	-0.660 ***	-0.743 ***	1.0													
CEC	0.794 ***	0.037	-0.293 *	1.0												
CaO	0.790 ***	0.484 ***	-0.564 ***	0.837 ***	1.0											
MgO	0.853 ***	0.175	-0.484 ***	0.916 ***	0.868 ***	1.0										
K_2O	-0.157	0.116	-0.251	0.620 ***	0.576 ***	0.649 ***	1.0									
Base saturation	0.310 *	0.889 ***	-0.739 ***	0.077	0.560 ***	0.321 *	0.264	1.0								
TC	0.749 ***	-0.093	-0.125	0.902 ***	0.734 ***	0.806 ***	0.485 ***	-0.048	1.0							
TN	0.697 ***	-0.043	-0.257	0.884 ***	0.751 ***	0.817 ***	0.549 ***	0.042	0.904 ***	1.0						
C:N ratio	0.187	-0.113	0.325	0.011	-0.069	-0.102	-0.226	-0.235	0.201	-0.193	1.0					
Sand	-0.705 ***	-0.068	0.334 *	-0.792 ***	-0.659 ***	-0.797 ***	-0.450 **	-0.133	-0.704 ***	-0.693 ***	-0.002	1.0				
Silt	0.583 ***	0.079	-0.365 *	0.685 ***	0.580 ***	0.734 ***	0.382 **	0.165	0.606 ***	0.609 ***	-0.047	-0.970 ***	1.0			
Clay	0.813 ***	0.052	-0.217	0.882 ***	0.720 ***	0.791 ***	0.517 ***	0.050	0.789 ***	0.754 ***	0.102	-0.855 ***	0.707 ***	1.0		
Silt+Clay	0.706 ***	0.076	-0.340 *	0.801 ***	0.669 ***	0.805 ***	0.456 **	0.137	0.712 ***	0.702 ***	0.001	-0.999 ***	0.970 ***	0.857 ***	1.0	
Gravel content	-0.870 ***	-0.049	0.254	-0.734 ***	-0.660 ***	-0.725 ***	-0.302 *	-0.072 *	-0.757 ***	-0.647 ***	-0.320 *	0.535 ***	-0.454 **	-0.625 ***	-0.545 ***	1.0

Significance of correlations indicated by *, **, and ***, are equivalent to p=0.05, p=0.01, and p=0.001 (n=48; only except grain yield, where n=15) to increase the percent base saturation and thus to enhance the fertility and favor productivity, farmers were observed using overdoses of fertilizers in these fields, which might affect the C:N ratio and increase the $EC_{1:5}$ of the soil. As a result, while the C:N ratio in most of the agricultural soil is constant, as found in the inland soil (10 to 12), dressed lands showed inconstant and wider-ranged values (5 to 19) within the same type of land condition in both study areas. Lower cation ratios also indicate the inferiority of soil fertility levels in these dressed lands. All of these chemical properties were found to have strong correlations with the proportion of finer and the coarser particles from different soils in the study sites. While none of the inland fields had more than 3.4% gravel contents, the undressed fields contained 6.4% (although there is some possibility that undressed fields might have some gravel parts carried by the tsunami water), and soil dressings contained between 14.1% and 25.8%, resulting in maximum percentages of 21.1% gravel content in dressed lands. During the survey, many volunteers were observed periodically sorting out gravel at the restored farmlands. All of these factors and activities individually and jointly deteriorated the nutritional balance and fertility of the soil in these specific lands.

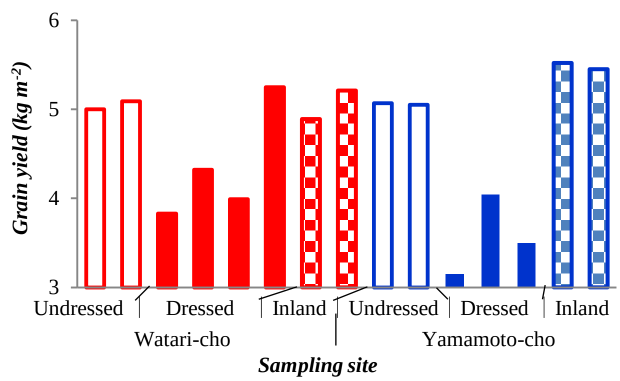


Fig. 7 Yields from paddy fields at different farmlands in Miyagi Prefecture

CONCLUSIONS

Several years have passed since the Great East Japan earthquake and tsunami disaster of 2011, and the tsunami-inundated farmlands have been influenced by many natural and anthropological activities. Therefore, to figure out the absolute status of fertility and productivity in the fields before and after the tsunami is very difficult. Soil samples from nearby inland fields were collected and analyzed of to provide an idea of the pre-tsunami soil quality in the area.

The analytical results indicate that soil in the restored (dressed) lands is inferior from the perspective of agricultural production compared to the non-restored (undressed) land. The extent of that inferiority becomes more distinct when compared with the soil inland, and the reason lies in the quality (or inferiority) of new soil used as a top dressing during the restoration. The findings of this study conclude that, in the tsunami-inundated agricultural fields, the presence of a soil dressing (i.e., mountain soil) with inferior physical properties (i.e., fewer fine fractions) contained poor and imbalanced chemical and biological constituents, making it less fertile, which ultimately affected soil productivity even after the restoration. It may take several years or even decades for the topsoil to regain its productivity, and the process can be accelerated only by proper fertility management after figuring out the specific cause(s) and extent(s) in the specific field(s).

This study also serves to remind that, in the case of agricultural practices with long-term histories and processes, rapid land restoration does not necessarily ensure land productivity, which is the most important to farmers and agriculturists. 'Slow but steady' mitigation processes, such as phytoremediation by using halophytes (Yaneshita, 2011), would be much more practical because the latter does not damage the inherent soil fertility in agricultural fields. Instead, over-fertilization will not only worsen the soil quality but also have drastic side-effects on soil and natural environment in the long run.

More detailed analyses considering more spatiotemporal data on soil humus, isotopes, and buried geology could give a clearer picture of the overall fertility and productivity in the area after the tsunami disaster. Future studies related to salinity mitigation in agricultural fields should include research using different inexpensive and locally originated materials, such as cotton waste, charcoal, fly ash, and halophyte species, all of which have salt removing potentials and are harmless to agricultural soils which is a precondition to sustainable agriculture.

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Research article

Development of a Device for Measuring the Load Bearing Capacity of a Farm Road

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Abstract The maintenance of infrastructure for agricultural production is essential to sustainable agricultural productivity. Farm roads are particularly important infrastructure for transporting agricultural products. Load-bearing capacity is a performance index for evaluating the soundness of a road, and recently, falling weight deflectometer (FWD) tests have been used to measure such capacity. However, an FWD is a stationary device, so its use is time intensive. This study aims to develop a moving wheel deflectometer (MWD) device that determines the load-bearing capacity continuously and economically, for the efficient management of farm roads. For that reason, the development of the MWD involved fabrication, testing and the verification of its practicality on a public road. The MWD was used to estimate the load-bearing capacity of a public road at travel speeds of 10 to 60 km/h. The soundness evaluated based on the MWD measurements were shown to be comparable to that as evaluated by the FWD at all travel speeds. The results demonstrate that the MWD has the potential to be used for the comprehensive measurement of load-bearing capacity.

Keywords pavement management, soundness, load-bearing capacity, falling-weight deflectometer

INTRODUCTION

The maintenance of agricultural infrastructure is essential for sustainable agricultural productivity, and maintenance and repair should be implemented at times and scales that extend the service life. Therefore, a sustainable, recycling-oriented society can't be realized without preventive management system for infrastructure. To apply that system to farm road management, the soundness of infrastructure must be quantitatively evaluated. In general, a road's soundness is evaluated in terms of its surface condition and load-bearing capacity. Road surface measuring vehicles are able to obtain continuous data on road surface conditions, such as cracking, rutting and roughness, along a survey road, so such devices enables the efficient determination of road conditions. In contrast, load-bearing capacity is evaluated in terms of road surface deflection. The falling weight deflectometer (FWD) test has been used to obtain road surface deflection data. This non-destructive testing device accurately measures road surface deflection, however, its use is too time intensive for comprehensive road measurement. Also, the FWD is a stationary device, which means that there is the risk of overlooking localized damage between measurement points. Therefore, a method needs to be developed for determining the load-bearing capacity continuously at high travel speed.

Devices that continuously measure road surface deflection have been developed in other countries since 1990 (Kano, 2008). The rolling wheel deflectometer (USA), road deflection tester (Sweden) and high-speed deflectometer (Denmark) have been put into practical use (Maruyama, 2012; Flintsch et al., 2012). These devices determine load-bearing capacity by road surface deflection measured by Laser displacement sensors or assumed by deflection velocity measured by Doppler vibrometer (Van, 2009; Elseifi 2012; Diefenderfer et al., 2008; Ferne et al., 2009). The Laser displacement sensor measures directly the distance between the sensor and the road surface. This direct measurement enables to obtain road surface deflection easily without numerical calculation. Also, the deflection measurement results are independent of running speed. However, the measurement accuracy is closely related to road surface conditions, and measurement at curved sections is difficult. In contrast, the measurement results by Doppler vibrometer are not affected by road surface conditions because the device measures the deformation velocity of the road surface. In addition, deflection can be assumed by integration of deflection velocity. However, the deflection velocity is zero in the stationary condition. This means evaluation becomes difficult at slow running speed.

In general, Farm road has important roles of not only transporting products but also carrying in and out agricultural machines. Measurement at high travel speed makes ensuring safety difficult during running test. In addition, there are many curved sections and narrow sections in farm roads. Currently available moving devices for measuring load bearing capacity are used by heavy trailer vehicles that generate large deflection, for example RWD consisting of a 16.3 m long semitrailer. It means these devices are not necessarily suitable for farm road management. Therefore, a device to be used by smaller vehicles and which is capable of measuring load bearing capacity without effect on travel speed should be developed. For that reason we developed a moving wheel deflectometer (MWD) to determine which points of a deteriorating road sections require more detailed survey, such as FWD test (Terada, 2012; Matui, 2013). The MWD performes measurements by using a laser displacement sensor in combination with a Doppler vibrometer, and consists of 8.25m vehicle. The Doppler vibrometer have been used to measure deflection velocity at high travel speed, and laser displacement sensors have been used at low travel speeds. In the present work, we propose a method for evaluating the pavement load-bearing capacity on farm roads by using an MWD equipped with a laser displacement sensor, and give the results of measurements on a public road.

METHODOLOGY

Outline of the MWD

Fig. 1 Installation state of deck for sensor

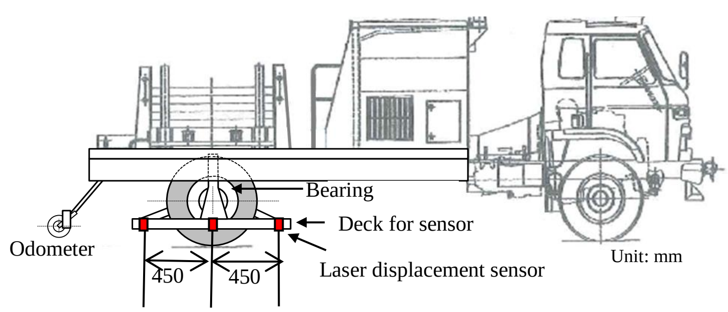


Fig. 2 Sensor configuration

In this study, load-bearing capacity is evaluated in terms of the deflection under the rear wheel as shown in Fig. 1. The deflection is measured by laser displacement sensor. Because of the vehicle's suspension, the axle and the body frame do not move in unison. Hence, as shown in Fig. 1, in order to make the sensor and axle move in unison, a sensor deck was attached to the wheel axle by the axle bearing. The sensor arrangement is shown in Fig. 2. One sensor is installed at the wheel axle, and other sensors are installed ±450 mm from the wheel axle. Additionally, running distance is measured by odometer installed in the rear body

Evaluation Method

The MWD test determines the load-bearing capacity based on road surface deflection generated by rear wheel load. Fig. 3 shows the concept of the determination method proposed in this study. In Fig. 3, the x-axis indicates the vehicle travel direction and the y-axis indicates the deflection direction. The origin of the x-axis is set at the wheel axle. Pavement deflection at the rear wheel is calculated by the following equation in the case of the ideal condition without vibration or torsion of the vehicle body.

$$w_0 = \Delta_0 - \Delta_d \tag{1}$$

Where,

w_0 : road deflection at the rear wheel ($x = 0$)

Δ_0 : distance between the wheel axle and the road surface at the rear wheel ($x = 0$)

Δ_d : distance between the wheel axle and the road surface without deflection ($x = d$)

The wheel radius and deformation are R and δ, respectively. If δ does not depend on pavement rigidity, then the difference between R and δ is always constant.

$$\Delta_0 = R - \delta = Const \tag{2}$$

As mentioned above, the deflection immediately below the rear wheel can be calculated by equation (1) under ideal conditions. However, measurement at the position $x = d$ is difficult, because measurement value in that position is influenced by vibration of sensor and the tilt of vehicle body in practical measurement. For that reason, as shown in Fig. 4, a deck for the sensors was attached to the wheel axle, and three sensors were attached so as to measure maximum deflection at the position $x = 0$ and deflection at the position $x = a, -a$; also, the deck is designed to tilt around the wheel axle. Therefore, in this study, the load bearing capacity was evaluated by the "deflection difference," i.e., the difference between deflection generated just under the rear wheel and deflection generated at any other point ($x = a$).（Assuming that the deflection curve is generated symmetrically with respect to the y-axis, the error of deflection measurement at the position $x = a$ due to the tilt of the sensor deck can be eliminated by averaging the measurement value at the position $x = a$ and measurement value at the position $x = -a$. Deflection difference is defined by following equation.

$$w = \Delta_0 - \Delta_a \tag{3a}$$

$$\Delta_a = \frac{1}{2}\left(\Delta_f + \Delta_b\right) \tag{3b}$$

Where,

w : deflection difference between deflection just under rear wheel and that at any other

Δ_f: distance between the sensor and the road surface at the position $x = a$

Δ_b: distance between the sensor and the road surface at the position $x = -a$

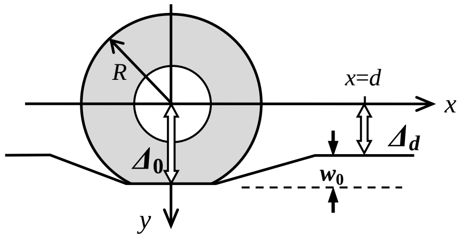


Fig. 3 Concept of deflection

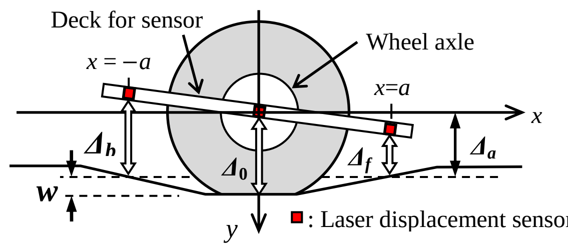


Fig. 4 Correction of displacement for the sensor deck tilt

MWD Testing

The MWD test was carried out at the testing course of the Public Works Research Institute in Tukuba, Japan (Fig. 5). The length of the testing section was approximately 1400 m. To assess repeatability and the effects of running speed, measurement was implemented three times for each with six running speed (10, 20, 30, 40, 50 and 60 km/h). Also, FWD test was conducted at the same test course to demonstrate accuracy of MWD. The pavement consists of an asphalt layer (14 cm) and a granulated subbase course (31 cm), and there are many cracks at several points. The sampling frequency was 2000 Hz. The wheel load in a static state was 46.5 kN.

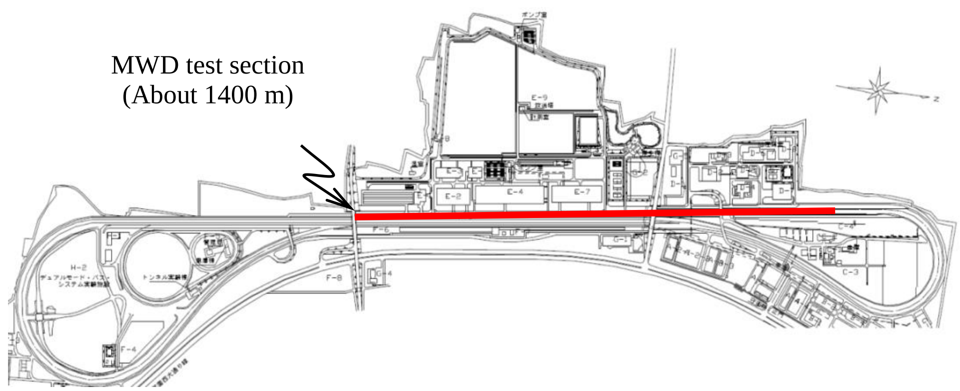
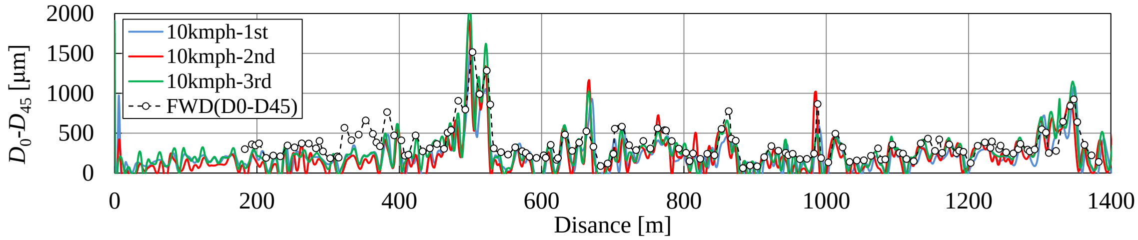


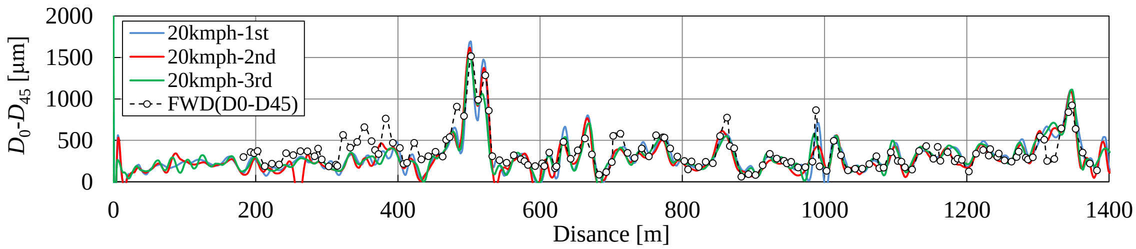
Fig. 5 Section for the MWD test

RESULTS AND DISCUSSION

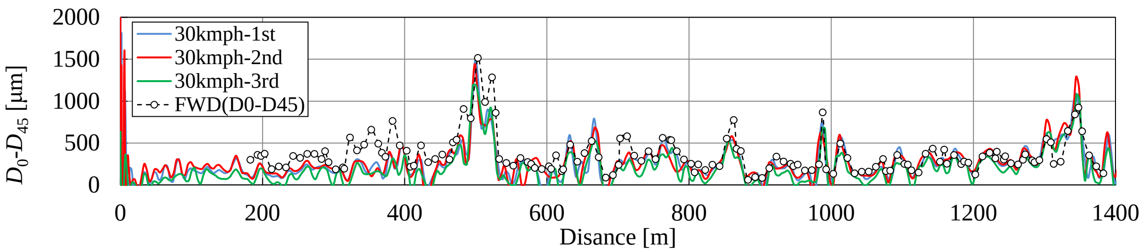
Figure 6 illustrates the measured pavement surface deflection difference, i.e., the difference between deflection just under rear wheel ($x = 0$) and deflection at an arbitrary point ($e.g., x = 45\text{cm}$) (hereinafter referred to as ($D_0 - D_{45}$)) calculated by equation (3a). The MWD test was implemented three times for each running speed. As shown in Fig.6, the results at each running speed were similar, which means that the measurements are repeatable. In addition, it is shown that the measurement accuracy is not closely dependent on the running speed. The results of FWD testing for a given measurement section is also presented in Fig. 6. In general, road surface deflection is affected by pavement temperature. Hence, temperature correction is necessary to get rid of effect of temperature on the measured deflection, and the MWD and FWD can measure pavement temperature during operation. The MWD and FWD tests were conducted in November and December respectively. As a result of temperature measurement, there was not almost difference of the temperature. For that reason, it was judged that there was no need for temperature correction. Also, the loads of MWD and FWD are different. Hence, the results of FWD testing are those after linear correction of load. As shown in Fig.6, it is showed that the results of MWD testing agree substantially with that of FWD. For example, the part and number of the biggest (D_0-D_{45}) obtained by MWD test are consistent with that of FWD test. It is possible that sensor deck designed to tilt around the wheel axle cleared measurement errors caused by tilt of sensor deck. In contrast, the results showed the scattering and uniformity of FWD and MWD data in approximately 350 m. It is possible that this is attributed to greater vibration and bouncing caused by road roughness during measurement. Also, these measurement results include effects on load change and impact load during measurement. Accordingly, the value of (D_0-D_{45}) does not always need to be accurate. However, in comparison with RWD that have been put into practical use, these results indicate that the MWD have enough accuracy as the device to specify deteriorating road sections which need detailed survey. Finally, the study determined from these results that the MWD has applicability as moving device for measuring load bearing capacity.



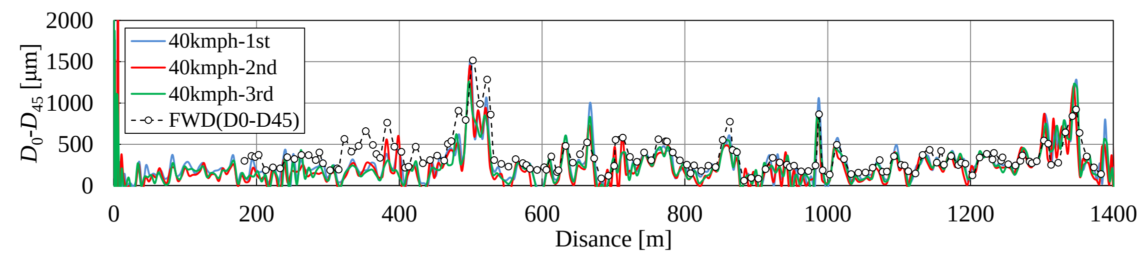
(a) Running Speed: 10 km/h



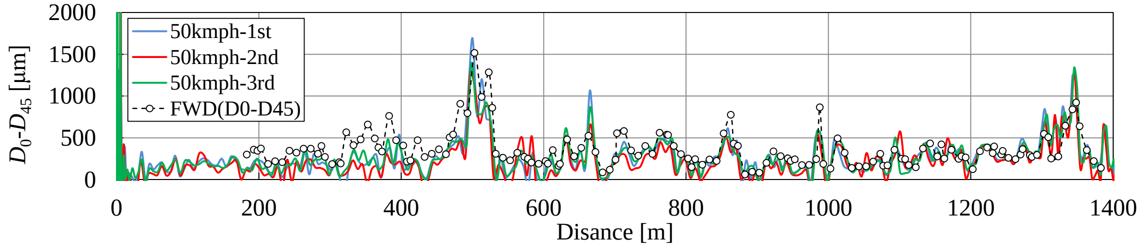
(b) Running Speed: 20 km/h



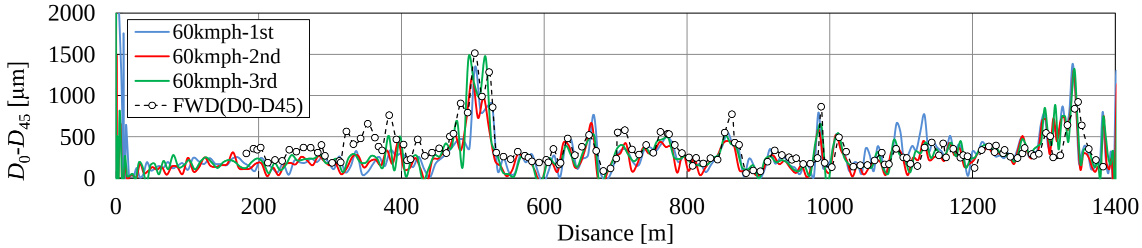
(c) Running Speed: 30 km/h



(d) Running Speed: 40 km/h



(e) Running Speed: 50 km/h



(f) Running Speed: 60 km/h

Fig. 6 The deflection difference (D_0-D_{45})

CONCLUSION

This study aims at developing a device for measuring the load bearing capacity and at establishing an efficient method for evaluating the soundness of farm roads. In this paper, we proposed a determination method that uses (D_0-D_{45}) obtained by MWD test. The results of MWD measurement showed that MWD deflection measurements are repeatable. Also, MWD measurement is not closely dependent on the running speed at travel speeds of 10 to 60 km/h. In addition, the results of MWD testing were agreement with that of FWD. Therefore, it is showed that the applicability of the MWD was demonstrated. A further direction of this study will be to accumulate test data under various conditions in order to improve the proposed method.

ACKNOWLEDGEMENTS

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Research article

Benchmarking Concepts of Community Wellbeing in an Area Vulnerable to Disaster due to Volcanic Eruption

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Abstract Victims of natural disasters have countless challenges to face on right after the event. Immediate local government unit and other community leaders are the first line of help to affected communities. The wellbeing of everyone in a vulnerable community is greatly affected by how the local sectors response. A deeper understanding of the concepts of community wellbeing is hereby realized through a qualitative research approach in the field. Several focus group discussions are done with five local sectors in the selected sites. The narratives of the victims are analyzed through thematic analysis in identification of sectoral concerns regarding concepts of community wellbeing.

Keywords community wellbeing, leaders, stakeholders, trust

INTRODUCTION

The recently heightening interest in local community wellbeing (CWB) indicators reflects a growing awareness of their importance in harnessing citizen engagement, strengthening community planning, and encouraging evidence-based policy making (Buot et al., 2016, Lee et al., 2015). Community Wellbeing (CWB) concepts are defined and measured for stakeholders and policymakers to be able to rethink the ways in which governmental priorities are debated and progress is scaled. Earlier studies related to CWB began in the 1960s, but only a limited area had been tackled (Cummins, 2001; Baum, 1999). It is undeniable that natural disasters are indeed real phenomena, and their impacts are becoming all the more pressing especially so with the current climate change scenario. This is why there has been a recent surge in risk reduction planning, capacity building, and community organizing activities.

The Philippines has always been prone to natural disasters. Filipinos are no stranger to volcanic eruptions, earthquakes, huge landslides, and typhoons, which are the most frequently occurring disasters in the country. These unfortunate events have always led to significant casualties and losses. From 2000 to 2014, approximately 17,232 died due to natural disasters, in addition to the insurmountable destructions of property reported (CRED, 2015). The goal of these activities is to prepare communities so that they can withstand the impacts of natural disasters and be able to adapt to the difficult situation ahead of them.

This study, which assessed the different concepts of wellbeing from the perspective of the five local sectors, contributes to a better understanding of how people survive the destruction and gradually make progress toward starting again.

METHODOLOGY

Albay, Philippines was purposively chosen as the province with the closest proximity to Mt. Mayon. Camalig was then chosen randomly from the list of communities (Fig. 1). A qualitative approach to determine the concepts of community wellbeing (CWB) in the aftermath of the disasters was used. Focus group discussions (FGD) were conducted as a form of group interview using discussion guides developed around the topic of CWB concepts. Probing questions were added if needed in order to encourage more personal responses. Among the sectors represented during the focus group discussion (FGD) conducted were the local government, education sector, business sector, people's organizations, and socio-civic sectors (Table 1). All participants were survivors of previous disasters. They either lost properties or jobs owing to terrifying and fatal events like the volcanic eruption in Albay. Group sizes varied between 6 to 10 participants representing different The sessions lasted between 1.5 and 2 hours. Pseudonyms were used in order to protect the identity of the participants.

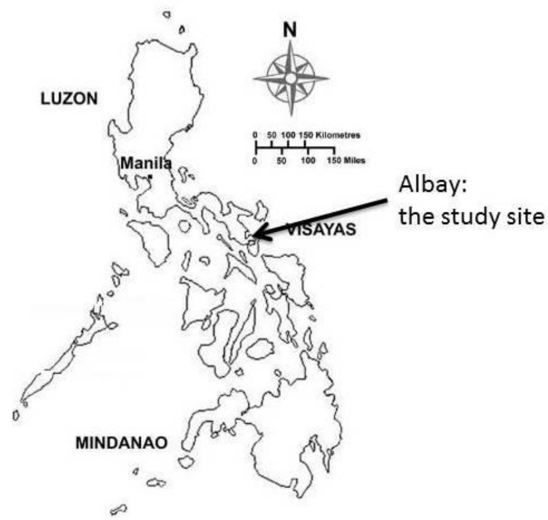

Fig. 1 The study site, Albay, Philippines

Table 1 Focus group participants.

SITE	SECTOR	AGE		MEAN AGE	GENDER		TOTAL
		Youngest	Oldest		Male	Female	
ALBAY	EDUCATION	26	65	47	2	4	6
	BUSINESS	32	70	53	6	-	6
	SOCIO CIVIC	23	34	27	3	3	6
	LGU	34	61	49	5	4	9
	PO	34	58	45	6	3	9
	TOTAL				21	15	36

RESULTS AND DISCUSSION

Salient Insights from Albay

On September 14, 2014, the provincial government of Albay declared a preemptive evacuation around the 8km extended danger zone (EDZ) of Mayon Volcano (PHIVOLCS, 2014). Several barangays of Camalig, Albay were affected like Anoling, Sua, Tumpa, Quirangay, Salugan and Cabangan. Mt. Mayon did not erupt but the affected families stayed in the evacuation centers (EC) for almost 3 months.

Education Sector. Six teachers from the public school represented the education sector (Table 1). All of them were married and had children. This sector felt most of the pressures in the wake of a disaster.

Teachers, for example, might not be affected personally by the event but their workplace was usually transformed into an evacuation center. The 2014 volcanic activity did not bring lahar or volcanic debris to their locality, but there were many evacuees who stayed for almost 3 months in the local school.

Doing duty even with disaster at hand (Table 2). Although classes were suspended for 2 weeks, the teachers were required to report to duty to help in the evacuation organization. When classes resumed after a while, they had to conduct classes while the evacuees were around. They knew that their students were disturbed physically and emotionally. The tents serving as their new classrooms were hot and the schoolchildren saw the discomfort of the evacuees, too.

"Naiyak ako kase ang mga bata nakabitbit ng pamaypay, nakahubad na. Naiyak ako. Ang init sa tent." – Mia (*I cried because the children were all bringing fans, they even took off their shirts. I cried. It was too hot in the tent.)*

Table 2 Thematic analysis of the narratives in focus group discussion of participants

Sectors	Themes
Education	Doing duty even with disaster at hand Acceptance of the inevitable
Business	Better basic services means comfort in life Disaster creates situation for Samaritan to emerge
Socio Civic	Welfare for all
Local Government Unit (LGU)	Dagus dagos (sustainability)
People's Organization	Common sentiments Desires and wishes at disaster time

The education sector willingly performed these duties even in the face of danger because they consider it as their moral obligation. They were hopeful that performing their role may bring a bright future to these small kids under their care. The education sector expressed that morality and values serve as the standard and foundation of a community. Respect and concern for the neighbors came out as real values that the community must do collectively in order to engage all towards one community goal. While they were helping the evacuees housed in their workplace, they were expecting that the evacuees themselves and other agencies which were trying to reach out to the affected families must not forget the basics of respect and concern.

Acceptance of the Inevitable. While maintaining their duty at the EC, the teachers knew and have accepted the fact that the promises given to them might never come. Glenn shared that they were all working to provide at least an enabling environment for the affected families. They tried to help with the most they could extend. Oftentimes they had to solve with the help of the principal, complaints about the comfort room, non-functional electric fans, and other basic necessities. In 2006, some of them, were themselves victims of the mudflow from Mayon volcano. Those past experiences had taught them countless lessons.

"Kami man ay experience sa bagyo at lahar. Naku nahulog ako sa may tubig. Pero ako talaga survive lang kase kami lang asawa ko. Lahar ay apekted na din. Kalahati na ang tubig. Muntik na abot ang bahay." – Glenn (*We have our own experience with typhoon and the lahar flow. I fell into the waters. But I had to survive because my husband and I were alone. Lahar was a threat. Water was everywhere. The flood water was almost in our house.)*

Ruth wanted to say that the volcanic eruption may not happen too soon. With this in mind, they wanted to stay put where they were at the moment. A stronger faith in difficult times may have given them more hope to stay (Nelson et al., 2011). But Mia, having experienced almost being killed by the impacts of Mt. Mayon, was ready to move out anytime.

Business Sector. Six participated from the business sector (Table 1).The participants were all successful in their own field. Pete retired from his work in the US and decided to come back to the Philippines. Noli, an engineer, started his business by opening a welding shop in the 80s. From there, he created jobs for his neighbors, relatives and other people. An economist, Manuel, made businesses out of the natural resources of Albay. He was into adventure tourism. Both Noli and Manuel somehow benefitted from the occurrence of natural disasters. Alan and Rey were into farming and the youngest businessman, Dani at age 32, was into retail.

Better Basic Services Means Comfort in Life (Table 2). As good citizens, the participants said that they paid their taxes religiously and on time. In return, therefore, they expect the government to provide them better basic services. Pete mentioned that he had paid high taxes in the US but never complaint because the services were at par with his expectations. Manuel strongly invoked his idea that community wellbeing could be attained only with improved basic services for all. Noli summed it up:

"Yun pong obligations ay nagagawa. Ang government ay hindi mabibigay sa atin yung services kung hindi natin din ginagawa ang obligations. Ang pera ay dapat maibalik in the form of services. Government should do also their tasks/responsibility very well." (*Obligations should be fulfilled. The government cannot give us the basic services if we do not fulfill our obligations. The resources we have shared should be given back to the community in different forms of basic services.)*

Insurance was also considered vital for their personal security and for the family in times of emergencies. Everybody in the business sector agreed that insurance was important for emergency cases and acknowledged it as a "social responsibility" of the government. Because both Alan and Rey were in agriculture, they strongly believed that farms should be insured as well. When natural disasters occur, the agricultural farms suffered a lot, even the agricultural animals, too. Alan categorically classified insurance as a "contingency fund and a savings" as well. Rey considered insurance as a "security" for people in the agriculture sector. Even with the destruction of the agricultural products during natural disaster, in this case, volcanic eruption, at least a contingency fund is available to the farmers for recovery purposes. Rey called it a "fall back that will be a source for us to stand again."

Disaster creates situation for Good Samaritans to emerge (Table 2). Disaster to some businessmen meant business. For example, Noli, being in the construction business benefitted in the aftermath of any disasters. But this kindhearted man, never thought about the benefit. He was thinking of his employees every time a suspension of work happened. Although he was not personally affected by the preemptive evacuation in Albay last 2014 he had experienced the after effect of Mt. Mayon's activity in 2006 and other effects caused by strong typhoons. If not for their neighbors, whom they had not really known before, his family might not have survived. Noli described the disaster as "an eye-opener. And he added that "the best person who could help you would be your neighbor." He realized that no one had taken time to know more about his neighbors and that disasters brought neighborhood together.

" Naging blessing ang trahedya. Ipaparealize nya talaga sa iyo ang maraming bagay na minsan yung kapit bahay mo na hindi mo pinapansin yun pa pala ang tutulong sa iyo." – Noli (*During disasters, the goodness in the heart was revealed. Tragedy becomes a blessing. One can say that disaster is an eye opener. A tragedy would make one realize that the neighbor you wouldn't even notice in ordinary days, became the source of help*.)

Whatever the social status, everyone is on equal footing whenever in a disaster. Manuel described disasters as a "great leveler." Jokingly, he added that social status does not matter if "pare-pareho kayong masasalanta at kakain ka din ng sardinas." (when everyone was affected by disaster and one had to eat canned sardines.) No one can be choosy about what to eat. On the other hand, occurrence of disasters became a "wake up call" for the government to be always ready. Bicol region, specifically Albay, had a long history of disaster incidence like typhoons, floods, or volcanic eruptions. Therefore, the effort of preparation and mitigation for the worst disaster ever since was at the top on each local government units' agenda.

Socio Civic Sector. The socio civic participants were young leaders who joined the volunteer group to help the community in times of disaster. Three males and 3 females joined the FGD (Table 1). Their mean age was 27 years old. All of them had their own jobs and they were all singles. A sense of fulfillment in doing volunteer works and the acquired value in each unique experience were considered essential by each of them.

Karahayan san Gabos (Welfare for all) (Table 2). When one gives his/her time in order to extend help to the community, it means sacrifices too. Even though the socio-civic sector participants expressed that they received invaluable lessons by giving their time and they felt fulfilled and happy, a certain part of themselves were also given away. Commitment to help without expecting in return was embedded in each story shared by the participants. Great concern for the affected communities can be shown in all the community works they had participated in. In addition to concern for the welfare of others, it was a strong grass root participation that would help boost one's wellbeing. Jessica showed that real concern for the welfare of the community can be shown even by simply listening to the stories of the afflicted families. Sharing time with the victims was necessary and was expected of them. To be proactive was necessary for the welfare of everyone as shown by "precaution and warnings given." Since the participants were church-based, the spirit of faith and hope were strongly evident in the narratives.

Dace highlighted how participation contributed for the good of the community, and for him, everything was a result of a collective effort. All of the participants strongly expressed that community effort was only successful with concerted personal efforts.

The Local Government Sector. The FGD sessions were participated in by members of the barangay council (6), municipal office (1), and one each from the provincial DRRMO, and from the Civil Defense Office (Table 1).

Dagus-dagos (Sustainability) (Table 2). Sustainability of the effort from the LGU leadership down to the lowest bracket of the organization was always basic in order to see the seriousness of whoever was in command. Albay is very vulnerable to any Mt. Mayon's activity. In Camalig alone, 6 barangays are situated along the 8km EDZ. A small tremor from the volcano would mean thousands of families would have to be evacuated. Education through continual training and workshops, serve as a constant reminder to the community members that the municipal leadership was really sincere in attaining a zero casualty objective. The health workers present were focused on giving what they commit to do. Just like the political leaders, the health workers, showed consistency in the continuous effort to bring the community to zero sickness. Lou, Lil and Beth shared that they would not stop imparting the right knowledge to the residents. If the people would not come to the health clinics for certain reasons, then they themselves visited them. Specifically, for Lou, she related that "house to house" was an option to take because she considered it as her "social responsibility" to increase the people's knowledge about health.

Jo, a 61 year old kagawad, continued to serve the community even if he lacked the financial capability. He believed that serving meant finding other sources of help by going to the right persons. He always projected a positive attitude to tap other linkages in order to bring help to the constituents. Sense of "*pagkukusa*" (initiativeness) was cited by Lou and Jo. Indeed, the barangay local leadership did not wait lethargically but was more proactive. Security or people's safety for their lives and possessions dominantly echoed in Efren's shared stories. As Jo and Efren narrated, community wellbeing meant a "visible leadership." Not only during extreme events but more so during the planning stage to prevent a disastrous effect of a volcanic eruption (Atkinson and Sapat, 2014).

Sustenance of the effort towards "*karahayan*" (welfare) of the entire community started with the individual's initiative and reaching its climax with initiative and dynamic leadership.

People's Organization. The Mayon's Farmer Association was under the oversight of the municipal Department of Agriculture (DA). Forty-five years was the mean age of the participants (Table 4.1). Six males and 3 females joined the FGD. These farmers obviously were risk takers because they continued to farm even under the constant threat of Mt. Mayon. Their farms were located in Sua, a barangay within the 6-8 km EDZ. During the last preemptive evacuation in 2014, these farmers were personally affected.

The common experiences and sentiments (Table 2). Their proximity to the volcano sometimes gave them an edge over other policy makers, national or local. They knew when to stay or flee. But because of the zero-casualty program of the provincial government, these farmers could not refuse to flee during a volcanic activity. During the prolonged preemptive evacuation of 3 months, most of the money saved by the farmers were gone. Going to an evacuation center was not a welcome news but they could not do otherwise. Sonia, being a mother, was always worried about the safety of the children, thus she openly declared that she wanted the needs of the family to be provided while staying at the EC. Elvie and the rest of the participants concurred that they could not just depend on the government for all their needs and therefore they had to work. Because they were farmers and their source of living was from their farms, they wanted to go home as soon as possible. Elvie was vocal about their need to go home. Jona was talking about the sustainability of their source of income which might be destroyed if they stayed away from their farms far too long. Yes, relief goods were distributed but Jona believed that it "was not enough to accommodate the needs of the family" for several months.

Personal desires and wishes at disaster time (Table 2). The provision of basic needs was foremost in every parent's mind in the aftermath of a disaster. During this uncomfortable situation, everyone wanted to have " extra money" for emergencies. Odie and the rest of the participants felt this financial need. Security against crime was also essential in this most troubled times. Thus the visibility of the policemen was a welcome sight for them.

A public leader they could easily approach during extreme need was the plea of Ebie. It was also a symbol of hope for her to see leaders who "were available and willing to help." In addition to that, Ebie hoped to have a safe neighborhood so that the feeling of security would be enhanced. Emil, the chair of the organization desired to have a safe community for all. For him it meant, safe for him "to move around, and to continue working without mental worries." Having a safe neighborhood improved the feeling of trust in other people of the community.

A community that experienced intermittent natural disasters have members who are risks takers. In addition, Odie included the people's "strong faith in God who would not put them into more risks they cannot handle." Odie shared that the more one takes risks, the more one "becomes strong and determined to survive for the family and the community as well."

CONCLUSION

Concepts of community wellbeing can clearly be visible at the wake of disasters, when all the victims were trying to use rationality to understand the damage and the loss. Having intact value system made one to be kind and patient. All the business representatives agreed that a "positive mindset" is necessary when disaster strikes, it will be a temporary state of affairs. Having a positive mind was necessary so that the victims might be able to put everything back, after the experience. Trust in the leadership and unity perhaps can erode but every sector might regain in due time. Faith was what people always arm themselves as fall back during times of fatal disasters.

The decision of what a community needs should be shared by all sectors so that conflict can be eliminated immediately. If everyone works for the good of the community, problems will be solved and the level of community wellbeing can be enhanced.

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Research article

Coral Transplantation Technology for Sustainable Fisheries and Underwater Tourism

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Abstract Application of coral transplantation technology was the project funded by Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (PCAARRD DOST). Implemented by Bohol Island State University – Candijay Campus in partnership with Provincial Government of Bohol, Municipality of Anda, and AMUN Ini Beach Resort. 30,000 coral fragments from dislodged coral colonies were transplanted in damaged reef areas in Anda, Bohol, Philippines. Coral fragments were attached in the nailed concrete nails, fixed with plastic cable ties, and tightened with aqua epoxy clay from 5 m to 12 m depth. After year of transplanting corals, it was found that the total mean average of survival = 37.1 percent, however, in term of significant difference of survived coral it was revealed that there is a significant different due to "p value = 0.367" which is higher than the p = 0.05". With regards to the influence of transplanted corals to fish, it was observed that there were 38 families with 52 species of fish, and thousands of individuals attracted and settled in the rehabilitated area. The dominant species of fish in both areas were Pomacentridae and Apogonidae with the occurrence of other attractive animals such as sea slugs, sea turtles, leopard anemone shrimp, whale shark and eagle ray.

Keywords coral, coral fragment, rehabilitation, reef fishes, transplantation

INTRODUCTION

Coral reefs are underwater structures formed as a result of the deposition of calcium carbonate by living organisms, predominantly by corals. Coral reefs are home to thousands of coral polyps which feed on planktonic organisms or photosynthesize by means of their symbiotic algae called zooxanthellae. Corals can only grow in shallow waters where light is not limited by depth. Corals are only found along the shallow coastlines of more than 100 countries worldwide (Moberg and Folke, 1999). Coincidentally, coral reefs attract wide range of organisms. In fact, there are up to 9 million of reef living animals and plants described up to date (Knowlton, 2001a) making it appropriate to call coral reef as the rainforest of the sea (Mulhall, 2008; Knowlton, 2001b). Coral reefs have also been considered as one of the most productive ecosystem on earth. In the Philippines, it provides livelihood for more than a million of fishers who contribute almost US$ 1 billion annually to the country's economy (White et al. 1998). Unfortunately, coral reefs are in serious deterioration-suffering massive, long term declines in abundance, diversity and habitat structure due to overfishing, pollution, tourism, and other anthropogenic and natural disturbances (Abelson, 2006).

Anda is considered one of the prime tourist destinations, next to Panglao, in Bohol and is now starting to experience surge of beachfronts developments to accommodate growing number of local and foreign tourists. Recreational services provided by these resorts are diving and island tours, thus increasing the number of boats anchoring directly on the shallow reef flats causing destruction within the area. To make matter worse, the sheer number of tourist divers with poor buoyancy control and lack of spatial awareness adds to the destruction of reefs in popular dive sites.

Result of the participatory coastal resource assessment (PCRA) conducted by Bohol Environment Management Office (BEMO) and Department of Environment and Natural Resources (DENR) last 2011 revealed that in all eight coastal barangays in Anda (Badiang, Linawan, Talisay, Bacong, Virgen, Candabong, Poblacion, and Suba), only Virgen and Bacong was at a good condition having 57.5 % and 51.5% live hard coral cover (LHC), respectively, while the rests are found to be at poor condition with LHC ranging from 7.3-23.5%. Coral rubbles and dead corals covered with algae were predominantly dominated in the reef areas leading them to suggest previous dynamite fishing, and the use of poisonous and obnoxious substances were to blame. However, with the increased of boat use in the area, coral breakage due to anchors was also observed.

Transplanting coral fragments is one of the many ways of restoring damaged portions of reef. It has been observed that the use of coral fragments from donor colonies or from dislodged fragments (Monty et al. 2006), have the capacity to restart new colonies elsewhere when artificially attached to stable substrates (Thongtham and Chansang, 2008) as compared to waiting for new recruits to regrow (Fox et al. 2005). Several studies have shown the importance of coral nurseries in this endeavor (Shafir et al. 2006, Herlan and Lirman, 2008; Shaish et al. 2008). Nurseries provide a way to determine coral growth rates empirically as well as giving them a chance to heal before transplanting.

These techniques were pilot tested in the different parts of the Philippines, including Panglao, Bohol, through the national coral reef restoration program last 2012 and were found out to be effective. Amper J.A. et al. 2015 observed that the fragments attached to a nursery can grow up to 2.5 cm. in three months while according to the unpublished report by the University of San Carlos and Bohol Island State University (2013), same fragments transplanted in the area can grow up to 0.5 – 0.7 cm per month.

This coral transplantation was done in Anda, Bohol with funding support from Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (PCAARRD DOST), implemented by Bohol Island State University – Candijay Campus in partnership with the Province of Bohol, Municipality of Anda, Bohol, and AMUN Ini Beach Resort. The town is located in the eastern part of Bohol with coordinates 9˚45 N, 124˚34' E and a distance of 99 km from the City of Tagbilaran. The specific sites for coral reef restoration are strategically located in three barangays of Anda, Bohol, Philippines (Fig. 1). It was chosen because it passes the criteria of site selection.

OBJECTIVES

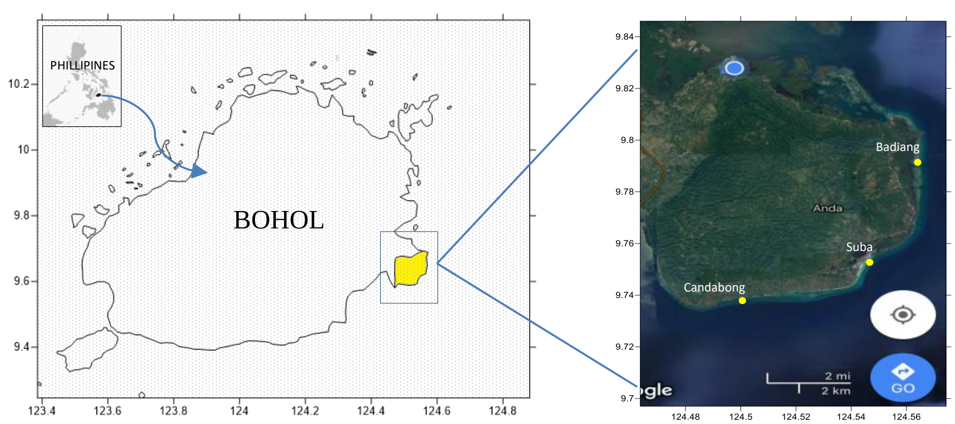

Fig. 1 Project sites

The objective of the project was to transplant 30,000 dislodged coral fragments from colonies, monitor the survival rate of transplanted corals after year of transplanting in the damaged reef areas, count the species of fish in the rehabilitated areas, and compare the population of fish before and after year of coral transplantation, and observe the environmental parameter on the aspect of temperature, and salinity. And, test the significant difference on the performance of coral transplantation after year of project implementation, and the fish abundance in the rehabilitated coral reef areas in the municipality.

MATERIALS AND METHODS

Dislodged corals from colonies were utilized as the planting materials. Damaged reef areas with live hard coral cover from 40 – 60 percent were chosen as the area for the coral rehabilitation. The method applied was the following.

Collection of Planting Materials: Detached corals from colonies were collected, placed in plastic crates, and transported to the project areas. Crate filled with coral fragments were carried out by the two divers to the rehabilitation areas where the other divers waiting the planting materials.

Rehabilitation of Damaged Reef Areas: Coral rehabilitation was done in areas with water depth from 5 m to 12 m. Coral fragments were attached in the nailed concrete nails number 4, reinforced with cable plastic ties (36 mm X 6 mm), and tightened with aqua epoxy clay. One hundred coral fragments were transplanted in one quadrat. Estimated size per quadrat was 5 m X 5 m or 25 m^2. The distance between coral fragments was one foot to one meter, depending on the topography of the reefs.

Monitoring on the Performance of Transplanted Corals: Transplanted coral fragments were monitored after year of coral transplanting. Ten sampled quadrats were monitored per project area. Transplanted live corals inside the quadrat were counted to determine the survival rate, to include counting of fishes by using fish visual census (FVC). Reef fishes were counted inside the 100 m transect line with 2.5 m side by side, at two replicate transects per project area, and aided by video.

Statistical Treatment Used: Simple mathematical computation was applied of understanding survival rate. Formula where: survive corals over 100 then times 10 to get the total mean average of the survived corals after year of transplanting. Kruskal Wallis Test was used of getting the significant difference of survival rate of transplanted corals, and Kolmogorov Smirnov Test was used to determine the fish abundance from before and after year of project implementation.

RESULTS AND DISCUSSION

Branching corals were used in the rehabilitation of damaged reef areas. The coral transplantation was started from February 2015 to January 2016. From one year period, the project team was able to transplant 30,000 corals in three areas (Table 1), from Badiang in the north, Suba in the east, and Candabong in the southern part of the municipality. 10,000 coral fragments were transplanted in per project area. Planting materials were taken from the dislodged coral fragments from colonies. This method differ on the method applied by Thongtham and Chansang, 2008, wherein they were utilized planting materials from the coral nursery. According to them, grown corals from the coral nursery have the capacity to start new colonies elsewhere when permanently attached in the stable substrates.

Table 1 Coral Fragments Transplanted in the Damaged Reef Areas

Reef Areas Rehabilitated	Number of Coral Fragments	Status
Barangay Badiang	10,000	Transplanted coral fragments
Barangay Suba	10,000	able to enhance the damaged
Barangay Candabong	10,000	reef areas in the project areas
TOTAL	30,000	

The following table describes the survival rate of transplanted corals after year of transplanting in the degraded reefs. It was found that the three project areas have great difference on the survival rate. Candabong was an excellent result of 87 percent, while the other two project areas were very low survival rates with 13.1 and 11.9 percent respectively. In term of the significant difference on the survival rate of the transplanted corals in three areas, it was disclosed after subjected to Kruskal-Wallis Test that p value = (0.368) which is higher than the p = 0.05 level of significance. Therefore, there is a significant difference on the survival rate among the three project areas. The result of Candabong area corroborate of the study conducted by Alasdair Edwards, 2010, that coral transplantation have delivered reasonable survival over a few years, just a first towards a trajectory of improving ecosystem structure and function.

Table 2 Survival of Transplanted Corals

Location	Number of Quadrats (100 corals/quadrat)										
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total Survival Rate (%)
Suba	6	12	8	9	6	23	10	14	11	20	11.9
Badiang	18	1	7	29	11	16	14	5	7	23	13.1
Candabong	98	78	73	89	87	92	85	93	95	80	87.0
Total Ave. Mean	40.67	30.33	29.33	42.33	34.67	43.67	36.33	37.3	37.7	41	37.33

There were 38 families with 52 species of fish found in the rehabilitated areas after year of transplanting corals. Pomacentridae and Apogonidae were dominated in the rehabilitated areas with present of some commercial fishes, species of sea slugs, sea turtle, seahorses and its relatives, leopard anemone shrimp, and the occurrence of whale shark and eagle ray. According to Feary et al. 2007 fish abundance, biomass and number of species are closely correlated with the condition of the coral community. A potential positive effect of coral transplantation on the fish community has been widely stated, only few studies have been published that included observations on this connection (Alfeche, 2003). This study describes that there is a positive connection of coral transplantation and attraction of fish. From very poor to very high fish condition was observed in barangay Candabong and Suba, if it is based of fish condition index published by Hilomen et al. 2000, however, barangay Badiang remains very poor condition.

It was perceived that one of the factors that contribute in the increased of fish individuals in two rehabilitated areas was the strict implementation of no-take zone policy. The significant difference of fish abundance in coral transplantation areas, revealed after subjected to Kolmogorov Smirnov Test that there is a significant difference from before with p = 0.910 and p = 0.998 after year of transplanting corals in degraded reef in three areas, which is higher than the significance level of $p < 0.05$.

Table 4 shows the surface temperature and salinity, and perceived cause of mortality of transplanted corals in project areas. It was observed that water salinity start to change from the month of September to December of same year. It was happened due to continuous rains and flooding. The perceived cause of high mortality rate of the two project areas (Badiang and Suba) was due to the changed of water salinity and weak of protection of transplanted corals. Fishermen sometimes engage fishing in the rehabilitated reef areas.

Table 3 Number of Fish Individuals Found After Year of Coral Transplantation (1,000 m^2/project area)

Project Area	Name of Families	No. of Ind./Family Before (Feb 2015)			No. of Ind./Family After (Jun 2016)		
		T1	T2	Total	T1	T2	Total
Barangay Suba	Acanthuridae	0	0	0	1	0	1
	Apogonidae	7	51	58	880	930	1,810
	Blennidae	0	0	0	1	1	2
	Caesionidae	0	0	0	8	8	16
	Chaetodontidae	1	1	2	5	2	7
	Gobiidae	0	0	0	3	2	5
	Labridae	2	3	5	31	27	58
	Mullidae	1	2	3	0	0	0
	Nemipteridae	0	0	0	2	1	3
	Ostraciidae	0	0	0	1	0	1
	Pomacanthidae	0	0	0	1	0	1
	Pomacentridae	9	63	72	415	259	674
	Serranidae	1	0	1	1	0	1
	Siganidae	0	1	1	2	0	2
	Scorpaenidae	1	0	1	1	0	1
	Synanceiidae	0	0	0	1	0	1
	Tetradontidae	1	1	2	2	0	2
Total	17	23	122	145	1,355	1,230	2,585
Barangay Candabong	Acanthuridae	2	2	4	2	7	9
	Amphiprionidea	3	3	6	0	0	0
	Apogonidae	3	4	7	0	0	0
	Blennidae	0	0	0	9	0	9
	Batrachoididae	0	0	0	0	1	1
	Caesionidae	0	2	2	0	0	0
	Callionymidae	1	1	2	0	0	0
	Chaetodontidae	1	3	4	5	2	7
	Epinephelidae	1	2	3	0	0	0
	Haemulidae	0	2	2	0	0	0
	Labridae	5	9	14	5	0	5
	Lutjanidae	0	1	1	4	0	4
	Mullidae	1	2	3	0	0	0
	Muraenidae	1	1	2	0	0	0
	Ophichthidae	1	1	2	0	0	0
	Pomacentridae	5	5	10	4,311	1,530	5,841
	Pinguipedidae	1	1	2	0	0	0
	Scaridae	1	1	2	0	0	0
	Serranidae	0	0	0	324	0	324
	Siganidae	1	2	3	3	1	4
	Sphyraenidae	0	1	1	0	0	0
	Syngnathidae	2	2	4	0	0	0
	Tetraodontidae	1	1	2	0	0	0
TOTAL	22	30	46	76	4,663	1,539	6,204
Barangay Badiang	Acanthuridae	1	1	2	0	0	0
	Amphiprionidae	2	2	4	2	4	6
	Apogonidae	7	7	14	24	15	39
	Balistidae	1	1	2	0	0	0
	Caesionidae	1	1	2	1	1	2
	Chaetodontidae	1	2	3	1	1	2
	Centriscidae	1	1	2	0	0	0

	Haemulidae	0	2	2	2	2	4
	Holocentridae	1	1	2	1	1	2
	Labridae	4	8	12	5	11	16
	Lethrinidae	1	1	2	1	1	2
	Lutjanidae	1	3	4	2	2	4
	Monacanthidae	1	1	2	0	0	0
	Mullidae	1	1	2	2	2	4
	Ostracidae	1	1	2	1	1	2
	Ogcocephalidae	0	1	1	0	0	0
	Nemipteridae	1	0	1	0	0	0
	Pempheridae	1	1	2	1	0	1
	Plotosidae	0	1	1	1	0	1
	Pomacanthidae	1	1	2	2	1	3
	Pomacentridae	5	6	11	40	103	143
	Scaridae	1	1	2	0	0	0
	Scorpaenidae	1	1	2	0	0	0
	Serranidae	1	1	2	0	0	0
	Siganidae	0	2	2	2	4	6
	Synodontidae	1	1	2	0	0	0
	Tetraodontidae	1	1	2	0	0	0
	Zanclidae	0	1	1	0	0	0
TOTAL	28	37	51	88	88	149	237

Legend:

0 – 200 very poor; 201 – 676 poor; 677 – 2,267 moderate; 2,268 – 7,592 high; 7,593 above very high

Table 4 Environmental Parameters

Period	Project Areas					
	Badiang		Suba		Candabong	
	Temp ˚C & Time	Salinity (Ppt)	Temp ˚C & Time	Salinity (Ppt)	Temp ˚C & Time	Salinity (Ppt)
Feb 6, 2015	24 (08:00AM)	33	24 (08:20AM)	35	24 (08:40AM)	35
Mar 6, 2015	23 (08:00AM)	33	23 (09:00AM)	35	23 (09:20AM)	35
Apr 3, 2015	26 (08:00AM)	34	26 (08:40AM)	35	26 (09:00AM)	35
May 8, 2015	28 (08:00AM)	35	28 (08:20AM)	35	28 (08:40AM)	35
Jun 5, 2015	29 (08:00AM)	35	29 (08:30AM)	35	29 (08:50AM)	35
Jul 10, 2015	26 (08:00AM)	35	26 (08:30AM)	35	26 (08:50AM)	35
Aug 7, 2015	32 (11:00AM)	35	32 (11:30AM)	35	32 (11:50AM)	35
Sep 4, 2015	29 (08:00AM)	30	29 (08:20AM)	31	29 (08:40AM)	35
Oct 9, 2015	31 (11:00AM)	30	31 (11:30AM)	32	31 (12:00NN)	35
Nov 6, 2015	32 (11:00AM)	30	32 (11:20AM)	30	32 (11:40AM)	35
Dec 4, 2015	28 (08:00AM)	29	28 (08:40AM)	30	28 (09:00AM)	35
Jan 8, 2016	26 (08:00AM)	30	26 (08:30AM)	31	26 (08:50AM)	35

CONCLUSION

After year of transplanting corals in the degraded reef areas, it was concluded that the corals transplanted in the cliff/wall area with water depth from 5 to 15 m has excellent survival rate than the coral fragments transplanted in rolling substrates with water depth from 4 to 5 m during lowest tide. Another was, the rehabilitated areas with strict enforcement of no-take zone policy was able to improve the fish population from very poor to high fish condition if based on the standardized fish condition index, and with the occurrence of different species like sea slugs, seahorse, sea turtle, leopard anemone shrimp, eagle ray, and whale shark.

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Research article

Mobility Assessment for Sustainable Rural Development: Conversion of Conventional Mobility Data and Historical Analysis

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Abstract Dawei Special Economic Zone (DSEZ) Project is one of the largest petrochemical industrial estates in South East Asia which aims to transform the country into a pivotal hub for regional connectivity and logistics. Socio-economic factors determine local lifestyles, including mobility pattern, and directly impact on rural sustainability. Changes in mobility may represent not only generating alternative opportunities associated with socio-economic development, but also the vulnerability of rural people which can be a significant challenge for social sustainability in a rural area. Consequently, mobility can be one of the powerful indexes to assess impacts resulted in socio-economic changes in a long-term. The objectives of this paper are to: convert conventional mobility data to spatiotemporal data and visualize them; and to assess the change of mobility in 2005, 2010 and 2015 with respect to social parameters such as sex and age. A total of 345 individual respondents were stratified-randomly selected for assessing one-day mobility. Conversion of conventional mobility data was conducted using online maps. Historical analysis of mobility data was conducted after performing mobility data validation. The result shows that different mobility was observed by sex and age group. Average increases of males' mobile distance between 2005/2010 and 2010/2015 show 2.6 and 1.7 times increase, while that of females shows 1.6 and 2.6 times, respectively. Especially, working age females show a high increase in 2010/2015. The study concluded that mobility data obtained in different formats in different time periods can be integrated and visualized for long-term mobility assessment. This contributes to better understand how local people is responding to such socio-economic development. Mobility can be an important parameter and further provides significant perspectives to policy development for sustainable rural development.

Keywords mobility, GPS-Logger, Myanmar, rural development, socio-economic changes

INTRODUCTION

The economic transition from an isolated country to opening up to the global economy is creating opportunities to develop a high potential for economic growth for Myanmar. Dawei Special Economic Zone (DSEZ) is one of the newly emerging largest petrochemical industrial estates in South East Asia. This aims to transform the country into a pivotal hub for regional connectivity and logistics. This project includes the development of the Dawei deep seaport, an industrial estate and highway road and rail links to Thailand with a total investment of 8.6 billion US$ (Mahesuan Kruewan, 2014).

In developing countries, socio-economic factors determine local life styles, including mobility pattern, and directly impact on rural sustainability. Changes in mobility may represent not only generation of alternative opportunities associated with socio-economic development, but also the vulnerability of rural people. This vulnerability is a significant challenge for social sustainability in a rural area. As sociological diversity such as age, sex, and economic status generates different mobility pattern, it is needed to understand heterogeneous diverse local impacts from socio-economic development for aiming sustainable rural development.

The increased flow of foreign investment in the telecommunication sector in Myanmar has facilitated to the mobile phone penetration (World Bank, 2015); therefore, ways of obtaining mobility data have been largely shifted from conventional methods such as questionnaire survey and diaries to Global Positioning System (GPS) survey by loggers and mobile phones. However, conventional mobility data can be mainly displayed as static (Sheller and Urry, 2006), and is visualized only at the individual level (Yu and Shaw, 2004). On the other hand, comparison of two different mobility data set obtained in different format was mainly studied only in the developed countries including Australia, Canada, Sweden, Switzerland, the UK, and the USA where geographic information has been well developed (Kelly, Krenn, Titze, Stopher, and Foster, 2013; Stopher, FitzGerald, and Xu, 2007). Furthermore, disaggregated mobility analysis by sociological components has not been focused. In this regard, integrating two different mobility data obtained in different formats in different time periods is needed for a long-term mobility assessment.

Therefore, the objectives of this study are to: (1) convert conventional mobility data to spatiotemporal data and visualize mobility data, and (2) assess mobility changes in 2005, 2010 and 2015 with respect to social parameters such as sex and age. This research is expected to contribute to integrate different mobility data set and assess a long-term mobility for rural sustainability associated with the socio-economic development.

METHODOLOGY

Study Area and Data Set

The study area is located in Dawei, Tanuntharyi Region, Myanmar, 132 km from the border of Thailand. The DSEZ consists of five zones such as heavy, medium, light industry and a combination of these, with a total area of 250 km^2 (Min & Kudo, 2012). Villages in the DSEZ mainly depend on agricultural activities such as plantation and paddy cultivation; however, the project development has led to the reconstruction of villagers' mobility patterns due to the creation of employment opportunities and development of roads. The study purposively selected rural villages dependent on rural agricultural activities (Fig. 1).

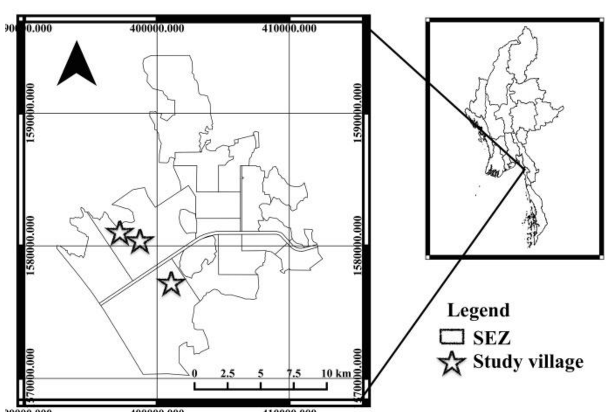

Fig. 1 SEZ in Dawei

A field survey was conducted in 2015 to collect mobility data and personal profiles. Stratified random sampling by sex and age was employed to understand characteristics of mobility. Non-spatial personal attributes such as age, sex, marital status, education level, household status, occupation, monthly household income and mobile mode were collected through a pre-tested questionnaire conducted earlier in 2014. Spatial information such as origin, destination, direction, distance, and duration in 2005, 2010 and 2015 was also collected. The study also employed formal and informal interviews with key informants such as village heads, using checklists.

Wearable GPS components such as " i-gotU USB Travel & Sports Logger – GT-600" were used to log mobility and validate the questionnaire mobility data. This device recorded 24-hour mobility with a 5-second interval using the motion detection mode. A maximum of 38 devices was distributed at one time to a total of 345 respondents aged over 16 years old. Both questionnaire and GPS log data are available from the 345 samples.

Research Flow

The following Fig. 2 is the overall methodology consists of four major steps. First, mobility data from the questionnaires was indexed and converted to spatiotemporal information such as time, speed/hr., direction, and geographical coordinate by utilizing online mapping service. Those converted mobility data was visualized in an animation format. All indexed spatiotemporal data are listed in a timeline and saved in a comma-separated values (csv) format. Simultaneously, non-spatial attributes such as age, sex, marital status, education level, household status, occupation and household income, were also integrated with the file. Visualization of the mobility was done using the visualization tool such as Mobmap (Center for Spatial Information Science, n.d.). Details of the moving segment such as the total number of mobility, mobile distance, and mobile duration were manually calculated from the questionnaires and listed. In this study, a single mobility is defined from a staring from a location to a destination, such as from home to a workplace.

Second, stay point and moving point extraction from GPS log data was performed. The spatiotemporal data such as time, latitude and longitude were extracted from the devices. The split of segments was conducted to extract stay points with outlier detection and removal technique utilized by Witayangkurn et al., (2013) Eq. (1):

$$Distance\ (p_{start}, p_{end}) < D_{threh}\ and\ TimeDiff\ (p_{start}, p_{end}) > T_{threh} \quad (1)$$

Where the parameters D_{threh}, considerable maximum distance as a stay point, and T_{threh}, minimum time spending at the same place, are adjustable. In this study, a stay point is detected if $T_{threh} > 20$ minutes and $D_{threh} <= 300$ meters. Extracted stay points are listed by start-time, end-time, duration, distance in meters, average speed in km/hr and the total number of stay points. Additionally, outlier detection and noise removal technique were applied by using standard deviation (σ).

Third, validation of two data sets was performed with respect to the selected parameters. The following Eq. (2) was used to calculate differences in the number of one-day mobility, mobile distance, and mobile duration.

$$Relative\ Change\ (x, y) = Absolute\ difference/\ Max\ (x, y)*100 = |\triangle|/\ Max\ (x, y)*100 \quad (2)$$

Where x is the data from the questionnaire and y is the data from the GPS loggers.

Fourth, changes in these parameters in 2005, 2010 and 2015 were further analyzed based on social parameters such as sex and age. In this process, mobility made out of villages such as in Yangon and Thailand, and unfixed mobility such as daily employment at various places within or outside the villages, were excluded.

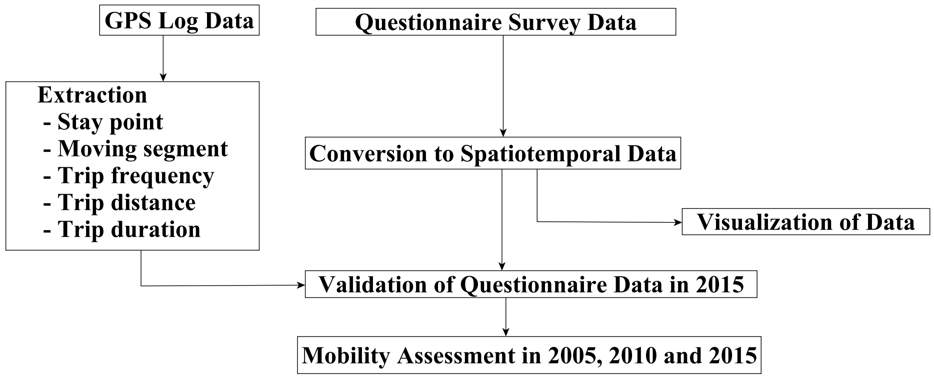

Fig. 2 Overall methodology

RESULTS AND DISCUSSION

Conversion of Questionnaire Mobility Data to Spatiotemporal Data and its Visualization

Mobility data obtained from the questionnaire survey was indexed and converted to the spatiotemporal data (Fig. 3). All mobility data is simultaneously visualized and shown in an animation format (Fig. 4). Those mobility data can be also displayed according to the attributes obtained from questionnaires. As traditional mobility data such as questionnaires and diary can be only displayed at the individual level (Yu and Shaw, 2004), visualization of a large volume of mobility data is difficult to display simultaneously and compare historical mobility. However, the study result makes mobility data visualize simultaneously, as a result, more useful mobile characteristics in different time periods can be extracted. Illustrative visualization is easy to understand and more information can be obtained for a better understanding of the underlying tendency behind the data (Andrienko, Andrienko, & Augustin, 2007).

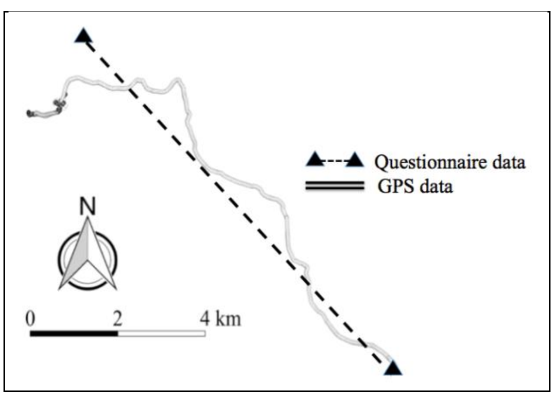

Fig. 3 Conversion of questionnaires data

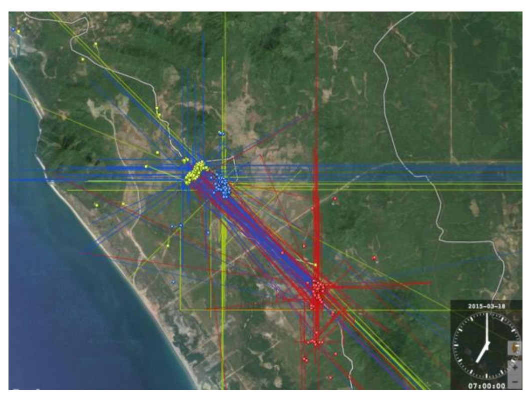

Fig. 4 Visualization of questionnaire mobility data

Comparison of Two Data Sets

To validate the questionnaire survey data, the average differences between two data sets were calculated. This reveals a total of 543 mobility, with a total 1,936.3 km of mobile distance and 7,457.0 minutes of mobile duration from the questionnaires while data from the GPS log shows a total of 403 mobility, 2,302.0 km of mobile distance and 7,403.6 minutes of mobile duration. The result shows the average differences between the two data sets as 25.1%, 34.9% and 38.0% in the number of mobility, mobile distance and mobile duration, respectively (Table 1). Those differences between the two data sets can be generated from different setting during data processing or understanding of individual mobility among local people. Several studies conducted in the developed countries such as Australia, United State of America and the United Kingdom show much larger differences in mobile duration between GPS and self-reported data, 75.4%, 62.4%, 46.7%, respectively (Kelly et al., 2013). In this line, the level of error allows us to utilize the mobility data in 2015, 2010 and 2005 obtained from the questionnaire survey.

Table 1 Average difference of two data sets

	Average differences (%)
Number of Mobility	25.1
Mobile Distance	34.9
Mobile Duration	38.0

Change in Mobility

Mobile distance in 2005, 2010 and 2015 was compared and the results of yearly change are described in Table 2. The results show that the number of mobility does not show much difference over a period of 10 years. Mobile distance increases yearly and the changes are 1.9 (2005-2010), 2.1 (2010-2015) and 4.1 (2005-2015) times. Mobile duration also increased in 2010; however, in 2015, it again decreased to a duration similar to 2005. Based on these trends, it can be said that the main change in mobile behavior is the increase of the mobile distance and this can result from the change in modes such as walking, traveling by motorbike, car or other modes. It can be confirmed that as the mobile distance increases, the mode also changes. Indeed, the motorbike mode increased 5.9 times from 2005 (9.2%) to 2015 (54.0%). Furthermore, project-induced employment opportunities as local project staff, surveyors, and road construction workers have largely contributed to this mobility increase.

Table 2 Average number of mobility, mobile distance and mobile duration by year

	2005	2010	2015
Number of Mobility	2.3	2.1	3.0
Mobile Distance (km)	2.3	4.1	9.2
Mobile Duration (min)	40.6	58.4	46.0

Change in Mobile Behavior by Sex and Age

Sex and age are among the important parameters for assessing mobility change. The mobile distances in 2005, 2010 and 2015 were compared with respect to sex and age (Table 3 & 4). The average increase rate of mobile distance during 2005-2010 and 2010-2015 is 2.6 and 1.7, and 1.6 and 2.6 for males and females, respectively.

The notable increase in the female age group 16-20 years during 2010-2015 (2.9 times) is due to occupational changes from being a student to working in agriculture, non-agriculture and other activities. Furthermore, some females travel to a city university, so making the search for higher education is one of the main driving factors for this age group. The higher increase rate for the female age group 21-30, and 31-40 years during 2010-2015 (4.9 and 3.7 times, respectively) is also found resulted in their engagement in project-related employment, including as office staff and as laboratory workers at the project camp, and business work in the city. This large increase was generated with the combination of a significant increase in the use of motorbike mode of travel to work. On the other hand, for the male age group 31-40, and 41-50 years, the rate during 2010-2015 decreases by 1.3 and 1.2 times, respectively. This is probably due to non-significant changes in occupation for males.

Furthermore, for the male age group 51-60 years, the rate during 2010-2015 increases by 3.0 times. This notable increase is the result of increased engagement in non-agricultural activities, such as driving car taxis.

Based on the findings of this study, it can be said that surrounding socio-economic development largely affects local activities. Furthermore, occupation and mobility modes are significant factors influencing the mobility of the villages.

Table 3 Average mobile distances by sex and age group

	2005		2010		2015	
Age	M	F	M	F	M	F
(A) 16-20	1.2	1.2	4.3	4.0	7.3	11.6
(B) 21-30	4.8	1.1	5.9	1.7	11.1	8.3
(C) 31-40	3.0	2.2	8.9	1.1	11.9	4.1
(D) 41-50	3.4	2.2	11.1	2.7	13.4	7.5
(E) 51-60	4.0	3.1	6.1	4.1	18.3	1.7
(F) 61<	1.4	0.9	4.2	1.5	5.7	1.6
Average	2.8	1.8	6.5	2.8	11.6	6.8

Note: M stands for male and F stands for female
Unit is km

Table 4 Increase rate of mobile distance

	2005-2010		2010-2015	
Age	M	F	M	F
(A) 16-20	3.6	3.3	1.7	2.9
(B) 21-30	1.2	1.5	1.9	4.9
(C) 31-40	3.0	0.5	1.3	3.7
(D) 41-50	3.3	1.2	1.2	2.8
(E) 51-60	1.5	1.3	3.0	0.4
(F) 61<	3.0	1.7	1.4	1.1
Average	2.6	1.6	1.7	2.6

Note: M stands for male and F stands for female

CONCLUSION

Socio-economic developments reconstruct local livelihood. Mobility largely represents changes of activities associated with the development. Thus, this study conducted mobility assessment in a long-term by integrating two different data sets in different formats in different time period, and visualized them. Mobility data from questionnaire survey was converted to spatiotemporal data and visualized together with GPS data in an animation format. Those mobility data from questionnaires was further validated by GPS log data for assessing historical mobility pattern. Mobility trend during 2005-2015 with respect to social parameters was further analyzed. Large increases in motorbike-based mobile distance for working age females employed either with the project or in non-agricultural activities were found. This mobility assessment and its visualization contribute to better understand activity changes and it diversity associated with project development. Mobility can be a powerful parameter to assess both opportunity and vulnerability along with the huge and accelerated project development. This further provides significant perspectives to policy development for sustainable rural development.

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Research article

Reducing Cadmium and Copper Uptake of Soybeans by Controlling Groundwater Level and its Impacts on Growth and Yield

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Abstract In Japan, cadmium (Cd), copper (Cu) and arsenic have been designated as specific harmful substances in the Agricultural Land Soil Pollution Act. Though the safety standards of these substances have not been provided for upland field crops in Japan, it is important to minimize the concentration of these contaminants in agricultural products for both international trading and our health. The objective of this study is to clarify the effects of controlling groundwater levels on Cd and Cu uptake and growth and yield of soybeans. For this experiment, three plastic containers were prepared, and then 14cm-thick of non-contaminated gravel, 15cm-thick of non-contaminated soil (0.12 mg Cd kg^{-1}; 2.4 mg Cu kg^{-1}) and 25cm-thick of contaminated soil (2.24 mg Cd kg^{-1}; 43.4 mg Cu kg^{-1}) were placed in this order from the bottom of each container. Then the groundwater level of each container was maintained as 5cm (GL5), 10cm (GL10) and 40cm (GL40) during the growing period. As a result, Cd and Cu concentration of soybean seeds of GL5, GL10 and GL40 were 0.25, 0.52 and 1.07 mg Cd kg^{-1}, respectively, and 5.08, 5.82 and 9.96 mg Cu kg^{-1}, respectively. Significant difference in both Cd and Cu concentration of soybean seeds were found among three models at 5% level. On the other hand, growth and yield of soybeans tended to decrease with the rise of the groundwater level. Noticeably, plant heights and weights of a hundred grains were significantly different among these three models. From the above, it can be concluded that controlling groundwater levels can reduce Cd and Cu uptake and affect growth and yield of soybeans.

Keywords soybeans, uptake of cadmium and copper, control of groundwater level, growth and yield

INTRODUCTION

Soil contamination in arable lands is a threat to human health through the intake of agricultural produce. In Japan, since there has been some serious problems as seen in such grave impacts of heavy metals in the cases of itai-itai disease induced by cadmium (Cd) and a decrease of rice yield affected by copper (Cu) (Yamane et al., 1997), “Agricultural Land Soil Pollution Act” was passed into law in 1970. According to this law, Cd and Cu, and arsenic were designated as specifically harmful substances (Kobayashi, 1978). In 2010, the safety standard for Cd in brown rice was lowered to 0.4 mg kg^{-1} in Japan, while other countries such as countries in the EU, China, Australia, etc., have stricter standards (MAFF, 2015). The safety standards for upland crops have not been provided yet in Japan. However, studies for reconsideration of Cd standards have been conducted as consumers’ interests in safety and security of food (MAFF, 2007).

In Japan, an expansion of growing areas of soybeans is one of the important counter- measures for increasing calorie based food self-sufficiency rate. Some countries provide the safety standard of Cd in soybean seeds as 0.2 mg kg^{-1}, while in Japan, Cd concentration in soybean seeds which have been produced even in non-contaminated field often exceeds this value (MAFF，2004). It is inferred, therefore, that soybeans produced in Cd-contaminated and semi contaminated fields may contain much more Cd. Thus there is real concern that Japanese domestic soybeans will not meet the standards of export-partner countries such as United States and Hong Kong etc. (Ishitsuka and Jindai, 2013) in international trading. As for Cu in soybeans, it is a future task for Japan to provide a safety standard value, while some other countries already have such, e.g., 20 mg kg^{-1} in China (MAPRC, 2005).

As similar to the case of paddy fields, some techniques for reducing Cd uptake of soybeans e.g., soil dressing, chemical methods such as controlling pH, and phyto -remediation etc. have been evaluated recently (Akahane et al., 2013; Dong et al., 2007）. These measures, however, cost much money and take a long time, and so they have not been implemented widely yet (Haque et al., 2014a, b). Furthermore, soil dressing needs a large amount of soil and so it causes a heavy environmental burden (MEGJ, 2010).

As a cost-saving and easy technique, Murakami et al. (2011) and Haque et al. (2014a, b) reported that the Cd uptake of soybeans decreased by controlling oxidation reduction potential of the plowed layer by changing the groundwater level since Cd becomes insoluble under a reduction condition.

Cu also becomes insoluble under reduction condition (Matsui and Okazaki, 1993) and thus it is expected that controlling the groundwater level is also effective in reducing the Cu concentration in crops. The effects of a shallow groundwater level, especially higher than 10cm, on the Cu uptake of crops have not been evaluated yet and neither the distribution of Cu in soybean plant bodies. Heretofore groundwater level was controlled by relief well and insoluble condition of Cu by pH control amendment was made (Matsui and Okazaki et al., 1993; Yamane et al., 1997).

Against this background, the objective of this study is to clarify the effects of the controlling groundwater level on Cd and Cu uptake and growth and yield of soybeans. To achieve the purpose, growing tests of soybeans were conducted by using Cd- and Cu- contaminated soil samples. During the experiments, the groundwater level was maintained as 5, 10 and 40cm to control the thickness of soil layer, in which Cd and Cu was soluble.

This study will help to clarify the effects of rice-soybean crop rotation in contaminated ill- and/or well-drained paddy fields on Cd and Cu uptake of soybeans and to develop techniques for reducing Cd and Cu uptake with a low cost.

MATERIALS AND METHODS

Soil Properties

In this experiment, we used soil sampled from the plow layer of a paddy field which had been contaminated with agricultural water from mine drainage. Non-contaminated soil had been sampled from the plow layer of the paddy field at Kanagi farm of Hirosaki University, Aomori prefecture, the northeastern part of Japan. Gravels had been collected from a nearby mountain, Mt.Iwaki, Aomori prefecture.

Chemical and physical properties of the soil samples are shown in Table1. Soil textures of contaminated and non-contaminated soil were both clay loam. Cd concentration in contaminated soil, non-contaminated soil and gravels were 2.27, 0.12 and 0.13 mg kg^{-1}, respectively while Haque et al. (2014a, b) had used contaminated soils of 3.39 and 1.57 mg kg^{-1}. Cu concentration in the contaminated and non-contaminated soil in this study was 43.4 and 2.4 mg kg^{-1}, respectively. The contaminated soils in this study contained seven times and twice as much Cd and Cu, respectively, as those in the average non-contaminated agricultural lands in Japan, the figures of which are 0.33 mg Cd kg^{-1} and 24.8 mg Cu kg^{-1} (Asami, 2010).

Table 1 Physical and chemical properties of the soil samples

Sample	Density (g cm^{-3})	Soil Texture	MgO *	Na_2O *	CaO *	K_2O *	Cu *	Cd *	T-N (%)	T-C (%)	C/N	OM (%)
Polluted Soil	2.57	CL	224	96	2032	232	43.4	2.27	0.28	3.39	12.2	5.86
Non-Polluted Soil	2.54	CL	120	64	400	120	2.4	0.12	0.16	2.07	13.3	3.62
Gravel	2.68	-	147	18	539	58	1.5	0.13	0	-	-	0.05

*Note: Soil texture is based on the International Soil Society classification. CL: Clay loam. Gravel diameter size 2-4mm. *mg kg^{-1}*

Experimental Design

In this study, a growing test of soybeans was conducted with stratified field models. Three plastic containers (41×61×63 cm) were prepared and then they were packed with 14cm-thick of gravels (dry bulk density ρ_d=1.40 g cm^{-3}), 15cm-thick of non-contaminated soil (ρ_d=0.89 g cm^{-3}) and 25cm-thick of contaminated soil (ρ_d=0.80 g cm^{-3}) in this order from the bottom of each container. After packing the samples, oxidation reduction potential sensors were inserted at depths of 2.5, 7, 9, 12.5, 14.5, 22, 32, 37, 42cm. Soil temperature sensors were also buried at depths of 5, 15, 25 and 35cm in each container. During the experiment period, the groundwater level of each container was maintained as 5, 10, and 40cm; hereafter we call the models GL5, GL10 and GL40, respectively.

Cultivation Procedure

We used *Ryuho* soy bean (*Glycine max* (L.) *Merr.cv.Ryuho*) as the breed variety of our cultivation experiment. The holes of 3 to 5 cm diameter at the four positions in each container were made, and then 5 to 6 grains were seeded in June 15, 2014. Thinning out was done in 15 days after germination and left two of normal growth. Harvesting was conducted between late September and early October, which is the grain filling period in Japan. The groundwater level after seeding was 15cm, the ground water levels after germination were 5, 10 and 40cm. The authors used Marriott bottles to control the groundwater levels and checking of each groundwater level was carried out by using three groundwater pipes attached to the containers. The recommended amount of chemical fertilizer for *Ryuho* soy bean was added. 2L of irrigation water was supplied in 4-days intervals (equivalent to 2.0 mm d^{-1}). Protection treatment was done when it was necessary.

Measurement Method

Oxidation-reduction potential (ORP) electrodes were installed for measuring oxidation-reduction potential at arbitrary depths of the soil boxes. Measuring with the ORP meters (model UC-23, Central Kagaku co. Ltd) was conducted during the entire period of cultivation experiment. The growth and yield assessments such as plant height, leaf age, branching, pod number and 100-grains weight, were carried out based on the cultivation guideline of soybean in Akita Prefecture (Akita Prefecture, 2015). After harvesting, Cd and Cu were extracted with HCL and HNO_3 and their concentration in stem and leaf, root, grain and soil, was quantified by analyzing their specimens with the atomic absorption spectrophotometry (MAFF, 1979). Other physical and chemical properties of the soil was also measured with the standard methods in Japan. We found a significant difference in the results of growth and yield assessments by using the Tukey-Kramer method.

RESULTS AND DISCUSSION

Oxidation-Reduction Potential (Eh)

For a long time, the reduction condition of soil has been known to cause insolubility of Cd and Cu, this has been utilized to Cd uptake suppression (Yamane et al., 1997). That is, by increasing the solubility of Cd and Cu in the soil in the oxidation condition, the uptake of these heavy metals from plant roots is promoted. On the other hand, it is known that the uptake of these heavy metals is inhibited when their solubility is reduced in the reduction condition. In the oxidation-reduction potential (Eh), the oxidation layer and the reduction layer are defined as Eh≧300mV and Eh＜300mV, respectively (Iimura, 1981).

Measured Eh values on each of the groundwater levels are shown in Figs.1, 2 and 3. In the GL5 container (Fig.1), Eh values measured at the 2.5cm depth was an oxidation layer of about 600mV; however, below the 7cm depth Eh values indicated reduction condition. In the GL10 container (Fig.2), Eh values at 2.5cm and the 7cm depths indicated more than 500mV; however, Eh values measured below the 12cm depth was a reduction layer of Eh ＜ -100mV. In the GL40 container (Fig.3), except for Eh values measured at the 42cm depth, all of the observation depths became oxidation layers of Eh ≧ 500mV.

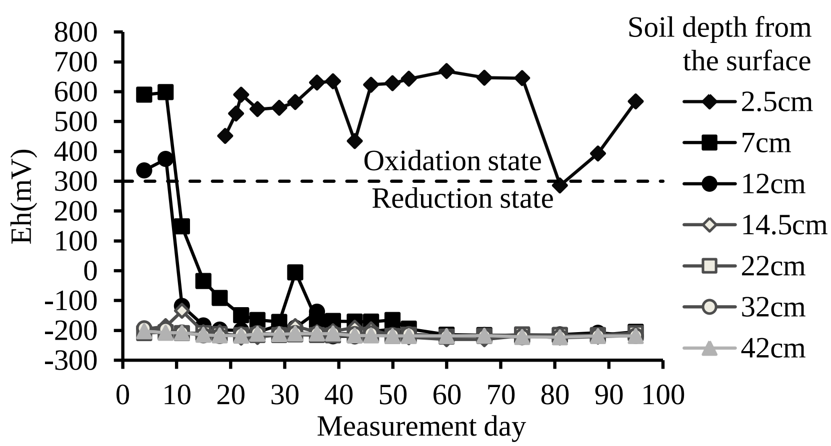

Fig.1 Temporal changes of Eh with GL5

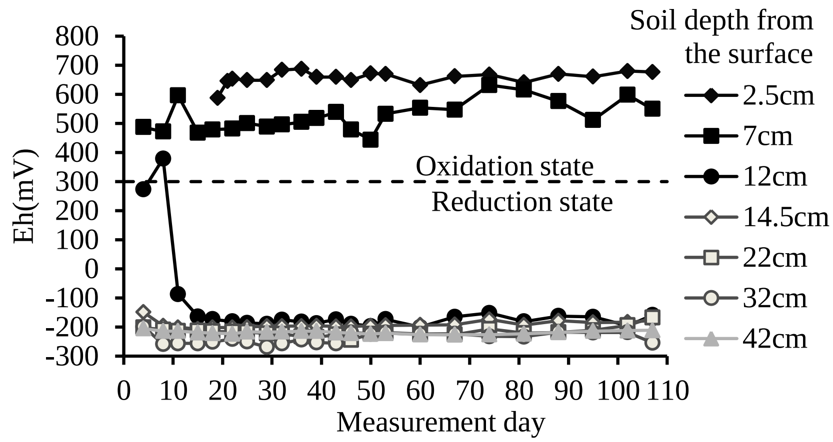

Fig.2 Temporal changes of Eh with GL10

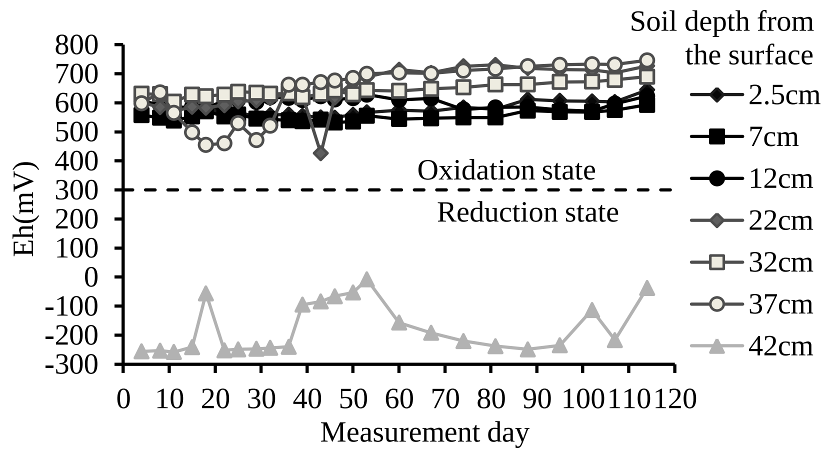

Fig.3 Temporal changes of Eh with GL40

From these results, it became apparent that controlling the upper part of the groundwater table to be an oxidation layer and the part below the groundwater table to be a reduction layer can be possible. It is inferred from this that thickness of supply layer of solubilized Cd and Cu are estimated as about 5cm for GL5, about 10cm for GL10, and about 40cm for GL40. From the temporal changes of Eh values measured at each level of the groundwater table, after clarifying the oxidation-reduction environment of the root zone, preparation for comparing values of the uptake behavior of Cd and Cu can be said to have been established. Although the values of heavy metal concentration in the contaminated soil were different, the vertical directions of Eh distribution controlled in the GL10 and the GL40 models were almost the same as the result of Haquet al. (2014a, b). In addition, it is estimated that the Eh values in the canonical paddy field depend on the soil crashing rate, the amount of organic matter, and soil pH.

Cd and Cu Concentration in Soybean Plants

Cd concentration in soybean seeds was GL5 (0.25mg kg^{-1}) < GL10 (0.52mg kg^{-1}) < GL40 (1.07mg kg^{-1}) and there were significant differences among the three treatments ($p < 0.05$) (Table 2). Those values were three to ten times greater compared with Cd concentration in soybeans in non-polluted soil (Murakami et al., 2011). Cd concentration in stems was GL5 (0.28mg kg^{-1}) < GL10 (0.45mg kg^{-1}) < GL40 (1.48mg kg^{-1}) and there were little significant difference between GL5 and GL10. However, there was significant difference between GL5 and GL40, and also between GL10 and GL40 ($p < 0.05$). Cd concentration in roots was GL10 (3.54mg kg^{-1}) < GL5 (4.92mg kg^{-1}) < GL40 (5.80mg kg^{-1}) and there was a significant difference between GL10 and GL40 ($p < 0.05$). The trend of Cd concentration in soybean plants were seed < stem < root as found by Haque et al. (2014a, b). Cd concentration in seeds was about 1/10 compared with the one in roots in the case of GL5 and GL10. Cd concentration in seeds was about 1/5 compared with that of roots in the case of GL40. It is thought that Cd concentration in soybean plants is affected by the groundwater level. Cd concentration in seeds was 0.25mg kg^{-1} in the GL5 treatment and it was close to the standard Cd content in non-polluted soil (MAFF, 2004). There is a high possibility that Cd concentration in soybean seeds can be suppressed when soybeans are cultivated in poorly drained Cd-contaminated paddy field. From these results, it was considered that the control of the groundwater level had the effect of reducing the Cd concentration in soybean seeds.

Table 2 shows Cu concentration in soybean plants. Cu also change the solubility by oxidation-reduction potential as well as Cd. Cu concentration in soybean seeds was GL5 (5.08mg kg^{-1}) < GL10 (5.82mg kg^{-1}) < GL40 (9.96mg kg^{-1}) and there were significant differences among the three treatments at $p < 0.05$. The average Cu concentration in edible soybeans in Japan, the United State and China is 0.97-1.07 mg kg^{-1} (MEXT, 2016). The Cu concentration found in our current study was about five times higher than the above figure. One reason may have been that the Cu concentration in the soil we used this time was twice higher than the average Cu concentration in typical Japanese soil. Cu concentration in stems was GL5 (2.45mg kg^{-1}) < GL10 (2.76mg kg^{-1}) < GL40 (5.58mg kg^{-1}) and there was little significant difference between GL5 and GL10. However, there were significant differences between GL5 and GL40, and also between GL10 and GL40 ($p < 0.05$). Cu concentration in roots was GL40 (14.06mg kg^{-1}) < GL10 (39.48mg kg^{-1}) < GL5 (50.04mg kg^{-1}) and there were little significant difference between GL5 and GL10. However, there was significant difference between GL5 and GL40, and also between GL10 and GL40 ($p < 0.05$). The trend of Cu concentration in soybean plants was stem < seed < root. Cu concentration in seeds, however, was higher than that in stems unlike Cd concentration in the plant. It is thought to be due to transfer characteristics of Cu in soybean plants. Cu concentration in roots in GL5 and GL10 was twice higher than that of GL40. The morphological characteristic of roots is that there are many thick roots in the GL40 treatment and many fine root mat in the GL5 and GL10 treatments. The different root morphology may have affected the uptake of nutrient by soybeans. Cu concentration in soybeans at low groundwater levels was relatively high. Cu concentration in soybeans was higher than that in brown rice (Paul et al., 2011). Soybean seeds tend to accumulate more Cu than brown rice. Cu concentration in soybeans is defined as less than 20mg kg^{-1} in China (MAPRC, 2005). On the other hands, there is no regulation value of soybean Cu content in Japan. However, those results of ours are valuable data because soybeans are important food and Cu in this food is detrimental for human health. From the above results, the control of the groundwater level is considered to be effective in reducing Cd concentration and Cu concentration in soybean seeds.

Table 2 Cd and Cu concentration in soybean of three different groundwater levels

Model	Seed-Cd	Stem-Cd	Root-Cd	Seed-Cu	Stem-Cu	Root-Cu
GL 5cm	$0.25{\pm}0.04^{a}$	$0.28{\pm}0.02^{a}$	$4.92{\pm}1.54^{ab}$	$5.08{\pm}0.27^{a}$	$2.45{\pm}0.19^{a}$	$50.04{\pm}13.93^{a}$
GL 10cm	$0.52{\pm}0.06^{b}$	$0.45{\pm}0.09^{a}$	$3.54{\pm}0.56^{a}$	$5.82{\pm}0.33^{b}$	$2.76{\pm}0.98^{a}$	$39.48{\pm}7.51^{a}$
GL 40cm	$1.07{\pm}0.17^{c}$	$1.48{\pm}0.41^{b}$	$5.80{\pm}1.03^{b}$	$9.96{\pm}0.62^{c}$	$5.58{\pm}0.51^{b}$	$14.11{\pm}3.66^{b}$

Note: Small letter indicates significant difference at 5% level according to Turkey-Kramer test; ± shows standard deviation. For Seed Cd analysis (n=8); for other cases (n=5). Unit: mg kg^{-1}

Soybean Yield and Its Components

Soybean yield and its components are indicated in Table 3. Average stem heights (n=8) were GL5 (59.7

cm) < GL10 (66.8 cm) < GL40 (78.8 cm). Significant differences were recognized among the three models. Murakami et al. (2011) and Haque et al. (2014a, b) reported that in excess soil moisture condition, soybean plants do not grow well after the germination and result in low yield. A similar result was obtained in this study that the high groundwater level conditions suppress the growth of the stem.

The averages of the stem diameter and the number of seeds per pod (seed/pod) did not show any significant difference. The average of the branch number showed little significant difference between GL10 and GL40. However, there were significant differences between GL5 and GL10, and also between GL5 and GL40. The averages of good seed weight per plant were GL5 (20.5 g) < GL10 (36.2 g) < GL40 (56.3 g), showing significant differences among them. Averages of 100 seeds weight also showed a similar trend as the good seed weight. The good seed weights of GL5 and GL10 models lowered by about 36 % and 64 %, respectively, compared with that of GL40 model, which suggested that even a slight difference in the groundwater level can bring a critical effect on the soybean yield under a high groundwater level condition. According to Shimada et al. (1995), it is important to control the groundwater level according to the rain condition in actual paddy fields. Arihara (2000) reported that the soybean yield was highest in the fields with a 40-50 cm groundwater level. His finding was based on the investigation on the relationship between groundwater level and soybean yield.

The soybean yield in this experiment using Cd contaminant soil was higher under the low groundwater level condition and lower under the high groundwater level condition.

Table 3 Soybean yield components of three different groundwater levels

Model	Stem height (cm)	Stem diameter (cm)	Branch No.	Seed/Pod	100 seed wt. (g)	Good seed wt. (g)
GL 5cm	59.7±6.3[a]	7.1±0.9[a]	3.6±0.9[a]	1.6±0.2[a]	28.3±2.3[a]	20.5±8.9[a]
GL 10cm	66.8±3.8[b]	7.6±0.8[ab]	5.1±0.8[b]	1.6±0.2[a]	37.2±2.1[b]	36.2±6.3[b]
GL 40cm	78.8±5.2[c]	8.5±0.7[b]	5.5±1.1[b]	1.6±0.1[a]	40.0±1.8[c]	56.3±4.7[c]

Note: Small letter indicates significant difference at 5% level according to Turkey-Kramer test; ± shows standard deviation. Seed weight at 15% moisture. In all case (n=8).

CONCLUSION

Soybean was cultivated in containers using Cd contaminant soil (concentration:2.27 mg kg^{-1}, thickness: 25 cm) under groundwater levels of 5 cm, 10 cm, and 40 cm with measuring the oxidation-reduction potential in the soil. Soil was in oxidation condition above the groundwater level and in reduction condition below it. Cd and Cu concentrations of stems and seeds were found to be lowered under a higher groundwater level condition. Under a higher groundwater level condition, Cd concentration in roots showed a low value but that of Cu showed the opposite result. It was confirmed, as earlier studies had reported, that growth and yield of soybeans were good when the groundwater level was low. Controlling groundwater level can be one of the simplest and most economical methods for reducing the Cd and Cu uptake by soybean plants. When we apply this method on site, relief well will be available for controlling ground water level. This can help minimizing toxic metals uptake from polluted soils of soybean cultivated fields with high groundwater level in developing countries.

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Research article

Analysis on Surface Deformation and Cracks in Paddy Fields by 2016 Kumamoto Earthquake Using GNSS and Photogrammetry

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Abstract Paddy fields in Kumamoto Prefecture were struck seriously by the 2016 Kumamoto Earthquake. The surface deformation and cracks damaged water distribution system for paddy fields. In order to clarify damages with rapidity, the surveying combining the aerial-based surveying and ground-based surveying was necessary. The aerial photogrammetry was conducted for the surface deformation and crack area, to clarify them quantitatively. The aerial photos application were photographed by airplane after earthquakes. The aerial photogrammetry by airplane is suited to compare the topographic model after earthquakes to the topographic model before earthquakes, because the topographic model before earthquakes was surveyed by airplane. The Global Navigation Satellite System (GNSS) surveying was also conducted at the ground points in the area of aerial photos. The orthophoto mosaic and the Digital Elevation Model (DEM) after the earthquakes were made from these surveying. Further, the orthophoto mosaic and the DEM after the earthquakes were input into the Geographic Information System (GIS), to analyze the surface deformation and cracks in paddy fields. The accurate positions for cracks were found by overlaying the translucent orthophoto mosaic on the existing map. The differences between the DEMs before and after the earthquakes were analyzed by overlaying the DEM after the earthquakes on the DEM before the earthquakes. As the results, it was found that the overall upheaval and the local cave-in arose in the focused paddy field. The overall upheaval was 0.0 m - 0.4 m. The local cave-in was about 2.0 m. In order to check the differences between the DEMs before and after the earthquakes expressed that, the DEM after the earthquakes was compared to the elevation value by the GNSS surveying at the verification points. As the result, it was verified that the difference was 0.118 m as standard deviation.

Keywords aerial photogrammetry, GNSS, DEM, GIS, paddy field

INTRODUCTION

The Kumamoto Earthquake was a series of earthquakes that struck Kumamoto Prefecture in the south of Japan on and after April 14, 2016. A foreshock with a magnitude on the Japan Meteorological

Agency seismic intensity scale of Mj 6.5 and with its epicenter at a depth of 11 km struck the Kumamoto area at 9:16 p.m. on April 14, 2016. At 1:25 a.m. on April 16, 28 h after the foreshock occurred, the main shock with a magnitude of Mj 7.3 and with its epicenter at a depth of 12 km struck the same Kumamoto area that had experienced the foreshock (Kato el al., 2016). Kumamoto Prefecture is highly productive in terms of agriculture, as evidenced by the fact that, before the earthquakes occurred, it was ranked the fifth most productive prefecture out of all the 47 prefectures in Japan in terms of the value of agricultural production. However, after the earthquakes, many paddy fields were seriously damaged because the vertical deformation and cracks made it impossible to irrigate them.

In this study, we conducted aerial photogrammetry and a Global Navigation Satellite System (GNSS) survey, because a survey consisting of both aerial- and ground-based studies was necessary for a prompt understanding of the complete picture of the damaged area. Aerial photogrammetry is a surveying technology utilizing ground-based three dimension (3D) models, which are constructed from photos taken from the sky, camera coordinate values, and coordinate values of ground control points (GCPs). In this study, we also built digital elevation models (DEMs) and orthophoto mosaics, because these were obtainable through the aerial photogrammetry. DEMs are models of the elevations of the land surface, excluding the heights of buildings and vegetation. An orthophoto mosaic is a single aerial photograph on which several orthographically projected aerial photographs are assembled. We conducted the GNSS surveying of the devastated areas to obtain the coordinate values of the GCPs. A GNSS surveying is a survey method to determine the positions using signals from positioning satellites such as the GPS, GLONASS and Galileo. The accuracy ranges from several meters to several millimeters, depending on the method used. In this research, we conducted a network-based real time kinematic (RTK) GNSS surveying to determine the coordinate values of the GCPs with high accuracy of several millimeters. We used the Geographic Information System (GIS) to determine the difference between the DEMs before and after the earthquakes in order to clarify the vertical deformation of the land surface in the paddy fields quantitatively.

The satellites have been used for surveying in Kumamoto (Research Group for High-resolution Satellite Remote Sensing, 2016; Obata and Iwao, 2016). The drones have been used for surveying in Kumamoto (Ishiguro el al., 2016). In this research, we considered that aerial photogrammetry by airplane would be preferable to satellite or drone for the comparison of the DEMs before and after the earthquakes, because an airplane survey had already been conducted to obtain a DEM before the earthquakes. For this reason, we used aerial photos taken from an airplane after the earthquakes. In Japan, the Geospatial Information Authority of Japan (GSI) has built a detailed database of the country’s land surface with airplanes, and it released the DEM before the earthquakes free of charge. We used aerial photogrammetry to build the DEM after the earthquakes, and analyzed the difference between the DEMs before and after the earthquakes. At the same time, we overlaid orthophoto mosaics we built from the aerial photogrammetry onto the existing maps to determine cracks on the land surface in the paddy fields.

METHODOLOGY

Figure 1 shows the target area of the survey and analysis. Kumamoto Prefecture is located in the southern part of Japan. Of the large area damaged by the earthquakes, we selected Aso City in order to focus on the damage to paddy fields. We used the photogrammetry software PhotoScan Professional, which is a structure-from-motion (SfM) software product. PhotoScan Professional allows for aerial triangulation with the help of multiple aerial photos and multiple GCPs. It creates DEMs through image matching and filtering treatments, and also creates orthophoto mosaics automatically. Fig. 2 shows the 3D model that we created. The blue rectangles in the sky show the 3D position and attitude of the aerial photographs. The circles on the land surface indicate the 3D positions of the GCPs where we conducted the GNSS surveying. The coordinate system we used is the Japanese Geodetic Datum

(JGD) 2011 Plane-rectangular Coordinate System Area 2 (Matsumura el al., 2004; Tsuji and Matsuzaka, 2004; Imakiire and Hakoiwa, 2004; Geospatial Information Authority of Japan, 2011). We successfully created a group of 3D points on the land surface through aerial photogrammetry. On the near side of the Fig. 2, the site of the landside disaster triggered by the earthquakes can be seen. The aerial photographs were taken on July 5, 2016. The digital aerial camera provides its orientation accurately because it was calibrated. Using the RTK GNSS surveying and Inertial Measurement Unit (IMU) technology, it was possible to provide the coordinate axes and attitudes of the digital aerial camera with high accuracy of several tens of millimeters.

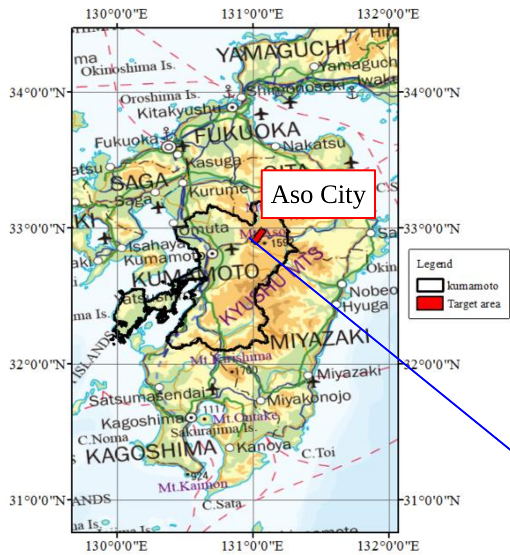

Fig. 1 Target area in Kumamoto

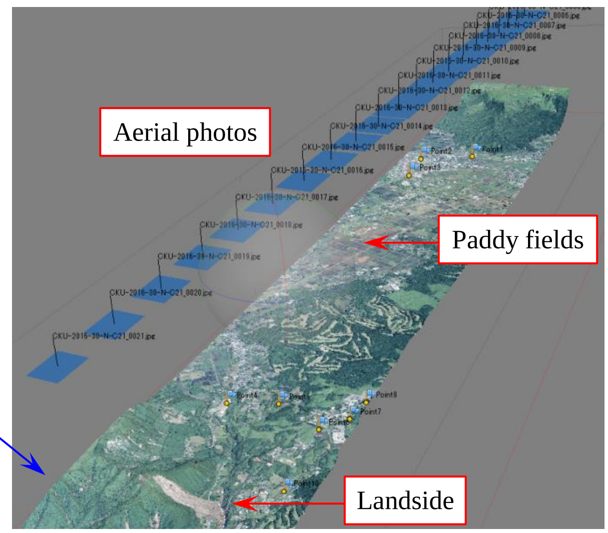

Fig. 2 3D model by aerial photogrammetry

Fig. 3 GNSS surveying

Table 1 SD values of residual errors of the most probable values of nine GCPs.

	X [m]	Y [m]	H [m]
SD	0.088	0.149	0.149

As the photograph in Fig. 3 shows, we conducted a network-based RTK GNSS surveying in Kumamoto on the 23rd and 24th of July 2016. We used the Trimble R10 for the GNSS surveying, and three types of satellite: GPS, GLONASS, and the Quasi-Zenith Satellite System (QZSS). In addition, we used two frequency bands: L1 and L2. The geoid model we used was "GSIGEO2011" (Miyahara el al., 2014; Kubodera el al., 2016). For conducting the GNSS surveying on the ground, we selected the four corners of the course, sites accessible by car, and pavements so that the aerial camera could take clear photographs. Based on the surveying calculations from the GNSS surveying, we found that the standard deviation (SD) of the most probable value was less than 0.01 m. We conducted aerial triangulation based on the 3D coordinate values of the camera and the GCPs. Table 1 shows the SD values of residual errors of the most probable values of nine GCPs. The SD values for the X and Y coordinates and elevation H were lower than 0.15 m, indicating a high accuracy. We created a DEM after the earthquakes with 1 m mesh, in order to determine the differences between the DEMs before and after the earthquakes as well as the elevation values. In addition, we created orthophoto mosaics to gain a clearer picture of the damage.

RESULTS AND DISCUSSION

Specifying the Position of Cracks with Orthophoto Mosaic

Fig. 4 shows the orthophoto mosaic developed on the GIS. For the aerial photogrammetry, we used the coordinate axis JGD2011 Plane-rectangular Coordinate System Area 2. The GIS software used was ArcGIS 10.4.1. We used the existing map as a background for confirmation of the positions. By doing this, we found that the created mosaic was developed on the designated positions correctly. The orthophoto mosaic indicates that this area consists of paddy fields. Subsequently, we set the transmission of the orthophoto mosaic at 50% and overlaid it onto the existing map to specify the positions of cave-ins. As shown in Fig. 5, we successfully specified the exact positions of the cracks. We were able to confirm cracks along the fault that occurred in the paddy fields. Fig. 6 shows a photograph taken by the second author of this study immediately after the earthquakes occurred in the area surrounding the paddy fields. It shows several cracks created along the fault. This visually confirms that there was a cave-in about 2 m deep.

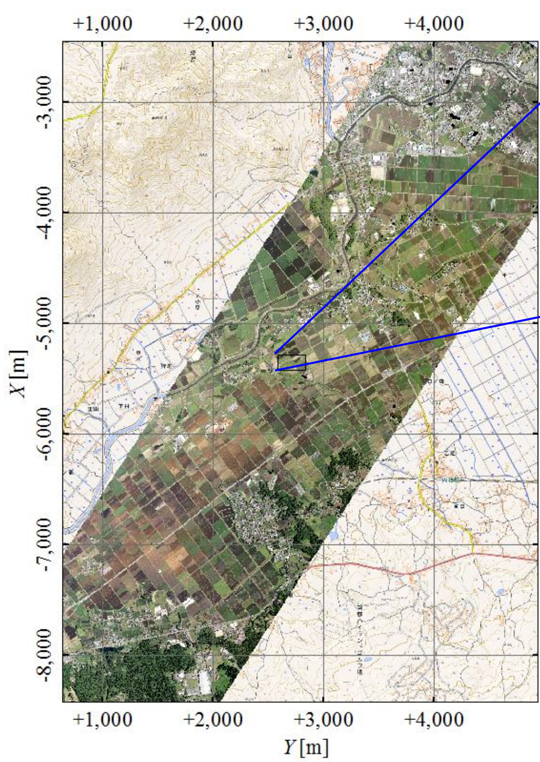

Fig. 4 Orthophoto mosaic developed on the GIS

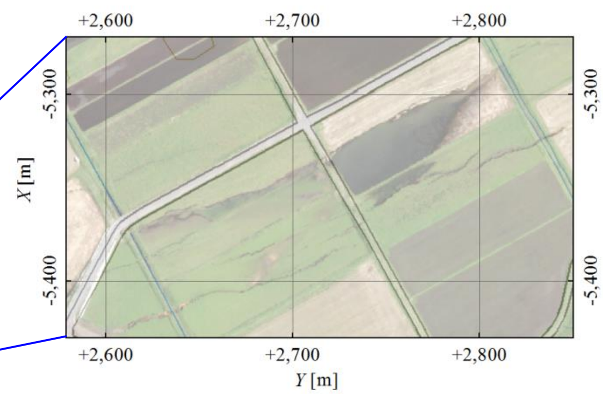

Fig. 5 Cracks in paddy fields


Fig. 6 Actual cracks

Differences between the DEMs before and after the Earthquakes

For the DEM before the earthquakes, we used the results (5 m mesh, elevation value in units of 0.01 m) obtained from the GSI. For the analysis of the difference between the DEMs before and after the earthquakes, we set the mesh sizes of the DEM before and after the earthquakes to 1 m. Fig. 7 shows the results of the analysis. We deducted the elevation values of the DEM before the earthquakes from those of the DEM after the earthquakes to obtain the differences. We blacked out the objects with a height difference greater than 3 m because these were assumed to be vegetation or buildings. The analysis results indicate that the area on which we focused underwent upheaval as a whole. When focusing on the agricultural roads, it was found that they underwent upheaval of 0.0–0.4 m. The paddy fields apparently underwent greater upheaval than the agricultural roads, but ambiguous places such as vegetation showed a low accuracy in matching. The rectangular part in the center of Fig. 7 is the cracked part shown in Fig. 5. Based on the analysis of the differences between the DEMs before and after the earthquakes, we successfully clarified the vertical deformation both dimensionally and quantitatively.

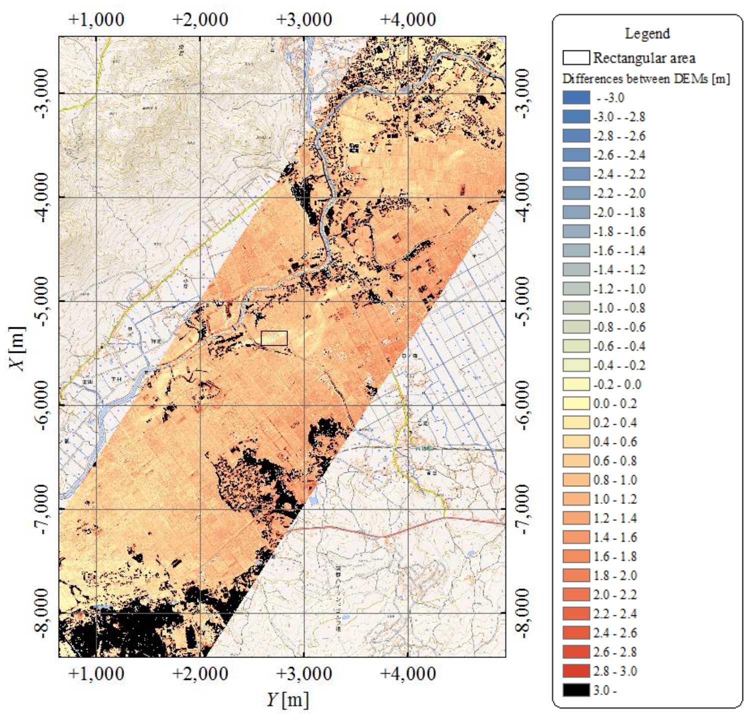

Fig. 7 Differences between the DEMs before and after the earthquakes

Accuracy Verification of Elevation Values

As Table 2 shows, we compared the elevation values of the DEM after the earthquakes and those of the GNSS after the earthquakes at verification points to verify the accuracy of the constructed DEM after the earthquakes. At these verification points, we did not adopt the GCPs by aerial triangulation, but rather conducted a GNSS surveying on the points. The GNSS showed a higher accuracy than the DEM. Based on the above results, we found that the elevation values of the DEM and the GNSS after the earthquakes closely matched each other with the discrepancies between them ranging from +0.031 m to +0.196 m. The SD of the elevation values of the DEM after the earthquakes was 0.118 m, assuming that the elevation values of the GNSS after the earthquakes were true values. That is, it is possible to state that the DEMs after the earthquakes was accurate with an SD of 0.118 m.

Table 2 Accuracy verification of elevation values

Name of point	Elevation value [m]		
	DEM after earthquake	GNSS after earthquake	Discrepancy
1	482.608	482.577	+0.031
2	479.938	479.888	+0.050
3	478.280	478.084	+0.196
		SD	0.118

Comparison of the DEMs before and after the Earthquakes with the Lateral Profile

We found several points where a cave-in could be confirmed by the orthophoto mosaic of Fig. 5, even though it was not possible to detect these when comparing the differences between the DEMs before and after the earthquakes, such as in the rectangle in Fig. 7. The reason for this may be that, although the point caved-in, it underwent upheaval as a whole. For this reason, we compared the DEMs before and after the earthquakes using a lateral profile. Fig. 8 shows the transverse line *A–A'* used to compare the DEMs before and after the earthquakes. We designated Points *B*, *C*, *D*, *E*, and *F* at distances of 4, 20, 30, 60, and 70 m from Point *A*. This rectangular area is the same as that shown in Fig. 5. Although the earthquakes caused a cave-in, a large difference could not be detected when comparing the DEMs before and after the earthquakes. This is presumably because the overall area underwent upheaval, thus causing a relative cave-in. Fig. 9 shows a cross section along the line *A–A'*. The section from Point *A* to Point *B* is a paved agricultural road, and it underwent upheaval of about 0.9 m as a result of the earthquakes. This upheaval can be observed from Points *A* to *C*. However, a sharp cave-in from the level before the earthquakes can be detected from Points *C* to *E*. At Point *D*, where the sharpest cave-in was observed, the height difference was about 2 m from the land surface. It could also be determined that upheaval resumed from Points *F* to *A'*. When comparing the DEMs before and after the earthquakes, it was found that the paddy fields had a more irregular elevation profile on the DEM after the earthquakes. This is presumably because the image mapping has a low accuracy in areas with vegetation. As a whole, we successfully clarified the vertical deformation of the cracks on the fault dimensionally and quantitatively.

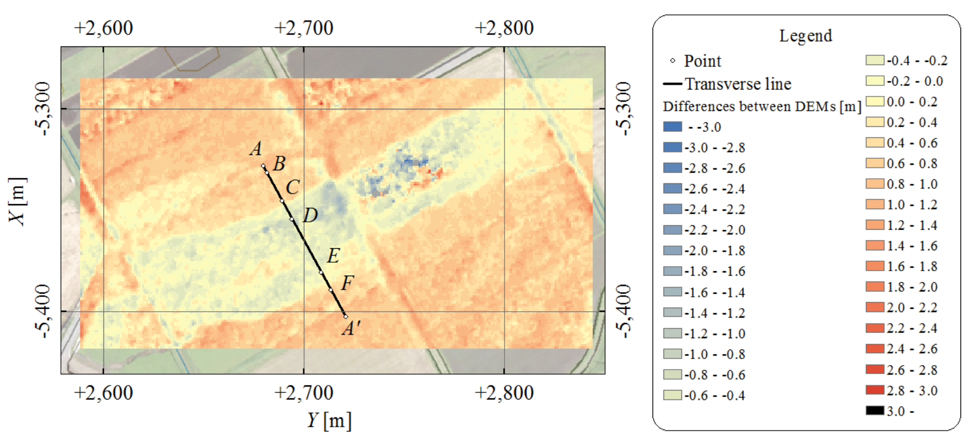

Fig. 8 Differences between the DEMs before and after the earthquakes at the cracks

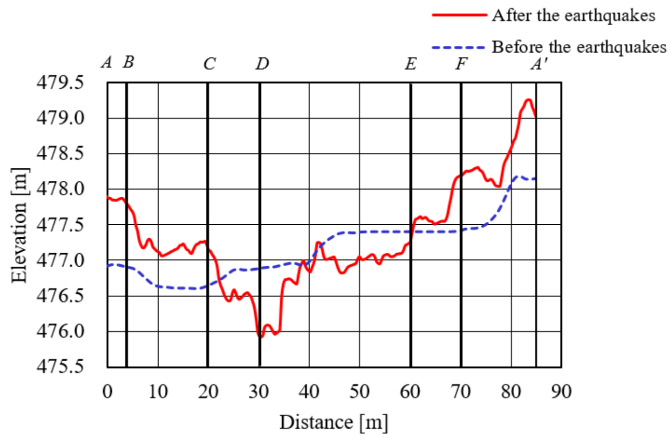

Fig. 9 Cross section at the cracks

CONCLUSION

As the conclusions, the points are summarized in the following.
(1) The exact positions of the cracks in paddy fields were specified by the orthophoto mosaic.
(2) Based on the analysis of the differences between the DEMs before and after the earthquakes, the vertical deformation was clarified dimensionally and quantitatively.
(3) The SD of the elevation values of the DEM after the earthquakes was 0.118 m, assuming that the elevation values of the GNSS after the earthquakes were true values. That is, it is possible to state that the DEMs after the earthquakes was accurate with an SD of 0.118 m.

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Research article

Spatial Assessment of Land Cover Change and Ecosystem Services from a Case Study in Savannakhet Province, Laos

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Abstract Land use without proper land management may cause deforestation and other negative impacts on ecosystem services (ESs), as defined in the Millennium Ecosystem Assessment of 2005. In Laos, natural resource sectors have received many investments in the past decades, during which a loss of ESs occurred. The aims of this study were to assess impacts on the potential provisions of ESs caused by land cover changes. The Savannakhet province in Laos was selected for the case study. Land cover changes were investigated using Landsat satellite images from 1988. A land cover map for 2010 was obtained from the government. After classifying the image into five land cover types, spatial analyses of the ESs were conducted by utilizing the primary unit values of six ESs. The results indicated that forests were converted to agricultural areas. Most of the potential provisions of ESs decreased due to these conversions in the past two decades.

Keywords ecosystem services, land cover change, spatial analysis, Laos

INTRODUCTION

Land use without proper land management may cause deforestation and other negative impacts on ecosystem services (ESs) as defined in the Millennium Ecosystem Assessment (MA, 2005). Appropriate land use management practices are required to provide adequate ESs. Goldewijk and Ramankutty (2004) and Chase et al. (2000) determined that land cover change was a key driver of environmental and ES changes. Numerous studies have focused on the relationship between land cover changes and the loss of ESs (Kay Khaing Lwin et al., 2016). An understanding of the spatial patterns associated with ESs could be applied for developing effective environmental policies and for decision-making (Izquierdo and Clark, 2012). In Lao People's Democratic Republic, land use changes associated with potential development might cause negative impacts on ES provisions (USAID, 2015; Yoshida et al., 2010) and natural resource sectors such as agriculture and forestry have received many investments in the past decades (Saunders et al., 2014). In Laos, Savannakhet province located in the south of the country received eight percent of the total foreign direct investments from 2004 to 2010, two-thirds of which were provided to the agriculture and forestry sectors (IUCN and NERI, 2011). This may cause agricultural expansion and forest degradation in this province. There are few researches conducted in this province. Therefore, a study of the spatial impact assessment by land cover changes is needed, with a focus on the changes of ES potential provisions in Laos, especially in the province. The results of the ES study could be applicable to land use planning and other decision-making processes related to ES conservation in this area.

OBJECTIVE

The objective of the study is to assess impacts on the potential provisions of ESs caused by land cover changes in the past two decades in Savannakhet province, Laos. A spatial analysis of ESs was conducted based on comparing a 1988 land cover map with those of a 2010 map.

MATERIALS AND METHODS

Study Area

Savannakhet province is the largest province in area in Laos and is located in the southern part of the country (the Administration Office of the province: 16° 34′ 15.2″ N, 104° 45′ 48.3″ E) (Fig. 1). The average annual temperature was 26.2 ℃, and the average annual rainfall was 1,672.3 mm (Lao Statistics Bureau, 2013). The total population was 969,700 (Lao Statistics Bureau, 2015), and the area covers 21,774 km^2, 90 % of which is flat (IUCN and NERI, 2011). The elevation of this study area ranges from 62 m to 255 m, based on the ASTER GDEM (ASTER Global Digital Elevation Model: http://www.jspacesystems.or.jp/ersdac/GDEM/E/index.html)

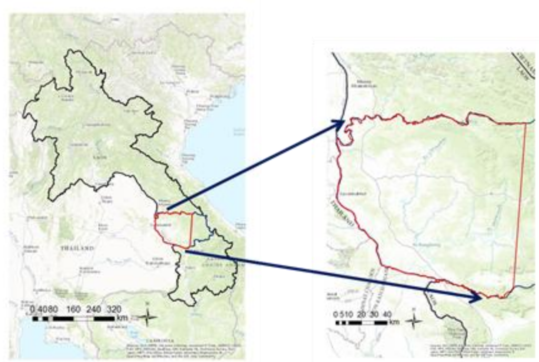


Fig. 1 Maps of Laos (on the left) and Savannakhet province (on the right)
Note: Black and red lines showed the country and the study area boundaries.

Research Process

The study consisted of three steps. The first step was the acquisition of satellite images and the development of a 1988 land cover map. Then we performed a reclassification of a 2010 land cover map provided from the Forest Inventory and Planning Center (FIPC), Government of Laos. The second step was an estimation of ES supply potentials by utilizing each ES unit value based on a literature survey, a land surface temperature calculation using band 6 (thermal band) of a Landsat 5 Thematic Mapper (TM) images, and the Universal Soil Loss Equation (USLE) analysis. Finally, after the normalization of the ES values by utilizing equal weights for each ES unit, a comprehensive analysis was conducted to understand the impacts on the ESs caused by land cover changes in the past two decades. ArcGIS 10.4.1 (ESRI) was used for the analysis.

1988 Land Cover Map Development and Reclassification of 2010 Land Cover Map

The following process was conducted for the development of a 1988 land cover map. Landsat 5 images for 1988 at 30 m x 30 m resolution were downloaded from the United States Geological Survey website *(http://landsat.usgs.gov)*. Four satellite images (WRS path/row 127049 and 127048 dated 16th March and 16th Feb. 1988, 126049 and 126048 dated 6th Feb. 1988) covered the study area. The images were subset to the study area located in the western part of the province, shown as a red line in Fig. 1. The images were classified into five types of land cover classes: forest, dry-forest, water, urban and bare land, and agriculture area. The normalized difference vegetation index (NDVI) and the normalized difference water index (NDWI) (McFeeters, 1996) were used to separate forest and water, respectively. For the classification of the remaining classes, namely, mixed-forest, dry-forest and grassland, urban and bare land, and agriculture area, supervised methods were used. Subsequently, the mixed-forest class was integrated into the forest class. Swamp areas were difficult to identify in the 1988 images; therefore, swamps were classified as “Other” together with clouds which were excluded from the ES analysis.

An accuracy assessment was conducted for the 1988 classification using ancillary data by creating approximately 100 random points for each land class, except urban and bare land class, which only 35 points were set due to the small ratio of urban area against the total area. Then the random points of the 1988 map were compared with 1988 Google Earth image and original satellite images as references. The result of the accuracy assessment was 0.853 by the kappa coefficient (Table 1). However, the resolution of the reference is not high. But we could not find any other reference for the old map.

We used a land cover map of 2010 provided by the FIPC, and reclassified the existing 22 land cover types into the same five land cover types used for the 1988 map (Table 2).

Table 1 Accuracy assessment of the 1988 land cover map

		1988 Google Earth image					Total
		Forest	Dry-Forest	Water	Urban and Bare land	Agriculture area	
Classified 1988 land cover map	Forest	90	10	0	0	0	100
	Dry-Forest	7	90	0	0	3	100
	Water	0	4	88	0	8	100
	Urban and Bare land	3	3	0	26	3	35
	Agriculture area	0	9	0	0	92	101
Total		100	116	88	26	106	436
Kappa coefficient					0.853		
Overall accuracy					86.7 %		

Table 2 Reclassification of the 2010 land cover map

National Level Classification System (NLCS) for Laos 2010 by FIPC	New category for this study by authors
11Evergreen Forest, 12Mixed Deciduous Forest, 14Coniferous Forest, 15Mixed Coniferous and Broadleaved Forest, 16Forest Plantation, 21Bamboo, 22Regenerating Vegetation	Forest
13Dry Dipterocarp Forest, 31Savannah, 32Scrub, 41Grassland	Dry-forest
81Water	Water
71Urban, 72Barren Land and Rock, 80Other Land	Urban and bare land
51Upland Crop, 61Rice Paddy, 62Other Agriculture, 63Agriculture Plantation	Agriculture area
42Swamp, 82Cloud, 83Cloud Shadow	Other

Note: Land cover numbers were defined under NLCS by FIPC

Table 3 shows the ES unit values based on a literature survey conducted by Kay Khaing Lwin et al. (2016) with several adjustments for this study, except temperature regulation and USLE estimation.

The ES categories from the MA (2005) were used, including provisioning, regulating, and supporting services, except for cultural services. For supporting services, gross primary production (GPP) and carbon stock were selected. For regulating services, temperature regulation (land surface temperature estimation: LST), USLE and water infiltration were chosen. For provisioning services, only agricultural products (averaging per ha production of local products, namely, rice, vegetables, maize, soil bean, peanut, starchy roots from Lao Statistic Bureau (2013)) were used.

Table 3 Primary unit values of ESs

Types of ESs	Forest	Dry-Forest	Agriculture area	Urban and bare land	Water	Source
Supporting Services:						
GPP (t/ha/yr)[1]	30.7	4.585	12.093	0	0	Chen et al. (2013) and Hirata et al. (2013)
Carbon stock (t/ha)[2]	131.61	41.19	0	0	0	Forest Carbon (2015)
Regulating Services:						
Water infiltration (mm/h)[3]	100	280	38.5	2	0	Chaplot et al. (2002)
Temperature regulation (°C)	2.93	1.06	0.26	0	5.23	by authors*
Provisioning Services:						
Agriculture Products (t /ha)	-	-	4.00	-	-	Lao Statistic Bureau (2013)

Source: Kay Khaing Lwin et al. (2016) revised by the authors,
**: developed by using Landsat 5 as explained in the land surface temperature estimation section below.*
[1]: Data were attempted to collect in the study area or nearest location. GPP for forest was obtained from Hirata et al. (2013)' Thailand data which was close to this area, and Chen et al (2013) estimated in GPP of Asian region that were used for dry-forest and agriculture area.
[2]: Carbon stock unit values in Laos were presented in Forest Carbon (2015) which used biomass equations originally from Chave et al. 2005 and 2014. Then the unit values for forest and dry-forest in this paper were revised by taking into consideration the ratio of evergreen forest and deciduous forest areas in Savannakhet comparing 2000 and 2010 values (NLCS for Laos 2000 and 2010 by FIPC).
[3]: Water infiltration unit value of tree plantation from Chaplot et al. (2002) was used for those of forest unit value in this study, and the fallow and pastures unit values in the same paper were used for dry-forest in this study. For agriculture area, the averaged figures of cultivated (corn, vegetables) and cultivated (with conservation) in Chaplot et al. (2002) were used.

Land Surface Temperature (LST) estimation: LST for 1988 and 2010 were calculated by using the band 6 images of Landsat 5 TM. Four image scenes were used for making the 1988 land cover map, but only two scenes of Mekong River side where majority of urban areas situated, were utilized in this LST estimation for each year, which included enough urban area with other land cover types. Then, the following 16 images in separate eight years were collected: for 1988 LST estimation (Path/Row of 127/049: 16 Feb. 1988, 11 March 1989, 18 Feb. 1990, 10 April 1991; and those of 127/048: 16 March 1988, 11 March 1989, 19 Dec. 1990, 10 April 1991) and for 2010 LST estimation (Path/Row of 127/049: 5 March 2007, 24 April 2008, 25 Feb. 2010, 28 Feb. 2011; and those of 127/048: 1 Feb. 2007, 24 April 2008, 25 Feb. 2010, 28 Feb. 2011). These images were used to calculate LST as a shot of LST in different time in each year. Most of the images were captured around 10a.m. in Laos local time. The images were acquired in dry season from January to April or beginning of May to avoid the effect of clouds. The following processes as described by Kumar et al. (2012) originally from NASA (2004) were used to estimate LST. The first is Eq. (1).

$$L_{\gamma} = \left\{ \frac{L_{MAX} - L_{MIN}}{QCALMAX - QCALMIN} \right\} \times DN - 1 + L_{MIN} \tag{1}$$

Note: *L_{MAX}=the spectral radiance that is scaled to QCALMAX in W/($m^2 \times sr \times \mu m$), L_{MIN}=the spectral radiance that is scaled to QCALMIN in W/($m^2 \times sr \times \mu m$), QCALMAX=the maximum quantized calibrated pixel value (corresponding to L_{MAX}) in DN=255, QCALMIN=the minimum quantized calibrated pixel value (corresponding to L_{MIN}) in DN=1, DN=Digital Number*

Table 4 Parameter values of Landsat 5 TM

Satellite/Sensor	L_{MAX}	L_{MIN}	K_1	K_2
Landsat 5 TM	15.303	1.238	607.76	1260.56

Source: the Landsat 5 TM metadata file

The values for L_{MAX}, L_{MIN}, *QCALMAX*, and *QCALMIN* were obtained from the Landsat 5 TM metadata in Table 4.

After converting *DN* to $L\gamma$, the black body temperature T_B was calculated using Eq. (2) which is called Plank's inverse function (Kumar et al., 2012).

$$T_B = \frac{K_2}{\ln\left(1+\frac{K_1}{L_\gamma}\right)} \tag{2}$$

The values of K_1 and K_2 were obtained from the Landsat 5 TM metadata file in Table 4. T_B was converted to LST using Eq. (3) (Yue et al., 2007; Kumar et al., 2012).

$$LST = \frac{T_B}{1+\left(\gamma\frac{T_B}{\rho}\right)\ln\varepsilon} \tag{3}$$

Note1: *γ=the wavelength of emitted radiance ($\gamma = 11.5\ \mu m$), $\rho = h\times c/\sigma$ p=1.438$\times 10^{-2}$ (mK), h=Plank`s constant (6.626 $\times 10^{-34}$ Js), c=the velocity of light (2.998$\times 10^{8}$ ms$^{-1}$), $\sigma$=Boltzmann`s constant (1.38$\times 10^{-23}$ JK^{-1}), ε=spectral emissivity (vegetation=0.95, non-vegetation=0.9, water=1.0 (Nichol 1996))*

Note2: LST results for 1988, 2007 and 2008 contained error points because of including little cloud part, the results were modified by excluding those parts out before adjustment by DEM data.

After converting the sea level elevation value for each pixel of the LST value by assuming as a constant of 6.5 °C/km lapse rate (a surface temperature decreases with an increase in altitude) (Minderet al., 2010), the LST values were averaged in each land cover type separately. Then the LST value differences were calculated based on the difference between the averaged LST value of urban areas and those of other land cover types in each year separately. Finally, the ES unit values for temperature regulation were estimated by averaging the LST value differences for eight years by each land cover category (Table 3).

USLE: USLE is based on a formula to estimate the quantity of soil erosion per unit area caused by surface water (precipitation) (USDA, United States Department of Agriculture: http://www.usda.gov/wps/portal/usda/usdahome). It was calculated using Eq. (4). The *R* value was calculated using Eq. (5) (Kobayashi et al., 2002). *A* in Eq. (5) used rainfall data from Savannakhet Meteorology Station by the years of 1990 and 2010. The *K* value was calculated by Eq. (6) to Eq. (10) (Wawer et al., 2005 originally by Williams, 1995) based on the soil map of Laos obtained from the FAO (Food and Agriculture Organization of the United Nations: http://www.fao.org/soils-portal/en/). The *L* and *S* values are topographical factors and were calculated in ArcGIS using the ASTER GDEM by a simple method, LS calculated just from the slope value in % using Eq. (11) (Mediavilla et al., 2017 originally by Ededo et al., 1995). The *C* value was obtained from Dubber and Hedbom (2008). The *P* factor was not considered. Hence, assuming that *P* = 1 (constant) when no soil conservation measures were practiced.

$$E = R\times K\times L\times S\times C\times P \tag{4}$$

$$R = 0.32\times\left(\frac{A}{100}\right)^{2.5} \tag{5}$$

$$K = K_W = f_{csand}\cdot f_{cl-si}\cdot f_{orgc}\cdot f_{hisand} \tag{6}$$

$$f_{csand} = \left(0.2 + 0.3 \cdot \exp\left[-0.256 \cdot m_s \cdot \left(1 - \frac{m_{silt}}{100} \right) \right] \right) \tag{7}$$

$$f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}} \right)^{0.3} \tag{8}$$

$$f_{orgc} = \left(1 - \frac{0.25 \cdot orgC}{orgC + \exp[3.72 - 2.95 \cdot orgC]} \right) \tag{9}$$

$$f_{hisand} = \left(1 - \frac{0.7 \cdot \left(1 - \frac{m_s}{100} \right)}{\left(1 - \frac{m_s}{100} \right) + \exp\left[-5.51 + 22.9 \cdot \left(1 - \frac{m_s}{100} \right) \right]} \right) \tag{10}$$

$$LS = \begin{cases} 0.009 \times p^2 + 0.0798 \times p, & p \leq 30\% \\ 0.2558 \times p + 3.248, & p > 30\% \end{cases} \tag{11}$$

Note: E: mean annual soil loss (t/ha/year), R: rainfall erosivity factor (MJ・mm/ha/h/year), K: soil erodibility factor (t・h/MJ/mm), L: slope length factor, S:slope steepness factor, C: crop management factor, P: erosion control practice factor, A: Annual rainfall (Savannakhet Meteorology station by statistic yearbook 2010), m_s: the sand fraction content (0.05-2.00 mm diameter) (%), m_{silt}: the sand fraction content (0.002-0.05 mm diameter) (%), m_c: the sand fraction content (<0.002 mm diameter) (%), p: slope (%), orgC: the organic carbon (SOC) content (%).

ESs Mapping

The land cover maps and the ES unit values were used to create maps for the potential provisions of ESs. A grid with a mesh size of 500 m × 500 m was created. A comprehensive analysis was conducted for the 1988 and 2010 maps by averaging each normalized ES score (0 to 1 scale). However, the USLE was converted to be a minus value before normalization because the original USLE value was high ES value in low USLE figure.

Table 5 Percent of land cover in 1988 and 2010

Land cover type	1988 (%)	2010 (%)
Forest	51.18	42.31
Dry forest	36.60	28.00
Water	1.33	2.06
Urban and bare land	0.05	0.42
Agriculture area	9.83	27.21

RESULTS AND DISCUSSION

Table 5 and Fig.3 show the results of the land cover classifications. Forest and dry-forest areas decreased considerably and in contrast, agricultural area increased markedly from 1988 to 2010. In order to compare both maps, the areas of cloud and swamp parts which were classified as “Other” category in the 2010 map were excluded from the 1988 map as well. The results of the spatial analysis are shown in Fig. 4. Some ES supply potentials have decreased especially for carbon stock and GPP because of the decrease of the forest areas in general. As agricultural area increased, the provision of food production has also increased. Fig. 4c) and 4d) defined the change of soil erosion quantities, the red color of the USLE maps was identified the lowest annual soil loss which means soil loss of the 2010 map was smaller than that of the1988. Water area had the highest value with regard to temperature regulation service, followed by forests (Table 3). Surface temperatures changed considerably between 1988 and 2010 mainly because of the impact from land cover change especially for the center and southwest parts where the transformation from forest and dry-forest to agricultural area have happened, which had the higher potential provisions of its service in forest and dry-forest than agriculture area. As consequent, as shown in the Fig. 4g) and 4h) the temperature regulation service was decreased in general. Water Infiltration service was identified as water infiltration capacity which also affected from land cover changes. As shown in the Fig. 4i) and 4j), water infiltration service in the southwest part of the study area was declined due to the change from dry-forest to agricultural areas, followed by forest transformation to agricultural areas.

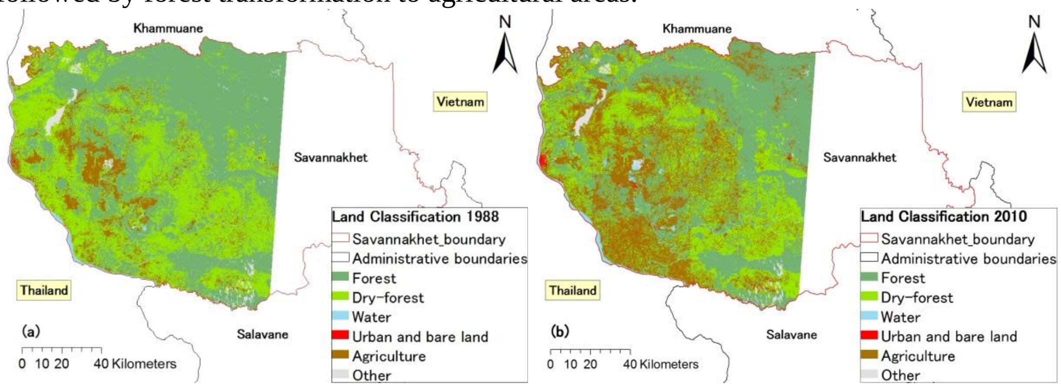
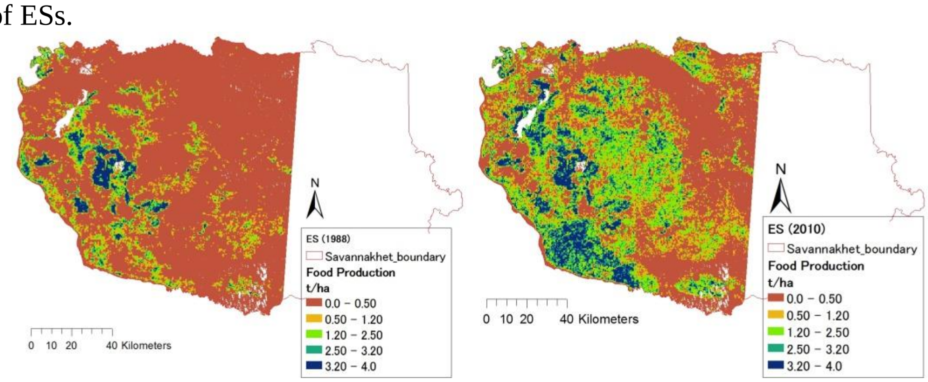
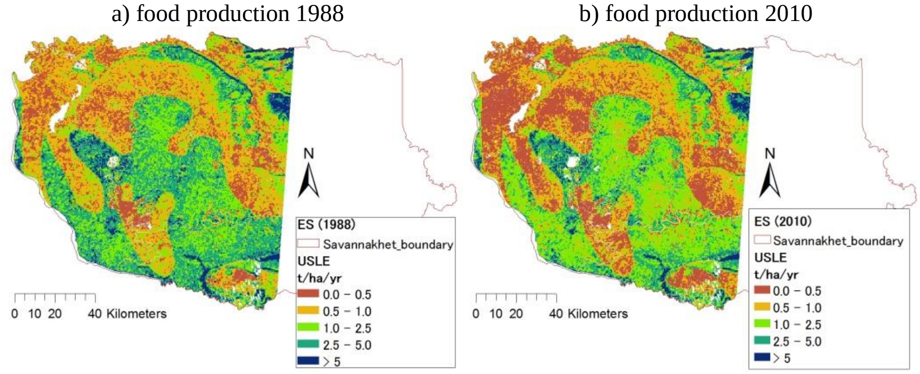


Fig. 3 Land cover classification (a) 1988 and (b) 2010

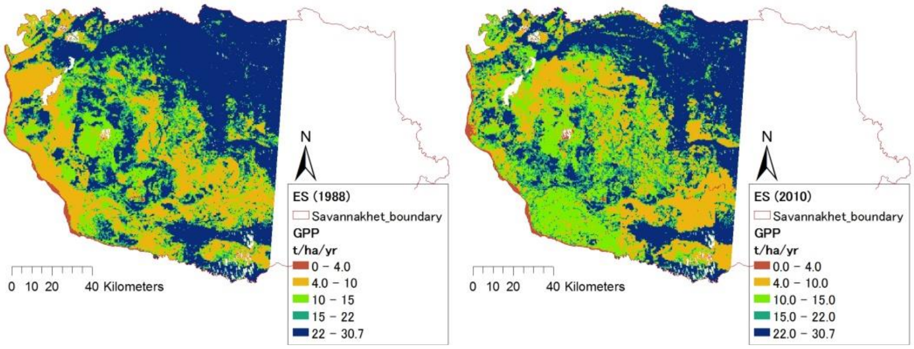
The results of comprehensive analysis were presented in Fig. 5(a) and 5(b) to prioritize ES conservation needs. The overall values of ES supply potentials were higher for 1988 than for 2010. Entirely, forest area had the highest importance of ES potential provisions in both maps. Therefore, the perspective of nature conservation, a land use policy sector should consider it properly for their future land use development policy, for example, land concession for industrial plantations which need the huge area of their cultivation. It will be one of the policy options to limit land use types, for example, introducing land use zoning policy, to protect forest area in order to avoid reducing the potential provisions of ESs.



a) food production 1988 b) food production 2010



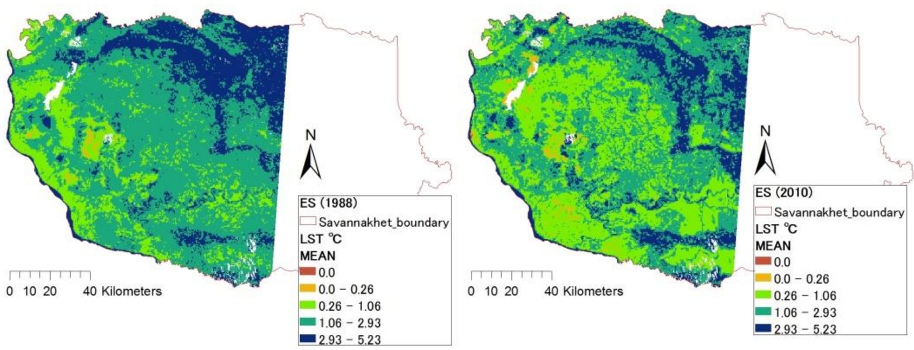
c) USLE 1988 d) USLE 2010



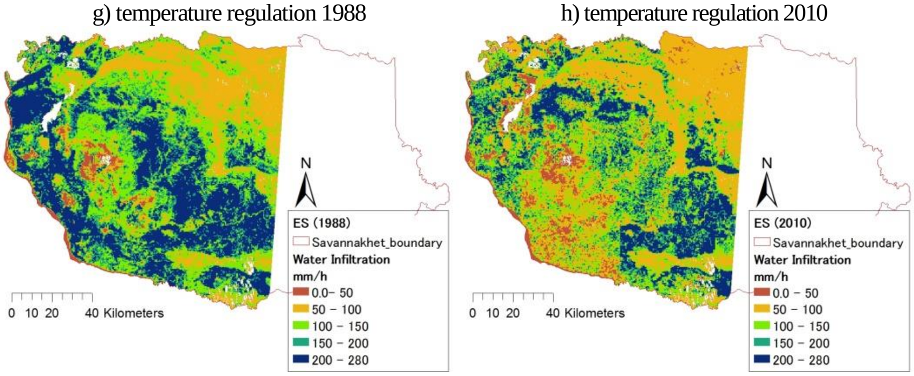
e) GPP 1988 f) GPP 2010

Fig. 4 Maps of ESs in the province for 1988 and 2010 [a) - f)]

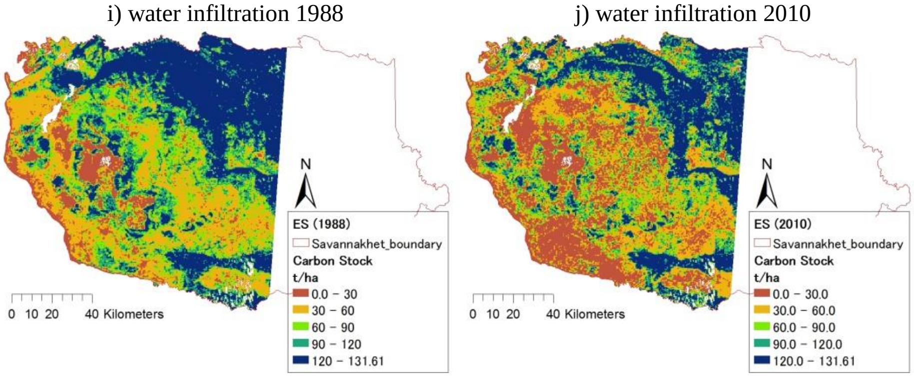
Note: Map of USLE Fig. 4c) and 4d) were higher values in the blue color which means higher area of soil erosion quantities (this means low ES provision)



g) temperature regulation 1988 h) temperature regulation 2010



i) water infiltration 1988 j) water infiltration 2010



k) carbon stock 1988 l) carbon stock 2010

Fig. 4 cont. Maps of ESs in the province for 1988 and 2010 [g) – l)]

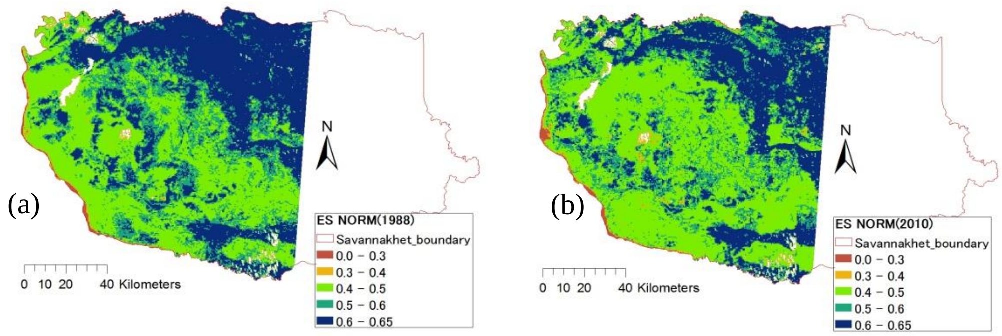


Fig. 5 Maps of comprehensive assessments for (a) 1988 and (b) 2010: 0 to 1 scale

CONCLUSION

A spatial analysis of potential provisions of ESs was conducted to understand the distributions of the ESs and to determine priority areas for conservation of the ESs. Forest area decreased considerably from 1988 to 2010 in contrast to agricultural area. Most of the changes in land cover type came from the transformation of forest and dry-forest to agricultural areas, and this might be the main cause for the changes in the potential provisions of ESs over two decades. Most of the potential provisions of ESs decreased due to these changes. The present study could be a useful tool for land use planning based on prioritizing conservation areas for ESs in this region. Our results illustrate the importance of considering ESs into land-use planning and land management policy. This approach could apply not only for this study area but also throughout nationwide and could probably be applicable for other developing countries. Future issues that require further study include the increased number of ESs, the collection of ES unit values for Laos, and the increase in the number of land cover classes. Culture services are also important in terms of social environment to understand the ES influence on their local livelihood activities.

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Research article

Application of Soil and Water Assessment Tool (SWAT) Model to Predict Streamflow and Sediment Yield in Wahig-Inabanga Watershed, Bohol, Philippines

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Abstract The study applied the Soil and Water Assessment Tool (SWAT) model -- to predict streamflow and sedimentation in Wahig-Inabanga Watershed, Bohol, Philippines. The applicability of the SWAT model was evaluated and its output was integrated to GIS to generate sedimentation hazard map. The result of the SWAT model performance evaluation on stream flows was satisfactory given prediction efficiency values: NSE = 0.6578; R^2 = 0.7038; PBIAS = 14.94%; and RSR = 0.5850. Satisfactory result was also achieved in model validation with model accuracy values on NSE, R^2, PBIAS and RSR of 0.41, 0.57, 25.09%, and 0.71, respectively. However, the model did not provide precise estimates of sediment yield in sub-basins and hydrological response units (HRU) especially with corn as single land use or one of the landuses even on flat to gently rolling terrain. Inaccuracy issue on sediment yield prediction deferred further analysis including thesedimentation risk valuation which supposed to provide baseline information for watershed management and land use planning.

Keywords Soil and Water Assessment Tool, SWAT, streamflow, sediment yield

INTRODUCTION

The Philippines is very vulnerable to natural disasters because of its natural setting (Palao et al., 2013; Principe, 2012; Luna, 2001), its socioeconomic, political, and environmental context, and especially its widespread poverty (DepEd et al., 2008; Lasco et al. [undated]). Moreover, the country is prone to geologic and natural hazards mainly because of its geographic, geologic, and tectonic setting. Disasters, whether natural or human-induced, have caused tremendous losses in the country's national economy. Storms, landslides, floods, and sometimes the combination of all three at once, displace as many as 8 million people every year. The National Disaster Risk Reduction and Management Council (NDRRMC) under the Office of the Civil Defense, Department of National Defense (OCD-DND) has recorded more than 15 major disasters to have devastated different parts of the country in the last five years alone, including typhoon Haiyan ("*Yolanda*"), said to be the greatest typhoon ever recorded in Philippine history. Being mountainous and rugged in topography, the Philippines is no doubt prone to massive erosions and landslides. These two, together with floods, typhoons, and fire, account for billions of pesos of government spending annually for disaster rehabilitation programs.

Soil erosion alone has been considered as a major threat to sustainable agriculture and to the environment (Paningbatan et al., 1995) especially in the developing world particularly the Philippines (Genson, 2006; Bantayan, 2006; Bantayan, 1997). According to a report from PCARRD (1999), some 74 to 81 million tons of soil is lost annually, affecting 63% to 77% of the country's total land area. Using the Global Assessment of Soil Degradation (GLASOD) database, FAO (2000) as cited by Genson (2006) confirmed the severity of land degradation giving an estimate of about 79%. Indeed, land degradation is a major environmental and development issue in the Philippines. Its process is advancing at an alarming rate due to deforestation and inappropriate agricultural activities in fragile and highly sensitive mountainous environments. This is further aggravated by frequent cyclones and thunderstorms due to climate change and weather extremes which somehow explain the very high sediment yield rates throughout the country (Palao et al., 2013; Principe, 2012; PCARRD, 2008).

The integration of SWAT and GIS in streamflow and sediment yield modeling in Wahig-Inabanga Watershed, Bohol, Philippines, is perceived to be of great advantage in terms of improved procedures and analyses, and yield outputs both for sub-basin and hydrological response unit (HRU) scale. Evidence of GIS and SWAT integration are the availability of several readily downloadable SWAT add-ins compatible with selected GIS software packages. One particular SWAT add-in used in this study was ArcSWAT, the SWAT geo-spatial interface in ArcGIS.

OBJECTIVES

The study aimed to apply and evaluate the performance of the Soil and Water Assessment Tool (SWAT) model in streamflow and sedimentation modeling in the Wahig-Inabanga Watershed using ArcGIS as the platform of geo-spatial analysis.

METHODOLOGY

Study Site

The Wahig-Inabanga Watershed, also known as Wahig-Inabanga River Watershed Forest Reserve (WIRWFR), is the biggest watershed in the province of Bohol, Philippines. From the Northwest Bay of Inabanga, the river dissects the central part of the island embracing a total land area of more than 610 km^2 (Figure 1). This watershed is about 15.20% of the total land area of the province.It is geographically located between 124^{o}3'36" and 124^{o}23'24" East longitude, and between 9^{o}43'48" to 10^{o}4'48" North latitude (GCS Luzon-Philippines 1911 datum).

(a) (b) (c)

Fig.1 Location of the study area: (a) map of the Philippines showing the Central Visayas; (b) map of the Central Visayas showing Bohol; and (c) map of Bohol showing the study area

SWAT Modeling

The SWAT model, being physical-based, claims for more complex types of input data in order to become operationally functional. In the study, there were several types of data (database input files, GIS required and optional input layers, and the observed or acquired measured data on streamflow) obtained from different reliable sources. The database input files which were used included: 2000-2012 climatic data from Bohol Experiment Station (BES); soil physical and chemical data from the Bureau of Soil and Water Management (BSWM); and daily rainfall datafrom two rainfall stations within the watershed, all of which need to be preprocessed and organized into a format readable by the SWAT model. In addition, the required GIS input layers were land cover (LULC) and soil, including a digital elevation model of the watershed in which the manual definition of slope was based. Other optional input layers like watershed mask and stream network were also used to reduce the processing time during watershed and sub-basins delineation. Unluckily, in the study area only streamflow dataset was available and this was applied for sensitivity analysis, calibration and validation of the model.

ArcGIS was used to preprocess some of the various SWAT model parameters observed and collected from the real watershed condition into a format that is acceptable by the model. Only the manual calibration method was applied in this study after parameterization. It was done by manually adjusting values of identified significant parameters. This was followed by model validation which aided in demonstrating whether a given site-specific model was capable of making sufficiently accurate simulations or otherwise. Results of the model simulation included the estimates on streamflow and sediment yield in sub-basin and HRU levels. Acceptance of the model was based on the satisfactory values of the model efficiency indicators such as Nash-Sutcliffe efficiency, coefficient of determination, root mean square error–observations standard deviation ratio, and percent bias. Computation, however, was done outside the GIS interface. The ArcSWAT2009 version 488, unfortunately, does not directly provide spatio-temporal erosion maps. However, since the SWAT simulation was run within the GIS setting, visualization of the outputs was obtained by adding the sediment yield estimates in the attributes of sub-basin and HRU layers.

RESULTS AND DISCUSSION

Sensitivity Analysis

Auto-sensitivity analysis was performed on 20 relevant stream flow parameters for the period 1986-1991. The absence of sediment yield data limited the sensitivity analysis only to streamflow-related parameters. Based on parameter sensitivity scale rating of Lenhart et al. (2002), out of the 20 parameters evaluated, half were found significant on simulated vs. observed output. Table 1 shows the result of the analysis ranked according to sensitivity index values. The first three parameters were highly sensitive based on Lenhart et al. (2002) sensitivity rating while the rests were medium sensitive.Those parameters with less than 0.05 sensitivity index values were considered negligible based on Lenhart et al. (2002) sensitivity rating and, thus, were not included in model calibration.

Table 1 Ranking of significant flow parameters after sensitivity analysis with observed data

Parameter	Description	Rank	Sensitivity Index
CN2	Curve number for moisture condition II	1	0.9960**
CH_K2	Effective hydraulic conductivity in main channel (mm/hr)	2	0.8000**
ESCO	Soil evaporation compensation factor	3	0.7720**
ALPHA_BF	Baseflow alpha factor (days)	4	0.1920*
CH_N2	Manning's N value for the main channel	5	0.1660*
BLAI	Maximum potential leaf area index	6	0.0693*
GWQMN	Shallow aquifer threshold water depth (mm H_2O)	7	0.0665*
CANMX	Maximum canopy storage (mm H2O)	8	0.0542*
SOL_AWC	Available water capacity of the soil layer (mm H_2O/mm soil)	9	0.0512*

Note: Sensitivity Rating (Lenhart et al., 2002): **= high; * = medium (moderate)

Stream Flow Model Calibration and Validation

SWAT stream flow model calibration was performed using the 9 significant parameters during the same simulation period (1986-1991). Model validation, on the other hand, was done for the period 1991-1996. Each run was evaluated using model efficiency indices such as NSE (Nash-Sutcliffe efficiency coefficient), R^2 (coefficient of determination), PBIAS (percent bias), and RSR (root mean square error – observations standard deviation ratio). The results of the simulation passed the model efficiency criteria as required by each of the pre-identified indices. Summary results of the stream flow (runoff) initial run, calibration and validation evaluation are presented in Table 2.

Table 2 Summary result of model prediction efficiency evaluation of the stream flow model for Wahig-Inabanga Watershed

SIMULATION	PERIOD	NSE	R^2	PBIAS	RSR
Initial Run	1986-1991	0.5035	0.6831	25.2796	0.7046
Calibration	1986-1991	0.6578	0.7038	14.9373	0.5850
Validation	1991-1996	0.4106	0.5699	25.0883	0.7083

Several SWAT users (Principe, 2012; Duan et al., 2009) suggested that models with NSE of more than 0.4 and R^2 greater than 0.5 for both calibration and validation can still realistically simulate basin's hydrological processes. Thus, based on the calibration and validation results, it was assumed that the model captures the actual stream flow condition in the study area. According to the SWAT user group [https://swat.tamu.edu/media/82492/swat-user-group], it is a requirement that a SWAT model intended for soil erosion prediction through sediment yield must fulfill this condition.

Basin-Level Water Balance Tradeoff and Sediment Yield

Table 3 Basin-level water balance trade-off of Wahig-Inabanga Watershed during streamflow model calibration

SIMULATION	PARAMETER ADJUSTED	PRECIP	PET	ET	SW	PERC	SURQ	GWQ	LATQ	WYLD	SYLD
Initial run		1787.38	796.52	604.01	2055.93	405.91	563.37	383.43	217.32	1164.12	5444.37
Calibration	CN2	1787.38	796.52	604.52	2095.12	702.93	177.64	674.66	306.30	1158.60	1968.05
	CH_N2	1787.38	796.52	604.52	2095.12	702.93	177.64	674.66	306.30	1158.60	1968.05
	BLAI	1787.38	796.52	608.42	2087.86	700.50	176.80	672.39	305.65	1787.38	1949.72
	GWQMN	1787.38	796.52	608.42	2087.86	700.50	176.80	655.87	305.65	1138.32	1949.72
	CANMX	1787.38	796.52	643.89	2204.95	701.34	175.01	654.16	270.33	1099.50	1942.39
	SOL_AWC	1787.38	796.52	655.43	2754.11	667.04	169.89	619.60	298.15	1087.63	1868.54

Note: PRECIP = average annual precipitation (mm)
PET = average annual potential evapotranspiration (mm)
ET = average annual evapotranspiration
SW = average annual soil water (mm)
PERC = average annual percolation (mm)
SURQ = average annual surface runoff (mm)
GWQ = groundwater flow (mm)
LATQ = lateral flow (mm)
WYLD = water yield (mm)
SYLD = total average annual sediment yield (ton/h) for the whole watershed

CN2 = curve number for moisture condition II
CH_N2 = Manning's N value for the main channel
BLAI = maximum potential leaf area index
GWQMN = Shallow aquifer threshold water depth (mm H_2O)
CANMX = maximum canopy index (mm)
SOL_AWC = available water capacity of the soil layer (mm H_2O/mm soil)

The water balance tradeoffs and the resulting changes in sediment yield of Wahig-Inabanga Watershed as outputs of model calibration for streamflow are presented in Table 3. Results show a considerable decreasing pattern on sediment yield as values of significant parameters were adjusted from their default or assigned values. Out of the 121 sub-basins of Wahig-Inabanga Watershed, 47 exceeded the soil tolerable loss of 11.2 tons/ha/yr (Figure 3). The tolerable soil loss is based from Hudson (1995) and Lal (1994). It was noticed that all 47 sub-basins had CORN as a single land use or in combination with some other land uses. This only revealed that the model may have over predicted the SYLD for

CORN, and perhaps on some other LULCs, irrespective of slope class. In this regard, a comprehensive assessment is required in the HRU-level output of the model. Sub-basins with CORN as its single LULC had annual averages ranging from 31.38 tons/ha to 55.21 tons/ha, while those sub-basins with several other LULCs in addition to CORN had annual averages of about 11.81 tons/ha to 138.58 tons/ha.

HRU-Level (LULC) Water Balance and Sediment Yield

Another important output of each simulation in SWAT is the HRU-level water balance and sediment yield. Rearrangement of the output was purposely done to determine which among the LULC types have been mis-predicted by the model in terms of sediment yield prediction. Table 4 presents the water balance and sediment yield after having adjusted all flow sensitive parameters.

Table 4 HRU-level water balance and sediment yield (ton/ha) of calaibrated flow model using flow sensitive paramerets summarized by landuse and land cover

LULC	PRECIP	PET	ET	SW	PERC	SURQ	GWQ	LATQ	TLOSS	WYLD	$SYLD_A$	$SYLD_{MN}$	$SYLD_{MX}$
URBN	1818.29	787.47	613.93	2570.17	496.54	622.16	459.93	86.82	7.10	1161.81	16.91	0.63	66.53
CORN	1797.33	789.69	563.08	2427.83	606.64	205.91	557.43	422.98	1.50	1184.82	91.68	1.86	481.18
FRST	1787.98	790.65	727.55	2242.42	487.00	122.74	434.35	452.23	0.92	1008.40	0.22	0.00	1.11
OILP	1765.20	793.10	766.30	2289.35	525.68	133.58	476.59	341.77	0.85	951.09	1.43	0.00	12.34
RICE	1810.38	788.30	562.01	2528.71	716.84	184.21	669.88	348.85	1.40	1201.54	4.98	0.21	26.20
RNGB	1695.28	800.50	575.96	2518.90	548.75	106.86	499.18	464.04	2.23	1067.85	3.12	0.01	17.46
RNGE	1768.66	792.69	579.93	2388.19	550.46	155.12	504.11	484.13	2.87	1140.48	8.44	0.01	33.39
WATR	1692.91	1170.35	819.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WETF	1482.25	823.39	696.12	4337.22	382.87	386.60	321.46	0.97	0.72	708.26	0.01	0.00	0.02

Note: Water Balance Component:

PRECIP = precipitation (mm)
PET = potential evapotranspiration (mm)
ET = evapotranspiration (mm)
SW = soil water content (mm)
PERC = percolation (mm)
SURQ = surface runoff (mm)
GWQ = groundwater flow (mm)
LATQ = lateral flow (mm)
TLOSS = transmission loss (mm)
WYLD = water yield (mm)
$SYLD_A$ = average annual sediment yield (ton/ha)
$SYLD_{MN}$ = minimum sediment yield (ton/ha)
$SYLD_{MX}$ = maximum sediment yield (ton/ha)

SWAT Landuse and Land Cover:

URBN = urban for built-up
CORN = corn
FRST = forest mixed
OILP = oil palm for perennial cultivated and plantations (dominated by coconuts and other perennial crops)
RICE = rice
RNGB = range-brush for wooded grassland
RNGE = range-grasses for grassland
WATR = water
WETF = wetland forested for mangrove

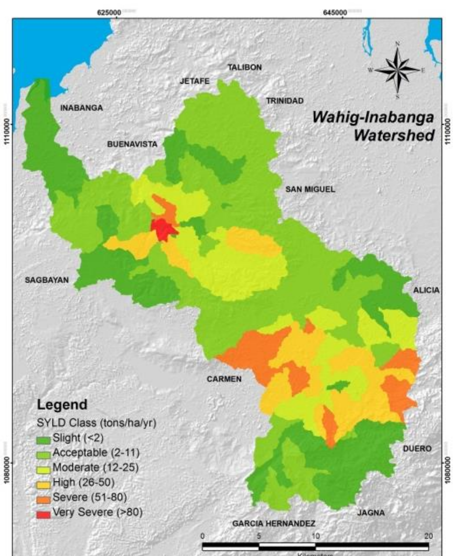

Fig. 2. Sub-basin-level sediment yield class ratings of Wahig-Inabanga Watershed

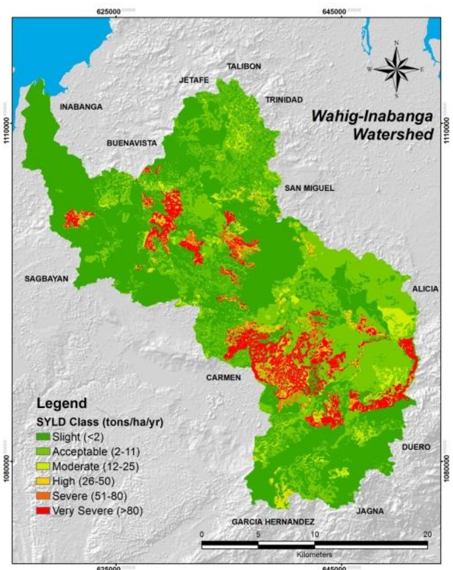

Fig. 3. HRU-level sediment yield class ratings of Wahig-Inabanga Watershed

The spatial distribution of the predicted average annual soil erosion rates in terms of sediment yield (tons/ha) in sub-basin and HRU-levels are presented in Figures 2 and 3. The soil erosion (sediment yield) values for the whole watershed were divided into six levels: slight (< 2 tons/ha/yr); acceptable (2-11 tons/ha/yr); moderate (12-25 tons/ha/yr); high (26-50 tons/ha/yr); severe (51-80 tons/ha/yr); and very severe (> 80 tons/ha/yr). This classification, accordingly, is based from the tolerable erosion rate of 10 to 12.5 tons/ha/yr adopted from Paningbatan (1987) as cited by PCARRD (1991) and was also used by several local researchers in the Philippines.

The overall output of the model and given the limited available input data used in the simulations, it can still be assumed that the model is able to predict stream flow. However, it is not accurate in estimating sediment yield for some of the sub-basins and HRUs, particularly those with corn as a landuse. The inaccuracy in sediment yield estimation using the SWAT model deferred its risk quantification and valuation.

CONCLUSION

The study validated the applicability of the SWAT model only in simulating flow discharge dynamics of the watershed based on the satisfactory values of the statistical measures of model efficiency. However, it does not provide accurate estimates of the annual sediment yield in some LULCs such as grassland, rice, perennial cultivated crops, and especially corn, on flat to gently sloping areas in the watershed. The model, on the other hand, somehow precisely predicted annual sediment yield for built-up, open forest, mangroves, and inland water. The absence of sediment yield data restricts the calibration and validation only to streamflow-related parameters. The sediment yield input data, supposedly, should have been included in the sensitivity analysis with measured data for more efficient model calibration in case sediment yield prediction is the intention of the study.

RECOMMENDATIONS

In order to fully appreciate the utility of the SWAT model, its application must be employed only in watersheds with at least minimum required input data. Assumptions on the values of important parameters, if not provided quantitatively, will just complicate the interpretation of the results.

Acquired, measured or observed data on discharges (stream flows) and sediment yields are needed especially if the intention of using the model is for sediment yield prediction. The absence of acquired data on sediment yield in the present study which is supposed to be included in sensitivity analysis and used in calibration may have affected the results of sediment yield estimation. Therefore, subsequent or related studies, using the same model, are only suggested if these data are all available.

Parameters in the crop database must be studied well. The over-predicted values of sediment yield in corn and some other LULCs demand further examination of the crop database to determine which parameters need iteration. In addition, it is possible in the current and latest SWAT versions to delete, edit, update and add a specific crop type or LULC (e.g. agroforestry) which is not available in the crop database as long as matching parameter values taken in the field will also be provided. This is suggested primarily to address difficulty in model parameterization.

Fine-tuning of parameters in the SWAT model is generally a stumbling block to new users of the software. The task would be more tedious especially when some critical parameters need to be precisely adjusted to minimize error and increase accuracy of the model. Therefore, auto-calibration which was not performed in the study is suggested only for the identified sensitive parameters.

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Research article

Logging Effects on Soil Organic Carbon and Hydraulic Property in North Appalachian Region of Ohio USA

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Abstract Forest soils play an important role in the global carbon cycle. Thus, documenting changes in carbon stocks and hydraulic property by logging are essential to sustainable management. However, information on logging in relation to soil organic carbon (SOC) stock is scarce and it can be site specific. Thus, the effects of logging on the SOC stock and hydraulic property were analyzed after logging at a site in the North Appalachian Experimental Watershed (NAEW) near Coshocton, Ohio, USA. The objectives of the study were to quantify the impacts of logging on SOC stock and hydraulic property. Results show that for the 0-30 cm soil depth, SOC stock after logging (61.5 Mg ha^{-1}) was 54.5 % lower than that before logging (135.3 Mg ha^{-1}). Further, soil water retention at different potential was consistently higher before logging than that after logging. A plot of the hydraulic capacity vs. suction under natural forest differed significantly than that after logging at 0-10 cm soil depth. Thus, logging reduced SOC stock, and degraded hydraulic property of the surface layer.

Keywords forest logging, soil organic carbon, soil water retention

INTRODUCTION

Soils in forest ecosystems are a major sink of global carbon, in part due to the large area involved at a global scale. World soils contain an estimated 1550 Pg of carbon to 1 m depth, an amount that is nearly twice that contained in the atmosphere (Lal, 2004). Within the forest biomes, forest soils constitute 31 % of the total carbon stock (Kimble, 2003). Thus, forest soils play an important role in the global carbon cycle. However, land use change causes disturbance of the forest ecosystem and can influence the soil organic carbon (SOC) stock and soil hydraulic property (Lal, 2005). There have been numerous studies on forest resources and their management (Lorenz and Lal, 2010). However, field studies on forest management practices in relation to soil is scarce (Kimble, 2003). In addition, the effect of SOC stock and hydraulic property can be soil and site specific. Therefore, there is a need for significant advances in measurement of SOC stock and hydraulic property in the forest ecosystem. In the United States, the Renewable Resources Planning Act Assessment Report showed that in 2003, about 33 % of the total land area was under forest compared with 46 % in 1630. About 120 Mha of forestlands have been logged for the forest resources and converted to other uses (e.g., agriculture). Logging creates soil disturbance and compaction by machinery such as bulldozers, tractors etc. During logging, the use of heavy machinery is common in the United States and many parts of the world, which alters soil hydraulic and mechanical properties and adversely affect plant growth (Soane, 1990). Disturbed and compacted soil is highly prone to accelerated erosion and increased surface runoff (Sidle and Drlica, 1981). Displacement of surface soil can also occur during the logging operations. A soil under undisturbed native forest has a high macro porosity and low bulk density, and it is prone to compaction by heavy machinery (Huang et al., 1996, Lacey and Ryan, 2000). These factors adversely affect plant growth due to restricted root growth, and reduced air and water availability.

OBJECTIVE

The goal of this study was to assess differences in SOC stock and hydraulic properties for before and after logging sites in the surface layer. The hypothesis tested in this study was that logging reduces the SOC stocks, degrades hydraulic properties.

METHODOLOGY

Study Site and Soil Sampling

The experimental site was located at the North Appalachian Experimental Watershed (NAEW) near Coshocton, Ohio, USA (40°22'N, 81°48W'). The NAEW was established in the late 1930s to study the effect of soils, land management, geology and climate on water flow characteristics from agricultural and forest lands (Kelley et al., 1975). The NAEW is located within the mixed oak region of the unglaciated Allegheny portion of the Appalachian Plateau in east central Ohio (Kelley et al., 1975). The mean annual precipitation at this watershed is 950 mm and the mean annual temperature is 10.3 °C (Lorenz and Lal, 2010). Soils at NAEW are classified as Berks silt loam (loamy-skeletal, mixed, active, mesic, Typic Dystrudepts) (Dick et al., 1998; Kelley et al., 1975). The wooded areas were logged in July 2012. Soil sampling was carried out during September 2012 at after logging at shoulder position with triplicate, and before logging with triplicate.

Soil Organic Carbon and Total Nitrogen

SOC and total nitrogen (TN) concentrations were determined by the dry combustion method (960 ˚C) using a Vario TOC analyzer (Elementar Inc., Hanau, Germany). The SOC stocks were calculated based on an equivalent soil mass (ESM) basis to correct for differences in compaction among the sites (Lee et al., 2009; Ellert and Bettany, 1995). The SOC stock (Mg ha^{-1}) was computed by multiplying the SOC concentration by the bulk density and the equivalent soil depth using following Eq. 1:

$$SOC_{ESM\ stock} = \rho_b \times d \times SOC_{con} \times 10^4 (m^2\ ha^{-1}) \qquad (1)$$

where, SOC_{ESM} *stock* is the SOC stock associated with ESM (Mg ha^{-1}), ρ_b is the soil bulk density (BD) (Mg m^{-3}), d is the equivalent thickness of soil depth (m), and SOC_{con} is the SOC concentration (g kg^{-1}).

Soil Water Retention Curve

Soil water retention curve (SWRC) was assessed by using a combination of tension table and pressure plate extractors (Dane and Hopmans, 2002). The SWRC was determined at 0, –0.4, –1, –2.5, and –5 kPa with tension table and at –10, –20, –30, and –1500 kPa with pressure plate methods. All available soil hydraulic models, the van Genuchten-Mualem model is the most widely used in simulation of SWRC (van Genuchten et al., 1991). The function in Eq. 2 describes the SWRC:

$$\theta = \theta_r - \frac{\theta_s - \theta_r}{[1 + (\alpha|\psi_m|)^n]^{1-1/n}} \qquad (2)$$

where, θ is the volumetric water content ($m^3\ m^{-3}$), θ_r is the residual volumetric water content ($m^3\ m^{-3}$), θ_s is the saturated volumetric water content ($m^3\ m^{-3}$), and ψ_m is the matric potential (kPa). Parameters

α (cm^{-1}) and n are the empirical fitting parameters characterizing the shape of the retention curve by using Eq. 2. Change in soil structure, land use, or plotting the differential SWRC indicates soil management practices. A plot of the slope of SWRC $d\theta/d\psi_m$ vs. ψ_m can be used as an indicator of the change in soil structure and hydraulic properties, due to changes in land use (Radcliffe and Šimůnek, 2010; Lal and Shukla, 2004).

$$C_\theta = |d\theta/d\psi_m| \tag{3}$$

where, C_θ is hydraulic capacity (kPa^{-1})

Statistical Analysis

Statistical analysis was carried out for each soil depth separately, with different management before and after logging sites. The data were statistically analyzed using SAS code PROC UNIVARIATE GLMM (Generalized Linear Mixed Model) procedure(SAS 2007). Statistical significance was computed at $p \leq 0.05$, unless otherwise stated.

RESULTS AND DISCUSSION

Soil Bulk Density, Texture, pH and EC

Results for soil BD, texture, pH, and electrical conductivity (EC) at 0-10, 10-20, and 20-30 cm soil depths at before and after logging sites are shown in Table 1. For before logging, soil BD increased with increase in depth. However, for after logging, soil BD slightly decreased from 1.64 to 1.43 Mg m^{-3} going from 0-10 and 10-20 cm depths then increased to 1.56 Mg m^{-3} at 20-30 cm. For the 0-10 cm soil depth, soil BD under after logging (1.64 Mg m^{-3}) was 49.0 % higher than that before logging (1.10 Mg m^{-3}). For the 10-20 cm soil depth, soil BD under after logging was slightly higher than that before logging, but not statistically different at $P \leq 0.05$. Before logging soil had 36.3 and 8.2% clay content at 0-10 and 10-20 cm soil depth, respectively, but not statistically different those after logging soil. The pH and EC did not differ among before and after logging at any soil depths.

Table 1 Effects of logging on soil texture, pH, electrical conductivity (EC), and bulk density (N=6 for each depth)

Site	Depth (cm)	Sand %	Silt %	Clay %	Texture Class	pH -	EC µS cm^{-1}	Bulk Density Mg m^{-3}
After Logging	0-10	28.5a*	55.0a	16.5a	Silt Loam	4.99a	243a	1.64a
	10-20	27.5a	54.3a	18.2a	Silt Loam	5.05a	152a	1.43b
	20-30	28.7a	52.7a	18.6a	Silt Loam	5.23a	114a	1.56b
Before Logging	0-10	30.0a	47.5a	22.5a	Loam	5.34a	244a	1.10c
	10-20	27.6a	52.7a	19.7a	Silt Loam	5.50a	155a	1.32b
	20-30	28.3a	55.5a	16.2a	Silt Loam	5.47a	129a	1.60a

**Means with different letters (a, b, and c) among before vs. after logging soil for each depth are not significantly different at p ≤ 0.05.*

Soil Organic Carbon and Total Nitrogen

Results for SOC and TN stock associated with ESM (Mg ha^{-1}) for 0-10, 10-20, 20-30, and 0-30 cm soil depths for before and after logging are shown in Fig. 1. The logging event significantly influenced the SOC stock in 0-10, 10-20, and 20-30 cm soil depths ($P<0.01$, $P<0.01$, and $P<0.01$, respectively). For 0-30 cm depth, SOC stock after logging soil (61.5 Mg ha^{-1}) was 54.5 % lower than that before logging soil (135.3 Mg ha^{-1}). For 0-10, 10-20, and 20-30 cm soil depths, SOC stock was 58.3, 48.5, and 53.8 %, respectively, higher before logging soil (62.8, 37.7, and 34.7 Mg ha^{-1}, respectively) than after logging soil (26.2, 19.4, and 16.0 Mg ha^{-1}, respectively). For both before and after logging soils, SOC stocks decreased with increase in depth. Logging effects were more predominant in the surface layer. The TN stocks were significantly affected by logging at 0-10 and 10-20 cm soil depths (*P*<0.01, and *P*<0.01). Lower TN stocks were observed after logging soil (2.39, 1.85, and 1.62 g kg^{-1}, at 0-10, 10-20, 20-30 soil depths, respectively) than before logging soil (4.19, 2.69, and 2.67 g kg^{-1}, at 0-10, 10-20, 20-30 cm soil depths, respectively). For 0-30 cm soil profile, TN stocks after logging soil (5.87 Mg ha^{-1}) were 38.5 % lower than those before logging soil (9.55 Mg ha^{-1}).

Soil Water Retention Curve

The data in Fig. 2 (top) show the SWRC for 0-10, 10-20, and 20-30 cm soil depths for before and after logging, and fitted SWRC by van Genuchten-Mualem model using RETC code (van Genuchten et al. 1991). The hydraulic capacity vs. soil moisture potential are shown in Fig. 2 (bottom). The SWRC were well described by the van Genuchten relationship (R^2 > 0.94). Overall the SWRC before logging soils were consistently higher than those after logging soils at all depths. Between saturation and approximately 10 kPa, hydraulic capacity before logging soil was consistently higher than that after logging soil at 0-10 cm soil depth. For 10-20 and 20-30 cm soil depths, the hydraulic capacity across the suction did not differ among before and after logging soils.

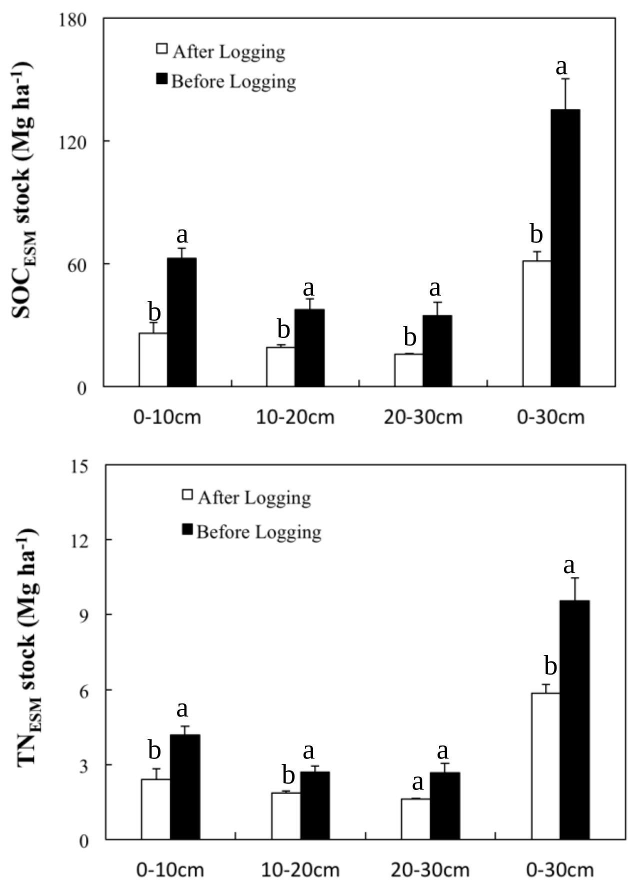

Fig. 1 Effects of logging on soil organic carbon (SOC) and total nitrogen (TN) stocks associated with equivalent soil mass (EMS) at the 0-10, 10-20, 20-30, and 0-30 cm soil depths. Means with different letters among after vs. before logging for each depth are not significantly different at *p ≤ 0.05*. Error bars indicate standard error (N=3).

Discussion

Logging significantly affected SOC stocks at all depths (Fig. 1). For the 0-30 cm soil depth, SOC stocks after logging soils were 54.5 % lower than those before logging soils. Decline in SOC stocks two months after logging may be due to logging practices such as harvesting, which involve heavy machinery for cutting and transporting of trees, causing severe soil compaction, drastic soil disturbance and a mixing of the forest floor into the mineral soils (Kimble, 2003). Furthermore, logging can cause altered soil water content and temperature regimes, which can accelerate decomposition and decrease net primary production (NPP) (Lal, 2005). The exposure of the soil also exacerbates losses due to soil erosion and leaching of dissolved organic carbon (Kimble, 2003). Further, SOC sequestration could be also decreased due to the reduction of biotic activities and decrease in soil moisture content (Lal, 2005). Effects of logging on the reduction of SOC stocks were more predominant in surface soil layer, due to the smaller inputs of fresh litter, decrease in decomposition with increase in depth. The SWRC is an important indicator of soil structure, and relative distribution of micro and macro pores (Nakajima and Lal, 2014). The SWRC at each potential was consistently higher before logging soil than that after logging soil (Fig. 2 top), primarily due to having greater hydraulic capacity between matric potential 0 to 10 kPa at the 0-10 cm soil depth (Fig. 2 bottom). At 0 kPa matric potential, (or saturation point), before logging soils had greater water holding capacity than after logging soils, indicating greater occurrence of macro pores. This trend persisted to 10 kPa, also an indication of greater occurrence of intermediate and micro sized pores and clay content. A lower hydraulic capacity over time or change in management practice indicates progressive declines in soil structure and degradation of soil physical properties (Lal and Shukla, 2004).

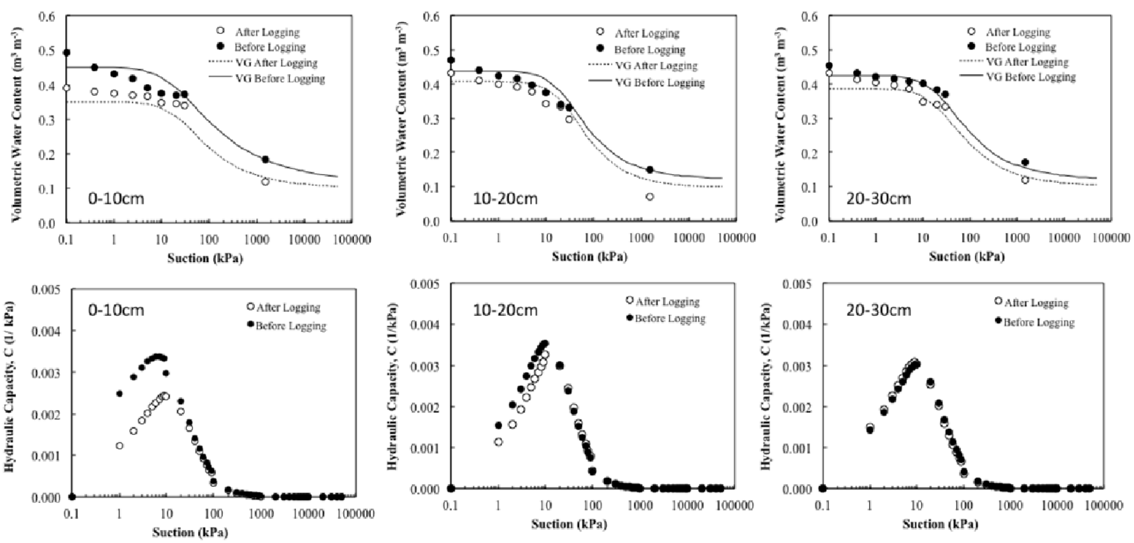

Fig. 2 Effects of logging on soil water retention curve (SWRC) (top) and hydraulic capacity vs. suction (bottom) for the 0-10, 10-20, and 20-30 cm soil depths. Lines (top) show the fit of van Genuchten equation (VG) SWRC using RECT code.

CONCLUSION

The hypotheses that logging in this study decrease SOC stocks and degrade soil hydraulic property were supported by the results. Results also supported the following conclusions (1) the SOC stocks after logging soil were 54.5 % lower than those before logging soil for the 0-30 cm soil depth. The

SOC stocks declined sharply by logging within 2-month period (2) logging adversely affected SWRC, especially in the 0-10 cm soil depth, probably due to decrease in macro pores and meso pores.

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Research article

Impact of the Land Use Diversity on the River Water Quality in the Agricultural Area

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Abstract Water pollution due to agriculture has become a serious global problem. Also, agricultural development has had major impacts on biodiversity. Impacts on the ecology of a watershed should be considered when proposing changes to land use and management for water quality conservation. Habitat diversity is one of the most important factors for conserving biodiversity in an agricultural landscape. In recent years, several fields of research have shown a positive correlation between a mosaic of land types and species richness. Herein, we evaluated the land use diversity of the Tokachi River basin and examined an appropriate spatial unit to calculate a land cover heterogeneity index for river water quality. The Tokachi River basin is located in the northern part of Japan and plays an important role in a food production area. The main land use types are forest, cropland, pasture, and dairy farming. Here we applied the Satoyama Index (SI) as a land cover heterogeneity index to examine land use diversity. SI evaluates a diverse mosaic of agricultural and non-agricultural land as an index from 0.0 to 1.0 based on Simpson's diversity index. High SI values are an indicator of high habitat diversity. The mean SI value of the Tokachi River basin (No.17) was 0.6, and SI tended to be high in the central basin and low in the headwater of mainstream and tributaries. SI values had negative correlations with total nitrogen, nitrate, and electrical conductivity (EC) of river water. Unified land uses for extensive agricultural land results in increasing nitrogen and EC of the river water and leads to monotonic habitat conditions in the Tokachi River basin.

Keywords Satoyama index (SI), land use diversity, river water quality, biodiversity, spatial unit size

INTRODUCTION

Ecologically sustainable agriculture is regarded as a strategy to respond to global population growth and food issues, environmental degradation, climate change, and degrading natural resources (Kassam and Friedrich, 2012; Robertson et al., 2014; Bedoussac et al., 2015). The concept of an "ecological farm" is an approach adopted to implementing ecologically sustainable agriculture that is in harmony with nature; it involves the use of cultivation techniques and breeding programs that do not rely on soluble chemical fertilizers, pesticides, herbicides, or artificial genetic modifications. The Food and Health Organisation (FAO) established the Globally Important Agricultural Heritage System (GIAHS) in 2002 to promote traditional agricultural systems and landscapes; these have been created, shaped, and maintained based on diverse natural resources, using locally adapted management practices. However, the agricultural production of eco-friendly agriculture still requires improvement.

In the Tokachi area, which is an important food production area in Japan, nitrogen pollution caused by agriculture has been reported (Yamazaki et al., 2013, 2014, 2015, 2016(a)). Yamazaki et al., 2016(b) showed that it is necessary to control the restructuring of land use to alleviate nitrogen pollution of the Tokachi River basin. Local ecosystems have to be considered when designing an effective layout of land use in an agricultural land to facilitate water quality conservation.

In recent years, several studies have demonstrated a positive correlation between land use diversity and species richness (biodiversity) in an agricultural area (Robinson and Sutherland, 2002; Firbank et al., 2008). Kadoya and Washitani (2011) proposed the Satoyama Index (SI), a biodiversity indicator which is a simple composite index of agricultural landscape heterogeneity and the contribution of nonagricultural land use. They showed that a high SI value is an indicator of high habitat diversity, whereas a low SI indicates a monotonic habitat condition, which is typical of extensive monoculture landscapes.

In this study, we analyzed land use diversity of the Tokachi River basin by SI and examined the relationship between the SI score and the river water quality to design an eco-friendly measure of water quality conservation in the Tokachi region, a large-scale agricultural landscape in Japan.

METHODOLOGY

The Tokachi River basin

This study was conducted in the Tokachi River basin located in the eastern part of Hokkaido, Japan (142.68–144.02 N, 42.55–43.65 E, 0–2,077 m altitude) (Fig. 1 and Table 1). The basin has a total area of 9,010 km^2 and a total stream length of 156 km. According to the Köppen–Geiger climate classification, the Tokachi River basin is characterized as a warm summer continental climate type (Dfb) with an annual mean air temperature of 6.8 °C and an annual precipitation of 887.8 mm/y; these measurements are the means of the recorded values at Obihiro City from 1981 to 2010. The soil types in the Tokachi River basin are volcanic soil, lowland soil, upland soil, and peat soil. In particular, volcanic soil (andosols) is widely distributed in this basin. The main land uses in this river basin are for agriculture and forestry, with 60% of the agricultural land used as cropland and 40% used as pasture. Both chemical fertilizers and livestock manure are applied to the agricultural land.

Water Quality Investigation and Analyses

The river water quality was monitored at 21 sampling points located on the main stream (No.17) and at each tributary (A–T) of the Tokachi River basin in June, in either August or September, and in October from 2007 to 2011 under base flow conditions. Water samples were analyzed for total nitrogen (T-N), nitrate (NO_3-N), total phosphorus (T-P), pH, biological oxygen demand (BOD), suspended solids (SS), and electrical conductivity (EC).

Satoyama Index (SI; Kadoya and Washitani, 2011)

We calculated the SIs of 21 watersheds in the Tokachi River basin. Calculation for SI is shown in Eq. 1 based on the agricultural landscape heterogeneity index (ALHI) using Simpson's diversity index (Lande, 1996; Eq. 2) by ArcGIS Desktop (ver.10, ESRI).

$$\mathrm{SI} = \mathrm{ALHI} \times \frac{p_{other}}{k} \times \frac{k}{k-1} \quad (1)$$

$$\mathrm{ALHI} = 1 - \sum_{i=1}^{S} p_{i^2} \quad (2)$$

p_{other} is the number of grid squares of the other land uses, and k is the total number of the grid squares in a spatial unit in Eq. 1. S is the number of different land cover items in a spatial unit, and p_i is the proportion of agricultural land to the total number of grid squares in Eq. 2. In this study, the following were the values used:

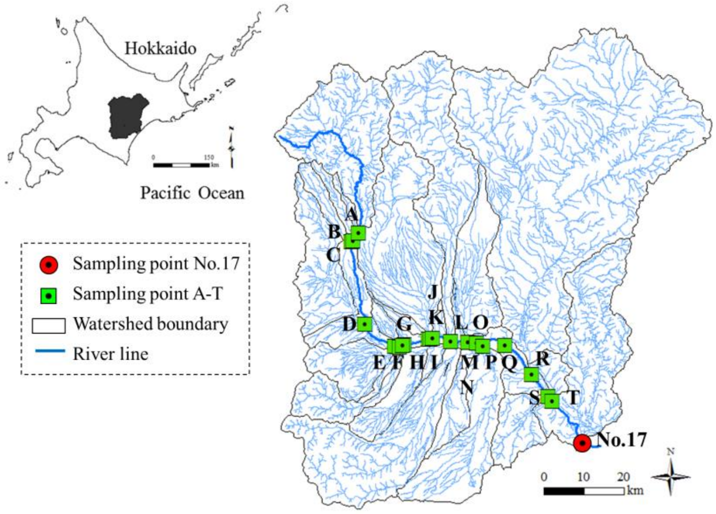

Fig.1 Locations of the 21 sampling points in the Tokachi River basin

"land use raster data" (100 m grid size; publication in 2009) published by the National Digital Information and "JAXA High Resolution Land-Use and Land-Cover Map (Ver. 16.02)" (10 m grid size; publication in 2016) published by ©JAXA. The proportion of agricultural land and forest land in Table 1 was calculated by "land use raster data". Also, Kadoya and Washitani (2011) set a spatial unit size of 6 km; however, we set four different spatial unit sizes (500×500 m^2, 1×1 km^2, 5×5 km^2, and 10×10 km^2) to calculate SI of the Tokachi River basin.

RESULTS AND DISCUSSION

Figure 2a, b shows the spatial distribution of SI calculated by a combination of 500 × 500 m^2 spatial unit size and 10 m or 100 m resolution (500 m unit size and 10 m resolution or 500 m unit size and 100 m resolution) in sampling point No.17. SI tended to be low in the center (lowland) of the watershed and high in the headwater of mainstream and tributaries of the watershed. In the Tokachi River basin, the center area is dominated by extensive agricultural land, resulting in monotonic habitat conditions; however, the headwater tributary areas were covered by forests and had rich habitat

Table 1 Watershed and land use information for each sampling point

Sampling point	Watershed area km^2	River length km	Proportion (%) Agricultural land	Forest land
A	23	47	0	98
B	48	27	2	96
C	72	29	2	97
D	337	42	25	68
E	210	25	40	53
F	26	16	73	11
G	35	18	79	18
H	180	38	16	74
I	164	36	73	17
J	33	22	52	44
K	667	67	47	44
L	693	94	18	61
M	197	80	71	70
N	704	43	30	12
O	316	41	65	28
P	127	31	79	12
Q	449	52	70	25
R	2850	150	19	76
S	173	25	23	73
T	66	13	44	51
17	8982	146	31	58

diversities. The spatial distribution of SI of combinations with other spatial unit sizes (1×1 km^2, 5×5 km^2, and 10×10 km^2) showed the same trend. SI of the 10 m resolution varied between the center area (low SI) and the headwater of mainstream and tributaries (high SI).

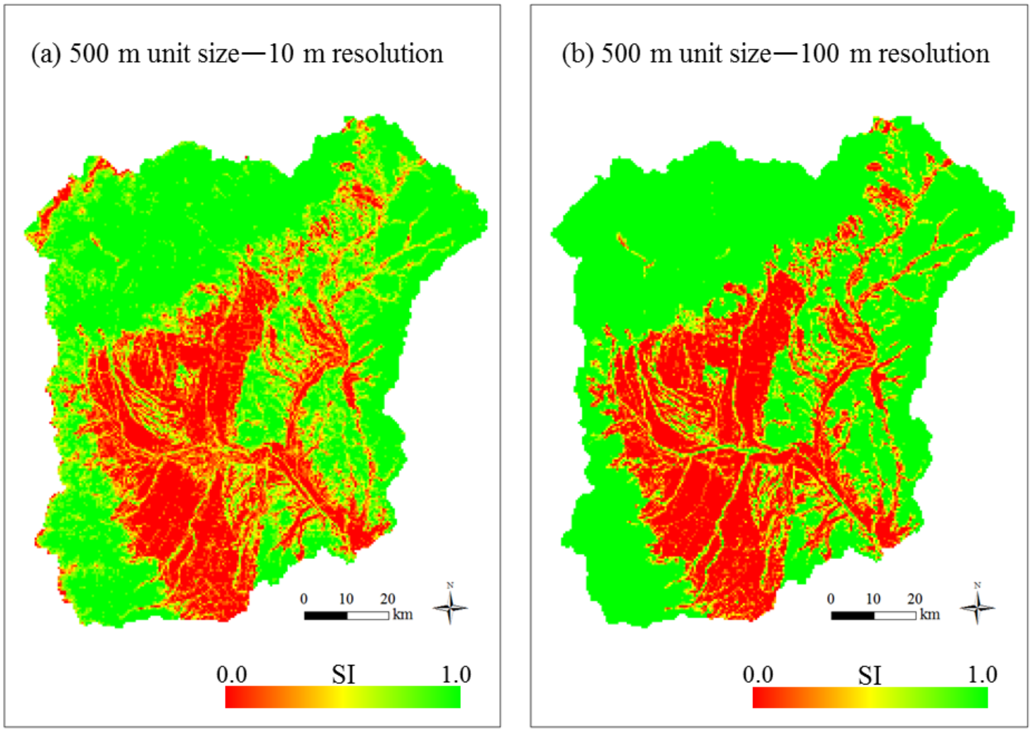

Fig.2a, b Spatial distribution of the Satoyama Index in the sampling point No.17

Fig. 3a, b shows the percentage of each SI value (0.0–1.0) calculated by a combination of four spatial unit sizes (500×500 m^2, 1×1 km^2, 5×5 km^2, and 10×10 km^2) and two resolutions (10 m, Fig. 3a; 100 m, Fig. 3b) in the sampling point No.17. SI–1.0 and SI–0.1 were high percentages of 10 m resolution, whereas SI–1.0 and SI–0.0 were high percentages of 100 m resolution. Also, SI–0.2 to SI–0.9 increased with increasing unit size of both resolution types. From this, the land use of the Tokachi River basin is polarized between either agricultural land area or forest area.

We calculated the mean SI of the each watershed of the 21 sampling point of No.17 and A–T. Fig. 4 shows the mean SIs of 500 m unit size–10 m resolution and 500 m unit size–100 m resolution in the sampling point No.17 and A–T as one example. Where the sampling points have less than 0.5 of SI value, Mean SI of the 500m unit size-10 m resolution and 500m unit size -100m resolution showed nearly the same value. However, the mean SI of the 500 m unit size-100m resolution was found to be higher than that of the 500 m unit size-10 resolution at the sampling points has more than 0.5 of SI value. It was considered that minor land use type recognized at 50 m resolution was excluded at 100 m resolution. Habitat diversity of the watershed at the sampling points A–D, H, L, R, and S were comparatively rich since mean SI of these sampling points was higher than SI–0.6. Conversely, the points on the watershed located at F, G, I, M, O, P, and Q were dominated by extensive agricultural land since mean SI of these sampling points was lower than SI–0.2. The same trend was confirmed of a combination with another spatial unit size (1×1 km^2, 5×5 km^2, and 10×10 km^2). However, SI tended to decrease with increasing unit size.

Table 2 shows the correlation coefficients of the relationships between seven river water quality variables (T-N, NO_3-N, T-P, pH, BOD, SS, and EC) and mean SI. The mean SI of 21 sampling points had a negative correlation with T-N, NO_3-N, and EC. This implies that nitrogen concentration and dissolved matter tended to increase with low SI (unified to agricultural land). When we compared the correlation coefficients of T-N, NO_3-N, and EC with each combination of unit size and resolution, the correlation coefficients tended to be higher in 10 m resolution than in 100 m resolution, and also tended to be higher in the small unit size.

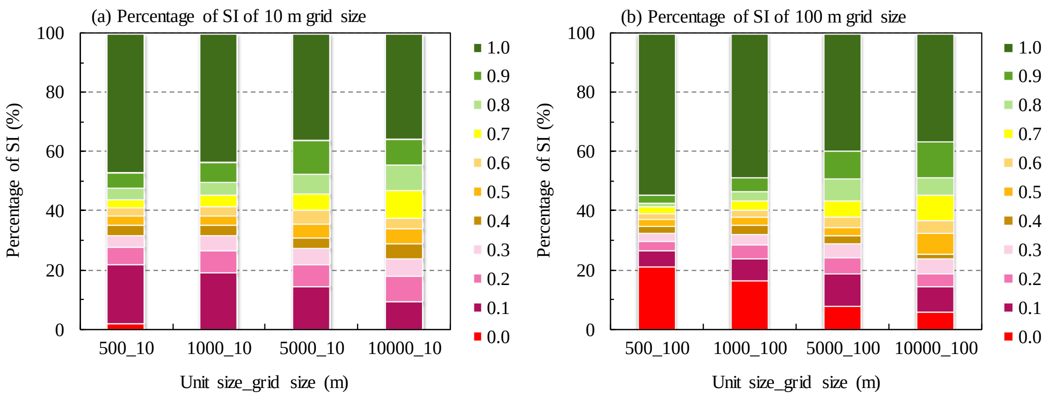

Fig.3 Percentage of Satoyama Index (SI)–0.0 to SI–1.0

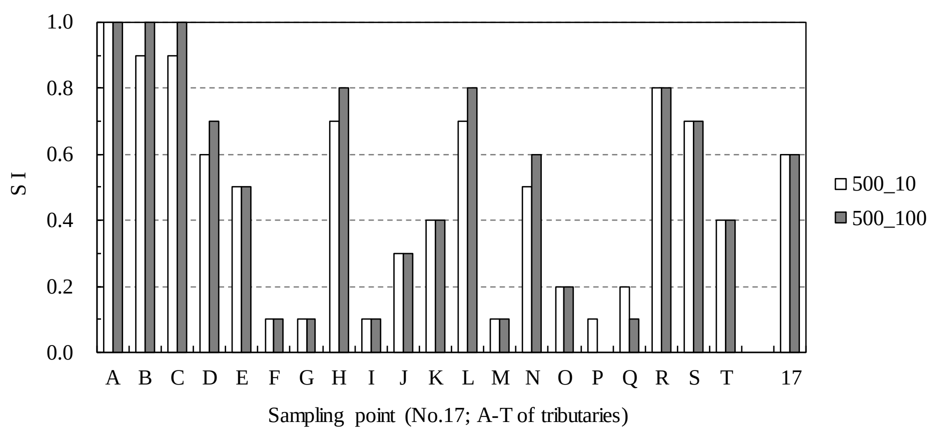

Fig.4 Mean Satoyama Index (SI) of the watershed in the 21 sampling point of No.17 and A–T

Table 2 Correlation coefficients of the relationships between water quality and mean Satoyama Index (SI). ** shows significance level ($p < 0.01$).

Water quality index		SI_ 10 m grid size Unit size				SI_ 100 m grid size Unit size			
		500 m	1 km	5 km	10 km	500 m	1 km	5 km	10 km
T-N	(mg/L)	-0.82**	-0.81**	-0.78**	-0.69**	-0.82**	-0.80**	-0.75**	-0.69**
NO_3-N	(mg/L)	-0.81**	-0.79**	-0.76**	-0.68**	-0.80**	-0.79**	-0.73**	-0.68**
T-P	(mg/L)	-0.32	-0.37	-0.34	-0.36	-0.36	-0.34	-0.33	-0.34
pH		0.18	0.12	0.10	0.01	0.14	0.15	0.13	0.03
BOD	(mg/L)	-0.41	-0.42	-0.42	-0.42	-0.41	-0.43	-0.38	-0.35
SS	(mg/L)	-0.06	-0.09	-0.07	-0.06	-0.05	-0.08	-0.06	-0.03
EC	(mS/m)	-0.83**	-0.84**	-0.79**	-0.73**	-0.82**	-0.81**	-0.75**	-0.69**

CONCLUSION

Herein, we analyzed the habitat diversity of 21 sites in the Tokachi River basin using the Satoyama Index (SI) and examined the relationships between the river water quality and SI. In the Tokachi River basin, the center (lowland) area had low SI and was dominated by extensive agricultural land, whereas the headwater of mainstream and tributaries had high SI and had rich habitat diversity. Mean SI of the 21 sampling points showed a negative correlation with T-N, NO_3-N, and EC. The nitrogen concentration and dissolved matter of the river water tended to increase in the sampling points dominated by extensive agricultural land. Also, it was suggested that the combination of 500 m unit size and 10 m resolution was optimal for explaining the relationships between SI and the river water quality.

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Research article

Comparison of Land and Water Improvement Projects and the Water Management System between Japan and Nigeria

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Abstract Food security is strongly linked to water security. Irrigation is recognized as a means to substantially increase agricultural productivity. Consequently, the Food and Agriculture Organization indicated that 75% of agricultural growth required in Nigeria by 2025 would have to result from intensification, with the remaining 25% resulting from arable land expansion. However, the total water demand in Nigeria was estimated to be 5.93 billion cubic meters (BCM)/year in 2010, which is expected to increase to 16.58 BCM/year by 2030. Irrigation water demands will increase from 30% to 40% under minimal utilization. Accordingly, as irrigated agriculture is likely to be promoted and expanded, there is a need for appropriate on-farm water management of the available water resources to avoid the potentially alarming problem of water shortage. Water improvement projects and the management system were described through a comparative study to investigate the major differences in water management systems. The aim was to formulate equitable and effective water management practices that can improve water use and increase food production in Nigeria. In this study, some major differences identified between Japan and Nigeria were the procedure for the development of water improvement projects; system of operation, management, and maintenance; and the relationship between water managers and farmers, which were found to be bottom-up and top-down processes, dependent and independent, and mutual relationship and individuality, respectively.A realistic solution to improve the Nigerian water management system has been proposed through an in-depth analysis based on a questionnaire and interview survey.

Keywords on-farm water management, water user association, water scarcity, Nigeria

INTRODUCTION

Food security is strongly linked to water security. Irrigation is recognized as a means to substantially increase agricultural productivity. Consequently, the Food and Agriculture Organization (FAO) indicated that 75% of agricultural growth required in Nigeria by 2025 would have to result from intensification, with the remaining 25% resulting from arable land expansion (FAO, 2005-NGA).

This will probably have to be achieved with reduced water use; this is particularly because agriculture is the major user of water, accounting for approximately 40% of a country's water resources. Accordingly, if irrigated agriculture is aggressively promoted and expanded, there is a need for appropriate water management of available water resources to avoid the potentially alarming problem of water shortage.

However, the total water demand in Nigeria was estimated to be 5.93 billion cubic meters (BCM)/year in 2010, which is expected to increase to 16.58 BCM/year by 2030; irrigation water demands will increase from 30% to 40% under minimal utilization (Sanyu, 2013).

The irrigation potential estimated in Nigeria varies from 1.5 to 3.2 million ha. The latest estimate provides a total irrigation potential of approximately 2.1 million ha, of which approximately 1.6 million ha can be realized from surface water resources and 0.5 million ha from groundwater resources. During the oil boom in the 1970s, an investment program in support of public irrigation was launched. Public irrigation in the Nigerian context translates to schemes run by River Basin Development Authorities.

The schemes that were developed have not yet been fully operationalized, or they have been implemented with inappropriate infrastructure and management processes. By 2004, only approximately 20% of the area planned for public sector irrigation had been developed and only 32% of the developed area was being irrigated.

The poor utilization of the developed irrigation area in the public irrigation sector in Nigeria can be attributed to a number of factors. These include 1) the lack of a coherent irrigation subsector development policy and strategy; 2) insufficient attention to management systems; 3) inadequate funding (including poor cost recovery); 4) high capital and operating costs; 5) inadequate farm support services; 6) poor operation, repair, and maintenance of irrigation facilities; 7) a low level of project ownership acceptance by direct beneficiaries; and 8) uncertain financial and economic viability. These factors result in inequity and inefficient water management practices, consequently resulting in a number of these schemes deteriorating considerably; these schemes are now in urgent need of major renovation and repair, less than 20 years after their inception (FAO, 2005-NGA).

Under the system of Land Improvement Districts (LIDs) in Japan, which are farmers' autonomous irrigation associations with total responsibility for irrigation system management, Japanese water management is one of the successful forms of participatory irrigation management (PIM) (Ishii and Satoh 2003). Therefore, the introduction of the basic ideas of LIDs to the irrigation management of large-scale projects in Asia, Africa, and Central and South America may be effective to improve their irrigation management (Minami, 2002).

Hence, successful knowledge transfer is important in anticipating future failures or difficulties in land and water improvement projects and the management system in Nigeria. This will assist in discussing how to adopt improved options for better agricultural production and sustainability. The objective of the present study is to investigate problems, causes, and solutions associated with the water improvement projects and the management system in Nigeria through a comparative study between Japan and Nigeria.

METHODOLOGY

Study Site

The Hadejia Valley Irrigation Project (HVIP) is one of the biggest public irrigation projects in Nigeria, and it considerably contributes to agricultural food production. This project is located in the Hadejia Local Government Area of Jigawa State, between the Hadejia River and its tributaries in the northern part of Nigeria. The average annual precipitation in Hadejia (project location) is 595 mm. The initial area proposed for development under the HVIP in the late 1970s was 12,500 ha under Phase I (Fig. 1), which consisted of stages I and II; however, work has not yet started on Stage II. Stage I was constructed in different steps; however, this stage remains incomplete. Stage I has a total command area of 5,300 ha, divided into 19 sectors (15 constructed, 4 unfinished) with 6,000 farmers cultivating approximately 90% rice and other crops such as maize and vegetables.

The major water source for the project is the Hadejia River, on which two dams (Tiga and Challawa dams) are situated at the upstream site, and the Hadejia Barrage is situated at the downstream site, which supplies water to the northern main canal through the feeder canal by gravity.

Although, land consolidation is yet to be done in HVIP unlike the Japanese land which undergoes a land consolidation to improve performance and productivity of the farmlands (through Land Improvement act 1949), making it into a regular shape for easy use of machineries and paddy rice cultivation. However, the standard agricultural lot in HVIP is 4 ha while it is 0.3 ha in Japan.

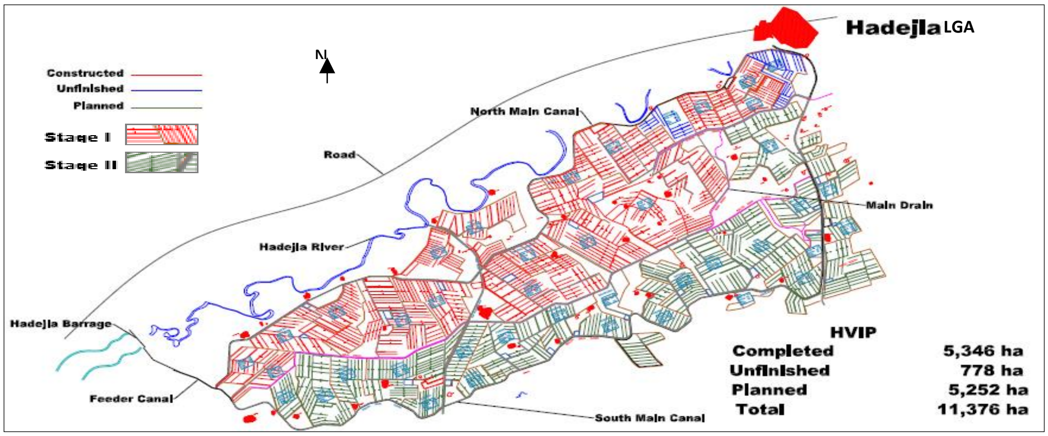

Fig. 1 Layout of Hadejia Valley Irrigation Project (HVIP) phase I (stages I and II)

For the purpose of comparison, the Toyogawa Irrigation Project in Aichi Prefecture, Japan, which is part of the Toyogawa Water Resource Development Project that was established in 1968, was selected as the study site. This project is one of the most successful modern water resource development projects in Japan. The study project covers newly developed irrigation areas of 16,000 ha (paddy: 5,000 ha, upland: 11,000 ha). This command area includes traditional paddy irrigation areas. The average annual rainfall is approximately 1,700 mm/year (Japan Meteorological Agency, 2016). However, dry spells in the region sometimes extend to 1 month; therefore, it is impossible for farmers to realize stable agricultural production without irrigation. The major water source is the Toyo River, and supplemental water originates from the adjacent Tenryu River basin. The Toyogawa Water Resource Development Project also encompasses the Ure and Ohshima dams in the upstream part of the Toyo River (Satoh, 2012).

Data Collection and Analysis

A comparative analysis of land and water management systems between Japan and Nigeria was conducted through 1) a questionnaire and interview survey, 2) a literature review, and 3) field investigations in both Japan and Nigeria. A total of 36 farmers, consisting 12 farmers each from the upstream, mid-stream, and downstream sectors of the HVIP in Nigeria were randomly selected to answer the questionnaire, which contained 37 open ended and 10 close ended questions both related to water availability, the irrigation system, organization for water management, and the method of operation and maintenance cost of the scheme. The questionnaire was structured for easy understanding of water user activities for water management and to determine the opinions of farmers regarding the equity of water distribution and operation of irrigation facilities. Interviews were conducted with four project supervisors from Hadejia Jamaare River Basin Development Authority (HJRBDA) staff and the three zonal office staff, and 15 officials of Water User Associations (WUAs) from all sectors, to obtain detailed information regarding the performance and structure of WUAs, organizations for water management, water allocation planning, operation and maintenance system of the facilities, and PIM in the HVIP (Nigeria). In addition, field visits to the study projects were conducted to visualize the scheme and to gain access to farmers to obtain information and answers to questionnaire structured for the study. However, after the analysis on irrigation water allocation, the project should be operated to achieve the purpose of fair water distribution among the entire beneficiary farmers. Thus, the WUAs and farmers will manage the irrigation facilities, as a result, the struggled and complained over inadequate water at the downstream will be resolved and farmers become more satisfied with the irrigation system.

In Japan, an interview with the head of Japan Water Agency (JWA) office in Kagawa Prefecture was conducted, where we discussed the operation of water resource systems (reservoirs, diversion dams, regulating reservoirs, and main canals) and their operation and maintenance arrangement. This was followed by a field visit to observe and understand what had been discussed. However, literature reviews containing detailed information concerning the Toyogawa Irrigation Project in Japan were also assessed for the comparison.

RESULTS AND DISCUSSION

Organizations for Water Management

According to the questionnaire and interview discussion, the organization currently responsible for water management in the HVIP is the HJRBDA, which is a public unit established to manage public irrigation schemes within state boundaries in Nigeria, and its zonal office, which assists the HJRBDA in the management of the HVIP. The HJRBDA is the agency responsible for the overall operation and maintenance of the main irrigation facilities (main and lateral canal and the drainage system including the Tiga Dam, Challawa Dam, and Hadejia Barrage). The zonal office manages on-farm facilities and also coordinates with farmers for the collection of water fees. A community of WUAs was formed, which assist the zonal office in collecting water charges and control certain secondary and tertiary canals. Although some members of the WUAs assist the zonal office, 60% of farmers interviewed at the downstream sector complained of inadequate water distribution during the maturity stage of their rice crop, whereas 90% of farmers at upstream and mid-stream sector were satisfied with the water distribution, although they were not involved in the management process. This shows that the participation of WUAs in partnership with the zonal office is poor, which leads to inequitable distribution of water among the farmers.

In the Toyogawa Irrigation Project in Japan, five types of organizations are involved in the water management of the project, which have different functions to ensure equity and fair management: 1) the JWA, which is a public entity that manages the construction project; 2) Toyogawa LID, which is an autonomous irrigation association of farmers established for the Toyogawa Irrigation Project; 3) local LIDs, which are established based on the administrative boundaries of cities or towns; 4) Management Districts, each of which corresponds to a traditional local community; and 5) Management Groups, which are established by beneficiary farmers of an on-farm irrigation facility (all LIDs are established after agreement by 2/3 of the beneficiary farmers). All these organizations are assigned roles in water management according to the level of a facility, from main to on-farm level. The JWA manages the main infrastructure of an irrigation facility (reservoirs, diversion dams, and regulating reservoirs) and main canals and is also responsible for delivering water to lateral canals. The Toyogawa LID manages lateral canals and diverts water to farm ponds. The Toyogawa LID staff patrol farm ponds daily to assess stored water, and they adjust the allocation of water to lateral canals as required. Local LIDs assemble requests from Management Districts and request water from the Toyogawa LID according to the need. Local LIDs, Management Districts, and Management Groups manage farm ponds and on-farm facilities in a group. Management Group leaders in a Management District adjust the water distribution among themselves (Kozuki, 2000).

Therefore, in the Toyogawa Irrigation Project, it is evident that farmers are responsible for the management of their irrigation; most farmers are categorized into different groups (Toyogawa LID, local LIDs, Management Districts, and Management Groups) and are assigned a certain responsibility to ensure equity distribution and fair management of the irrigation project. In contrast, in the HVIP, farmers are not responsible for the management of irrigation, and only certain selected WUAs assist the zonal office. To solve the problem of inequitable water distribution among farmers, water managers (the HJRBDA and zonal office) should be assigned to manage the construction of the project and the farmers should be divided into different groups, with each group assigned the responsibility of managing a different level of irrigation facilities. This will assist in resolving the inequitable and unfair distribution of water among farmers in the HVIP as was achieved in the Toyogawa Irrigation Project.

Water Allocation Planning

The result of the questionnaire and interviews shows that in the HVIP, the zonal office of the HJRBDA controls water gates from the dam (Hadejia Barrage) to main canals by constant releasing water at a fixed amount of 10 m^3/s (this is now the maximum carrying capacity of the main canal), which is a decreased amount from the actual designed capacity of 15 m^3/s. However, water allocation planning is completely absent from the zonal office, and only farmers (WUAs) arrange their water planning for distribution to the secondary and tertiary canals based on their experience, without any investigation on the water demand of each sector. This causes improper water planning and inequitable water distribution, resulting in the upstream water users using more water and in dissatisfaction by downstream water users, as stated by 60% of farmers at the downstream sector during interviews. The current water supply method in the HVIP is shown in Fig. 2.

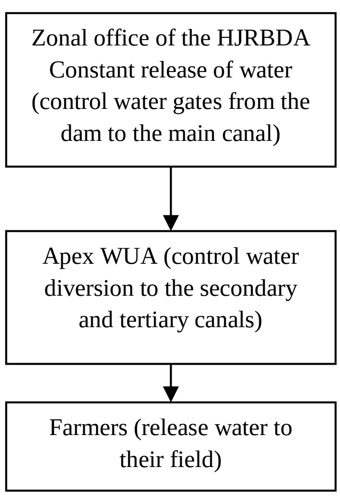

Fig. 2 Water supply method in the Hadejia Valley Irrigation Project

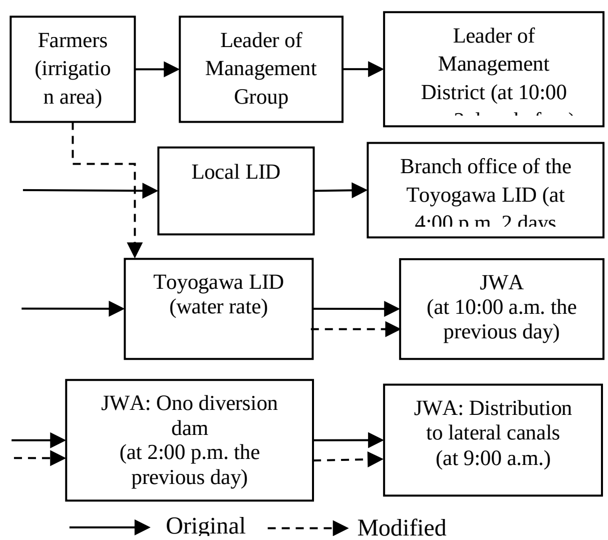

Fig. 3 The original and modified water allocation method and distribution process

In the Toyogawa Irrigation Project, some in-depth studies have been conducted to determine the water demand of each sector and a simplified process was established to meet the water demands of farmers following the process depicted in Fig. 3, which reflects the original water distribution method applied to the project. The water demand was calculated based on the declared daily irrigation area by farmers. The total area of irrigation was conveyed through the LID's hierarchical system, converted to a flow rate, and forwarded to the JWA. Because of the long procedure and resulting complaints by farmers, the water allocation and distribution system was improved to avoid this complicated procedure and the problems it induced. In the new system, the first four steps in the previous system are disregarded, and the Toyogawa LID branch offices take the first step to request water on behalf of farmers.

Therefore, water demand studies in each sector (upstream, mid-stream, and downstream) of the HVIP are important to avoid water conflict among upstream and downstream water users and also to determine whether the amount of water released is sufficient to irrigate crops or if there is a need to reconstruct or rehabilitate the main canal to meet the capacity of the water requirement identified. Again, after investigating the water demand, the water managers (the HJRBDA and zonal office staff) should simplify guidelines and support their procedures by providing proof of logical and technical information and also explain the effect of over-irrigation on crops and agricultural lands such as water logging and salinization problems to avoid the overconsumption of water by farmers. Likewise, water allocation plans in the HVIP should be decided in meetings attended by all delegates from different interest groups (beneficiary farmers, the HJRBDA, zonal office authority, and Chad basin management office). This will assist in achieving equitable distribution and improved understanding of the importance of appropriate water allocation planning among farmers which will increase the amount of water utilized effectively for irrigation and ensured water availability to all farmers.

System of Operation and Management Cost of Irrigation Facilities

From the result of the interviews and the field visit to the HVIP, farmers and water managers said government is responsible for the construction, operation, maintenance, and management costs of irrigation facilities; however, it was found that proper system operation is currently not possible at all levels of the systems. The main findings are that 1) operation and management (O&M) of the facilities has long since fallen to a level below what is required; 2) the water fee (0.4 $/ha) collected is insufficient to maintain the irrigation facilities, even when considering the amount provided by the government to cover the O&M cost of the irrigation facilities; 3) the systems are currently in such a technically poor condition that rendering proper system operation at most levels is impossible; 4) there has been a substantial loss of command area; 5) a weakened organization responsible for O&M has not been able to rectify the situation; and 6) farmers have developed mistrust in the HJRBDA's capacity and capability to perform its maintenance duties for which they are supposed to pay.

All costs for water management in the Toyogawa Irrigation Project are covered by beneficiary farmers. The Toyogawa LID assists the JWA in the collection of money from farmers. The membership fees are based on acreage as well as on the land use of paddy or upland fields. The JWA, Toyogawa LID, local LIDs, Management Districts, and Management Groups form a hierarchical system corresponding to facility levels and operate in an environment of functional role sharing in the Toyogawa Irrigation Project. In this environment, a directly interested organization is not allowed to operate independently, and instead, a higher level of organization is assigned responsibility. In this way, it is easy to distribute water in a fair and neutral way following the decisions made. It is difficult for farmers or farmers' organizations to operate modern, large-scale, complicated irrigation facilities as specialized knowledge and skills are required. Therefore, role sharing in the facility operation of a large-scale irrigation project is inevitable. In addition, a bulletin is periodically distributed by the JWA to every member farmer, thereby supporting the understanding of the state and functions of facilities and the processes of water management by every farmer, which includes the decisions, operation, monitoring, and feedback (Satoh, 2012).

Therefore, for the sustainability and proper performance of the operation and management of the HVIP, the water fee to be collected from farmers should be adjusted and added to the budget provided by the government for the operational and management costs of the project to enable the budget to fully cover the operation, management, and maintenance costs of irrigation facilities, under the supervision of a higher organization (HJRBDA). In addition, the government should disseminate information regarding how the fee collected was used for the operational, management, and maintenance costs of the facilities and also the status of irrigation facilities to local farmers. This will encourage farmers to contribute to management and operational costs. All related organizations should be assigned specific roles within operation and management at different levels of the facilities. By this practice, costs will be reduced and a physical transparency system of the operation and management of facilities will be implemented that will encourage beneficiaries to contribute to the operational and management costs for achieving the sustainability of the project.

CONCLUSION

The main points analyzed for the HVIP to develop an appropriate system to achieve water improvement and management practices include the following:

1) Involvement of farmers in management organization in such a way that farmers are categorized into different groups (e.g., HVIP WUAs, local WUAs, Management Districts, and Management Groups) and assigned a certain responsibility to ensure equitable distribution and fair management of the irrigation project.

2) Water demand studies for water allocation are important in the HVIP to determine the demand in each sector to avoid water conflicts among water users in the upstream and downstream sectors. The water demands should be decided in meetings attended by all delegates from different interest groups.

3) The water fee to be collected from farmers should be adjusted and added to the budget provided by the government for the operational and management costs of the project to enable the budget to cover the operation, management, and maintenance costs of the irrigation facilities, under the supervision of a higher organization (HJRBDA).

Therefore, the adoption and implementation of the identified processes of land and water improvement projects and the management system in the HVIP will play an important role in enhancing the equitable distribution of irrigation water. Similarly, this will enable a system of physical transparency of operation and management of irrigation facilities for better water use in Nigeria.

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Research article

Forest Ecosystem Services and Agricultural Production of Communities in Protected Areas: A Case Study of Phu Kao - Phu Phan Kham National Park, Thailand

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Abstract Forest ecosystems provide goods and services that support our livelihoods. However, forestlands are often cleared for agriculture due to nutrient availability for crop growth. This study examined forest ecosystem services and agricultural practices of three villages at Phu Kao – Phu Phan Kham National Park, northeastern Thailand. A survey on agricultural production and socioeconomics was conducted in June 2016, together with GIS spatial analysis to examine correlations between agricultural productivity and forest-to-farmland distances (FD) and vegetative cover (VC) surrounding farmlands within a 100m radius. We hypothesized that farmlands closer to the forests and/or surrounded by greater vegetative structure would receive more benefits from forest ecosystem services than those farther away. In total, 100 household representatives answered the questionnaire. Cassava was a major cash crop planted with approximately 8.94 tons/ha. Production costs of cassava plantation (i.e., labor and fertilizer) were estimated 24,67.95 Baht/ha, mainly from harvesting costs and chemical fertilizers. Forest-to-farmland distances and VC did not result in significant yields (tons/ha). However, the total production costs of cassava plantations closer to the forest (<1 km) were significantly smaller than those farther away (mean difference = -7,053 Baht/ha, p = 0.007), while VC showed a marginal difference. Farmlands with less VC (<1 ha) resulted in greater total production costs than those with larger VC (mean difference = 2,540.00 Baht/ha, p = 0.073). These findings illustrate that adjacent forests provide ecosystem services to cassava production, at least to some degree. Farmers incur smaller production costs, thereby receiving greater economic returns when their farmlands were closer to the forest and surrounded by larger amounts of vegetation.

Keywords forest ecosystem services, agricultural production, protected areas, Phu Kao – Phu Phan Kham National Park, Thailand

INTRODUCTION

Forest ecosystems provide goods and services such as food, fuel, and other basic necessities of life that support at least half of the world's population (World Resource Institue, 2008). The Millennium Ecosystem Assessment (2005) categorized ecosystem services into four types: supporting, provisioning, cultural and regulating services. Supporting services include biodiversity, soil fertility, nutrient cycling and the provision of water, while pollination, natural pest control and water purification are examples of regulating services and traditional ecological knowledge represents example of cultural benefits. Consequently, forestlands are often cleared for agricultural use because of high nutrient availability, thus making agriculture the main force of deforestation (Lawson, 2014). Reducing the amount of deforestation caused by agriculture is not as simple as asking farmers to stop clearing the land, although it is the cheapest option in the short run. Furthermore, household livelihoods are a higher priority than forest protection. Several studies have shown the benefits of forests over agricultural production (Olschewski et al., 2006; Ricketts, 2004), so farmers can see what has been gained in the conversion process, especially supporting and regulating services e.g., pollination, soil fertility and pest control, in addition to direct provisioning services such as non-timber forest products and potential reserves for agricultural expansion.

Instead of simply asking villagers to stop land encroachment and/or agricultural expansion, this study showed the benefits of forest ecosystem services. It investigated farming practices and household socioeconomic conditions since these factors affect agricultural production. The study was conducted at Phu Kao – Phu Phan Kham National Park (PKNP) in northeastern Thailand. The area attracted some attention because of community settlement inside the park, which is not allowed in protected areas. However, this case was an exception since the villages claimed that they were established before the park was designated. Land conflict between villagers and park authorities continued until the Cabinet Solution in 1998 in which usufruct rights were granted to villagers who were able to prove existence before park designation. Following the 1998 Cabinet Solution, approximately 1,600 ha of protected lands were set aside for agricultural and residential use purposes, together with land use rules and regulations. Moreover, management authority was transferred from the Department of National Parks, Wildlife, and Plants Conservation to local authorities, complicating law enforcement efforts. Rule violations, including land encroachments outside the permitted area, agricultural expansion and plantations of prohibited crops/trees (i.e., para-rubber), can be observed. The PKNP authority recorded at least 21 lawsuits of land encroachments inside the park during 2015. Furthermore, the community has expanded substantially, from small villages of seven to 10 households at the beginning to 528 households in 2015 (Office of Civil Registration, 2015).

OBJECTIVES

This study examined correlations between agricultural productivity, FD and VC surrounding the farmlands. We hypothesized that farmlands closer to the forests and/or surrounded by greater VC would receive more ecosystem benefits than those more isolated (Olschewski et al., 2006; Ricketts, 2004). Therefore, farmers should obtain greater yields and/or incur less costs.

METHODOLOGY

Study Area

The boundary of PKNP, Thailand's 50th national park, crosses three provinces in northeast Thailand (Khon Kaen, Nong Bua Lamphu, and Udon Thani) covering approximately 32,200 ha. The park consists of two main areas, including Phu Kao and Phu Phan Kham. This study took place at Phu Kao (PK), located between latitudes 16° 51' - 17° 1' N and longitudes 102° 24'- 102° 31'E in Nong Bua Lamphu. Phu Kao consists of diverse landscapes, including sandstone mountains, undulating topography, and a vast floodplain of Pong River, creating the Ubonrattana Reservior – the largest dam in the northeast. The major vegetation is dry Dipterocarp forest, covering approximately 80% of PK, followed by mixed deciduous forest and dry evergreen forest. Intermixed within the park are Phu Kao National Forest Reserves, making forest access less restrictive when compared to the national park lands because they are managed by a different agency, the Royal Forest Department. Moreover, approximately 1,600 ha of park lands were set aside for community agricultural and residential use purposes as part of the 1998 Cabinet Solution. These communities include Dongbak, Wangmon and Chaimongkol village. Management authority over this designated area was transferred to local administrative organizations of Nonsang District, Nong Bua Lamphu Province.

Data Collection on Agricultural Production and Household Socioeconomic Conditions

A questionnaire was used to collect data on agricultural production, household socioeconomic conditions, and other relevant information e.g., forest use and villager adaptation to environmental and socioeconomic change. The survey was semi-administered by household representatives (i.e., head of the family, spouse and/or main labors) who were personally interviewed by the researchers. The interview was conducted in the following order: household socioeconomic information, agricultural activities and production, boundary locations of farmlands, crop yields, and production costs. Village leaders were contacted prior to the actual visits, which occurred in June 2016, to inform them of the study and seeking their permission to participate. In total 100 household representatives from all three villages were selected randomly. In addition, personal interviews with the village leaders and onsite observations were performed for confirmation and clarification.

Spatial Data Analysis

In addition to surveyed data, FD and VC surrounding the farmlands were estimated using ArcGIS 10.1. First, household representatives were asked to identify their farm location and boundaries using GoogleEarth images. Midpoint coordinates for each of the identified farmlands were specified for calculation of FD and VC surrounding the farmlands. Calculation of FD were performed using Ruler Tool to measure a distance from each farmland midpoint to the nearest forest. Furthermore, calculation of VC was done using farmland coordinates and images downloaded from GoogleEarth. The coordinate system: WGS1984 UTM Zone 48N was used as referenced data for farmland coordinates and sizes of the actual areas before the dereferencing pointer adjusted the processed images to get accurate coordinates. The farmland midpoint coordinates from Excel were imported into ArcGIS, creating an entire data set of farmland coordinates. Afterwards, shapefiles were created to digitize VC within a 100m radius before reclassification and specification of areas and values of cells. The last stage was to buffer each sampled area within a 100m radius using the Calculate Geometry tool to compute size of VC until the set of farmland coordinates was completed.

Statistical Analysis

Data from the survey and spatial analysis were entered into SPSS version 20 for statistical analysis. Descriptive statistics were used to describe household socioeconomic conditions and their agricultural production activities. Pearson correlations were used to examine socioeconomic factors relating to agricultural production. Finally, independent t-tests were used to compare yields, farm inputs and production costs between farmlands with different FD and surrounding VC. Mean values i.e., 1,000m for FD and 10,000 m^2 (1 ha) for VC, were used to classify the variables (i.e., yields and production costs) into two groups.

RESULTS AND DISCUSSION

Household's Socioeconomic Conditions

In total, 100 household representatives (36 from Wangmon, 30 from Chaimongkol, and 34 from Dongbak), including village leaders, participated in the survey. Their socioeconomic conditions are shown in Table 1.

Table 1 Socioeconomic information of farmers participated in the study

Socioeconomic conditions	% of respondents			
	Wangmon (n=36)	Chaimongkol (n=30)	Dongbak (n=34)	Summed (n=100)
Gender				
Female	14	11	21	46
Male	22	19	13	54
Main occupation				
Farmer	35	25	34	94
Merchant	1	1	-	2
Government service	-	1	1	2
Hired labor	-	2	-	2
Household income (Baht/year)	141,083	111,340	183,894	135,538
Averaged size of agricultural lands (ha)	2.81	3.77	4.00	3.52

The majority of villagers (98%) earned most of their income from selling agricultural products, essentially cassava; and a small number of them made additional income from selling non-timber forest products (approximately 100 Baht/month). About 57% of participants reported growing rice. This number is small compared to other agricultural-based communities in the northeast, which is nearly 100%. Perhaps this is due to topographic unsuitability for rain-fed rice cultivation, which usually occurs in the lowlands, but the three villages are located on hilly terrain. All villagers indicated growing rice for personal consumption which helped to reduce household spending. However, almost three-fourths (71%) of the farmers faced rice shortage, so they needed to purchase extra amounts for household consumption. The estimated amounts of rice purchased were 392.21 kg/household or approximately 12,855 Baht/household per year.

Land Use and Agricultural Production

Two common cash crops were planted i.e., cassava and sugarcane for income generation. Since sugarcane prices have dropped in recent years while production costs remain high, many farmers have switched to cassava. Only five per cent of the villagers reported planting sugarcane during 2014-2015 crop year, while 98% grew cassava. Rice is cultivated for household consumption rather than income generation. Three farmers (one from each village) reported planting para-rubber trees even though this tree is prohibited to preserve natural forests in the park. High market demands, especially in the past 10 years when the government promoted para-rubber plantations in the northeast, gave villagers economic incentives to plant this tree, despite rules and regulations against it. Although this incident is considered illegal, park officers often compromise to avoid conflict by asking villagers not to expand their plantations.

Average sized farmlands, about 3.52 ha, are mainly used for cash crop plantations i.e., cassava. Average yields of cassava was 8.94 tons/ha, which is much lower than the average provincial yield (21.18 tons/ha) in 2015 (Office of Agricultural Economics, 2015). Total production costs were estimated from explicit costs of labor used in each of the plantation stages, together with costs of fertilizer application, including manure and chemical fertilizers. The average production costs were 24,676.95 Baht/ha. Harvesting accounted for the highest proportion of total production costs (53%), followed by farm maintenance (34%), planting processes (8%) and land preparation (5%) (Table 2). Farming is becoming more market-driven. Cash returns from agricultural activities are thought to be more valuable than subsistence benefits. Therefore, farmers increase crop productivity in an attempt to serve increasing market demands by using more chemical fertilizers and relying on hired labor. Subsequently, production becomes expensive with relatively smaller profits (Bowman and Zilberman, 2013).

Table 2 Production costs of cassava plantation

Process of cassava production	Households samples (n = 94)
Total costs of cassava production (Baht/ha)	24,676.95
1) Land preparation	1,335.15 (5%)
2) Cassava planting	1,853.52 (8%)
3) Farm maintenance	8,391.33 (34%)
3.1) Chemical fertilizer application	5,884.59 (70%)
3.2) Manure application	147.90 (2%)
3.3) Weeding	2,358.84 (28%)
4) Harvesting costs	13,096.95 (53%)

Factors Affecting Farmer Agricultural Production

Farm production depends on both ecological and socioeconomic factors. Ecological conditions e.g., nutrient contents, soil pH and moisture, and amounts of rainfall, directly influence crop growth. Nonetheless, quality of farmlands absolutely relies on farming practices, especially farm maintenance and land conservation. In this study, total production costs, amounts and costs of chemical fertilizers used in cassava plantations showed significant correlations with size of farmlands ($r = 0.363$, -0.247 and -0.241, $p<0.05$, respectively). All farmers reported using chemical fertilizers to help improve crop productivity. The amount and cost of chemical fertilizers varied according to the size of farmlands, which subsequently influenced the total production costs. The larger the planting areas, the smaller the amounts and costs of chemical fertilizers used per hectare. Size of agricultural lands also affected the amount of farm input since farmers can only provide so much labor, fertilizer, and other inputs to maximize crop yields. Nonetheless, average yields did not show significant correlations with total costs, amounts and costs of fertilizers and labor costs. Although farm input directly affected crop productivity, ecological conditions, including climatic and soil factors, also played an important role in determining productivity.

Farm Production Based on Forest-to-farmland Distance and Vegetative Cover

The analysis used to examine if FD influenced agricultural production illustrated that total costs in farm maintenance and total production costs (i.e., labor, manure and chemical fertilizers) of farmlands located closer to the forest were significantly smaller than those farther away (Table 3). Costs of chemical fertilizers showed a marginal difference; cassava plantations closer to the forest resulted in lower costs. Although average yields were not significantly different, they were smaller for cassava plantations with smaller VC, while total production cost and total labor cost were marginally higher for cassava plantations having smaller vegetative cover (Table 3).

To some extent, these findings imply positive contributions or services from the forest to cassava plantations, including the influence of FD on total costs in farm maintenance, total production costs and costs of chemical fertilizers used in planting cassava, and the impact of VC on total production costs and labor costs. However, average yields did not reveal connections with FD and VC because they do not solely depend on farm input, but also from climatic factors and soil conditions. History of landuse, crop rotation and farm maintenance practices directly influence agricultural land conditions and productivity. Longevity of land use, especially continuous use of chemical fertilizers, leads to a decrease in soil nutrients and higher erosion (FAO, 2016; Virto et al., 2015), which in turn, reduces crop yields. Moreover, some studies reveal that VC can hinder crop growth since it could reduce sunlight and other necessary growth factors, causing low productivity of crops (Yasmin et al., 2016; Wang et al., 2012; Cerdan et al., 2012).

Table 3 Comparisons of agricultural production (t-tests) between farmlands with different forest-to-farmland distances and vegetative cover

Group variables	Test Variables	$\bar{x}$ ±SD	Mean Difference	t-test		
				t	N	p-value
	1) Costs of chemical fertilizer application (Baht/ha)					
	Zone 1 (0-1,000 m)	5,212±4,216	-1,466.61	-1.726	51	<u>0.088</u>
	Zone 2 (>1,000 m)	6,679±3,966			43	
Forest-to-farm Distances	2) Total costs in farm maintenance (Baht/ha)					
	Zone 1 (0-1,000 m)	9,805±6,149	-7,063	-2.99	51	0.004*
	Zone 2 (>1,000 m)	16,868±14,379			43	
	3) Total production costs of cassava plantation (Baht/ha)					
	Zone 1 (0-1,000 m)	15,215±7,631	-7,053	-2.77	51	0.007*
	Zone 2 (>1,000 m)	22,269±15,115			43	
	1) Total production costs of cassava plantation (Baht/ha)					
	Zone A (0-10,000 m^2)	19,273±16,411	2,540.00	0.898	49	<u>0.073</u>
Vegetative covers	Zone B (>10,000 m^2)	16,733±9,489			45	
	2) Total labor costs (Baht/ha)					
	Zone A (0-10,000 m^2)	13,712±15,998	3,616.77	1.323	49	<u>0.092</u>
	Zone B (>10,000 m^2)	10,095±9,332			45	

Note: * significantly different $p<0.05$, underlined numbers represent marginal difference

CONCLUSION

There is a strong interdepency between forests and farmers, although it can be difficult to quantify. The forest provides benefits and services that support farmer livelihoods, while its existence depends on farming practices. Increasing demands for food and other types of agricultural products e.g., energy crops, force farmers to expand their production, which in turn, leads to deforestation. Unfortunately, authorities cannot simply ask farmers to stop agricultural practices just to halt deforestation. Therefore, one way to motivate farmers not to expand their agricultural lands into nearby forests is to show how the forests can contribute to their production. This study illustrates that FD and VC influence farm production, at least to some extent. Farmlands close to the forest and/or surrounded by large patches of vegetation benefit from the forest, resulting in lower costs of chemical fertilizers, total costs in farm maintenance and total production costs. Finally, the protected forest in Phu Kao, Nong Bua Lamphu Province is an example to reiterate that it helps provide ecosystem services that improve farmer's agricultural production. Typically, forest protection and agriculture are in opposition, but should be viewed as complementary. Therefore, effective forest protection is beneficial for agricultural production rather than hindering it – a new paradigm to better understand their interconnectivity.

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Research article

Estimation of Soil Erosion Based on USLE and ArcGIS in Gardez Basin of Paktya Province, Afghanistan

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Abstract Soil erosion is a serious problem in Afghanistan which has been accelerated by improper land management day by day and a growing problems especially in the area of agricultural. The land in the country is facing continuous soil loss and sediment accumulation due to the irregular topography, deforestation and desertification. It does not only reduce agricultural and livestock production, but also decrease the water availability for irrigation purpose. This study focused on the estimation of the rate of soil loss and soil erosion risk using Universal Soil Loss Equation (USLE) and ArcGIS for the Gardez basin Paktya Province, Afghanistan. All factors used in USLE (R, K, L, S and C) were calculated for the study area using local data. The best equation for estimating R value from the annual rainfall was discussed on the basis of the observed annual rainfall with the installed rain gauge. Also, all factors were presented by raster layers in ArcGIS platform then multiplied together to predict soil loss (A). The results indicated that the annual soil loss within Gardez Basin ranges from 0 to greater than 100 t ha^{-1} y^{-1}. The value was divided into five (5) risk classes. The result showed that slight class of soil loss having a range of soil loss between 0 to 5 t ha^{-1} y^{-1}, moderate class having rates between 5 to 10 t ha^{-1} y^{-1}, high class having rates between 10 to 50 t ha^{-1} y^{-1}, severe class rates between 50 to 100 t ha^{-1} y^{-1} and very severe class rates greater than 100 t ha^{-1} y^{-1}, covering 64.31%, 13.95%, 19.76%, 1.76% and 0.22% of the Gardez Basin area, respectively. Most of the agricultural lands are slight to high soil loss categories. However, high soil erosion is found in the barren land, rangeland and rainfed agricultural land. The soil erosion risk is extremely higher on steep slope and foothills. Based on the mean soil erosion value of different land use classes, target land use for conserving strategies was discussed for planning soil conservation practices.

Keywords USLE, ArcGIS, Gardez Basin, soil loss, Afghanistan

INTRODUCTION

Erosion is one of the major ecological problems which threaten our national reserves as well as the whole world. It also reduces soil fertility significantly and crop yields. Afghanistan is located in the south and central Asia which is under high soil erosion effect mostly due to deforestation, arid and semi-arid climates and irregular topography. Soil erosion has resulted in prolonged and great impact on social and economic development in the region, in fact, recent environmental assessments indicated that decades of war and continuous drought have caused widespread environmental degradation throughout the country.

The Universal Soil Loss Equation (USLE) was developed by Wischmeier and Smith in 1978. It has been the most commonly used model for predicting soil erosion loss. The USLE and its modified versions such as RUSLE (Renard et al., 1997) and MUSLE (Williams, 1975) have been widely used in various scales and regions.

Soil erosion has received scanty attention in Afghanistan. However, the study conducted by Sahaar, (2013) using combined Revised Universal Soil Loss Equation (RUSLE) model and Geographic Information System (GIS), the annual soil loss of Kabul Rivers was estimated 19 t acr^{-1} y^{-1}, (4748 t km^{-2} y^{-1}). The excessive sedimentation clogs stream channels and increase costs for maintaining water passage structures. Similarly, the annual soil loss of the Lower Harirud watershed in Heart province used RUSLE model and GIS ranges from 0.025 to 778 Mg ha^{-1} y^{-1}, which is 3.6 times greater than maximum tolerable soil erosion (Ehsan, 2015). Field study conducted by US Military Agricultural Development Team, (2011) in Dawlatzai village of Paktya province, soil erosion depended on area ranges between 500 t/ha to 1200 t/ha.

Estimation of soil erosion is economically and environmentally very important in Paktya province, Afghanistan. Soil erosion is not only reduced soil fertility and degradation water quality but also severe interrupts of irrigation network. Poor vegetation cover, steep slopes deforestation and high intensity rainfall in short time are the main factors influenced soil erosion in Paktya province. Therefore, to evaluate the impact of these factors on sustainable agriculture and environment, to quantify the extent of soil erosion it needs for appropriate and applicable erosion model. For this reason, the USLE model has been widely used worldwide approximately more than four decades to predict soil erosion. Recently, there are many type of research were conducted regarding the USLE model in conjunction with GIS technology has been used to predict the annual soil loss. The objective of this study is to evaluate soil erosion risk using ArcGIS technique and empirical Universal Soil Loss Equation in Gardez basin of Paktya province, Afghanistan.

MATERIALS AND METHODS

Study Area

The study was conducted in Gardez Basin located east part of the country and also it is the capital of Paktya province, Afghanistan. The basin covers approximately 48,104 ha (481.04 km^2) as shown in Fig 1. It is geographically positioned between latitude N 33° 46′ 0″- N 33° 28′ 0″ and longitude E 69° 26′ 30″- E 69° 26′ 30″. It topographically ranges in slope between 0 to 65 degrees with an elevation of approximately 3663 m above sea level. The rainfall data obtained from the daily automatic rain gauge installed in the study area for one-year duration (July 15, 2015 to July 14, 2016), the annual rainfall is 354.6 mm y^{-1} and exhibits a dry climatic condition with a minimum and maximum temperature of -11 °C and 41 °C, respectively.

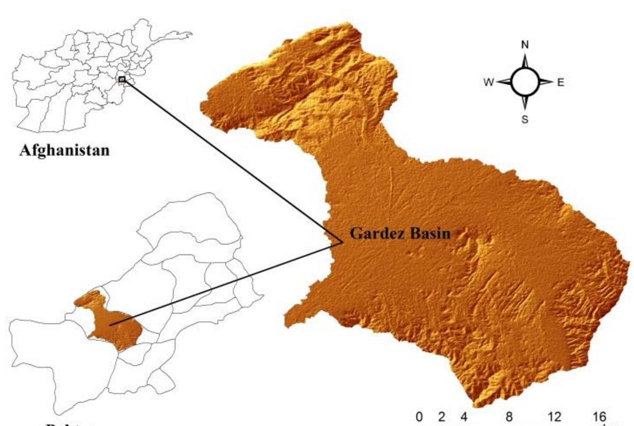

Fig. 1 Map of study area in Paktya Province, Afghanistan

Methods

The USLE model was developed by Wischmeier and Smith (1978), as an equation representing the main factors controlling soil erosion, namely climate, soil characteristics, topography and land cover management. The expression is shown Eq. 1.

$$A= R\times K\times L\times S\times C\times P \quad (1)$$

Where A is computed annual soil loss per unit area (t ha^{-1} y^{-1}), R is runoff erosivity factor (MJ mm ha^{-1} y^{-1}), K is soil erodibility factor (t ha hr ha^{-1} MJ^{-1} mm^{-1}), L is slope length factor, S is slope steepness factor, C is cover management factor and P is supported practice factor.

In the present study, annual soil loss rates and scale were computed based on USLE in GIS platform and different data sources were referred to analyze the estimation of soil loss in the study area. A digital elevation model (DEM) with 30 m resolution was obtained from Aster Global Digital Elevation Model (Available online: https://asterweb.jpl.nasa.gov/gdem.asp), the elevation range is from 2205 m to 3663 m as shown in Fig. 2. The DEM was used to estimate slope gradient, flow direction, basin area, flow length and flow accumulation for the study area using ArcGIS 10.3.1. The slope length and slope steepness (LS) factor required by USLE was calculated. The land cover classification map developed by Food Agriculture Organization (FAO, 2016), was used for the analysis of crop management factor (C-value). Soil classification map developed by United States Department of Agriculture, Soil Conservation Services (USDA-SCS, 2001) was used for analyzing the soil erodibility factor (K-value). Analysis of rainfall erosivity factor (R-value) was derived from area automatic rain gauge data in Gardez city and mean annual rainfall data in surrounding areas.

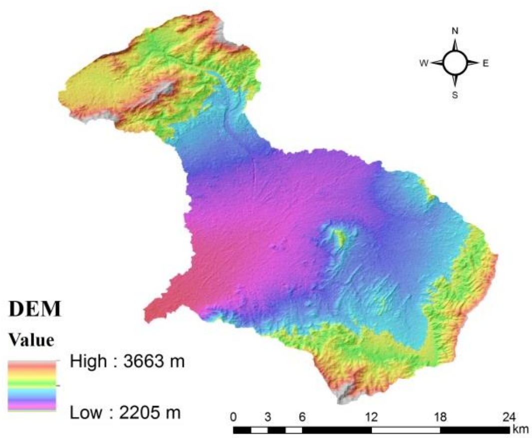

Fig. 2 DEM map of Gardez Basin

RESULTS AND DISCUSSION

Rainfall Erosivity Factor (R)

Rainfall erosivity is defined as the aggressiveness of the rain to cause erosion. Rain has a direct impact on the surface of the soil. The kinetic energy of the raindrops destroys the soil aggregates, making them susceptible to transfer by runoff water. The R factor was computed using the Eq. 2 and 3 developed by (Wischmeier and Smith, 1978).

$$KE = 11.87 + 8.73 \log I \quad (2)$$

Where I is the rainfall intensity (mm h^{-1}) and KE is the kinetic energy (Jm^{-2} mm^{-1}).

$$R = \frac{\sum EI_{\max}}{1000} \tag{3}$$

R is rainfall erosivity factor in MJ m km^{-2} h^{-1} y^{-1} and EI is the total storm energy in Jm^{-2} mm^{-1}. The R value was calculated from energy-intensity relationships. Daily rainfall data was recorded using automatic rain gauge located in the study area for the duration of one year, (July 15, 2015 to July 14, 2016). Using Eq. 2 and 3, the data in Table 1 was obtained.Overview of National Policy and Legislation

Table 1 Calculation of the erosivity factor

Max. intensity ($mm\ hr^{-1}$)	Total energy ($J\ m^{-2}$)	Rainfall erosivity ($MJ\ m\ km^{-2}\ hr^{-1}\ y^{-1}$)	Rainfall erosivity ($MJ\ mm\ ha^{-1}\ hr^{-1}\ y^{-1}$)
3.95	402.06	1.59	15.9
3.72	343.16	1.28	12.8
3.57	272.62	0.97	9.7
3.98	270.63	1.08	10.8
21.27	292.55	6.22	62.2
8.20	294.06	2.41	24.1
11.11	341.36	3.79	37.9
15.88	277.45	4.41	44.1
Total		21.75	217.5

Using the data obtained from the automatic rain gauge installed in the study area for one-year duration, the R-factor value was calculated as 21.75 MJ m km^{-2} hr^{-1} y^{-1} (217.5 MJ mm ha^{-1} hr^{-1} y^{-1}). The original method for calculating the R value for a storm event requires rainfall amount in mm, intensity in mm h^{-1} and the maximum 30 minutes intensity in mm h^{-1}. Due to lack of adequate metrological data and long-term rainfall intensity data in some countries such as Afghanistan, it is hard to apply Eq. 2 and 3. It is therefore necessary to interpolate between available data hence, the attention should be paid to investigate new methods and equations to calculate the erosivity factor using annual rainfall. R factor based on annual precipitation were computed using various equations shown in Table 2.

Table 2 List of equations used to investigate correlation

No	Reference	Equation
1	Morgan, 1974	R = 2.28P - 8,838
2	Foster et al., 1981	R = (0.27P75)/100
3	Cooper, 2011	$R = 9.17P^{0.20}$
4	Eltaif et al., 2010	$R = 23.61e^{(0.0048P)}$
5	Deumlich et al., 2006	R = 12.98 + 0.0783P
6	Renard and Fremund, 1994	$R = 0.04830P^{1.510}$
7	Yu and Roswell, 1996	$R = 0.0438P^{1.61}$
8	Parveen and Kumar, 2012	R = 29 + 0.363P
9	Singh et al., 1981	R = 79 + 0.363P
10	Arnoldus, 1980	$R = 0.03P^{1.9}$
11	Renard and Freimund, 1993	$R= 0.07397F^{1.847}/17.02$
12	Roose, 1975	R = 0.5P

However, the erosivity index calculated using Eq. 4 by Singh et al., 1981 showed the best fit was achieved between R value calculated with USLE and the mean annual rainfall for the Gardez Basin. The results based on Eq. 4 was summarized in Table 3.

$$R = 79 + 0.363P \tag{4}$$

Where P is the mean annual precipitation (mm) and R is the erosivity factor (MJ mm $ha^{-1} hr^{-1} y^{-1}$). In terms of ArcGIS layers, each weather station was represented by a point. The Inverse Distance Weighted (IWD) interpolation method in ArcGIS was used to create a raster map for R factor. However, rainfall erosivity (R) was calculated using rainfall data from six rainfall stations across the Gardez Basin. The high erosivity was found in the northeast and low erosivity was found in the southwest part of Basin. The R-factor varied from 157.58 to 199.72 MJ mm ha^{-1} hr^{-1} y^{-1} as shown in Fig. 3.

Table 3 Rainfall erosivity, (R value)

No	Station	Rainfall (mm y^{-1})	R value (MJ mm $ha^{-1} hr^{-1} y^{-1}$)
1	Tera Garden (Gardez city)	333	199.88
2	Rhoni Baba farm (Zarmat District)	216	157.41
3	Khost (Province)	330	198.79
4	Sharana (Paktika Province)	219	158.50
5	Urgoon (Paktika Province)	252	170.48
6	Logar (Province)	294	185.72

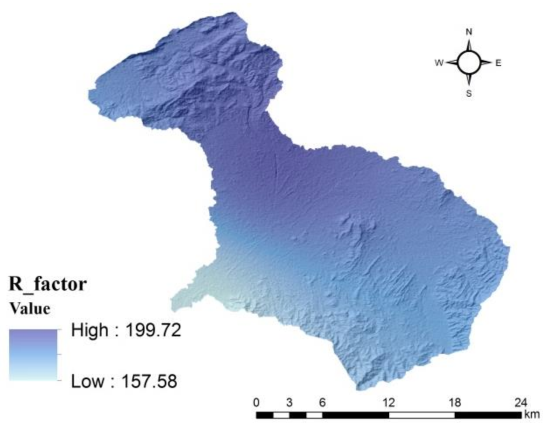

Fig. 3 Rainfall erosivity map of Gardez Basin

Soil Erodibility Factor (K)

The soil erodibility factor indicates susceptibility of soil particles or surface materials to be detached and transported by rainfall and runoff (Renard et al, 1997). Soil erodibility factor was obtained from soil classification map of the country which is presented by USDA-SCS, 2001 as shown in Fig. 4. Based on the classification of soil and soil texture classes, the K factors (t ha hr ha^{-1} MJ^{-1} mm^{-1}) are shown in Table 4.

Table 4 Soil classification and erodibility values

No	Soil classification	Soil texture	Order	K value
1	Xerochrepts with Xerorthents	Silt loam	Xeric	0.048
2	Haplocambids with Torriorthents	Silt loam	Aridic	0.040
3	Torriorthents with Torrifluvents	Silt clay loam with cobbly loam	Aridic	0.038
4	Haplocambids with Torriorthents	Silt loam with fine sand	Aridic	0.063

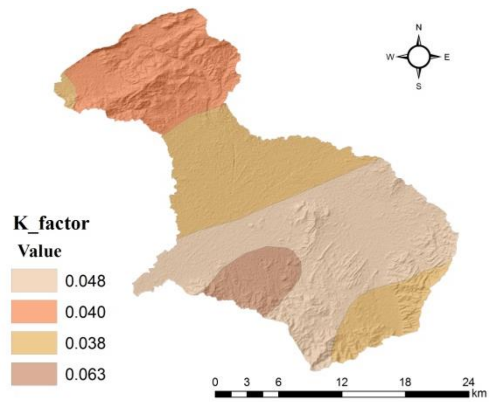

Fig. 4 Soil erodibility map of Gardez Basin

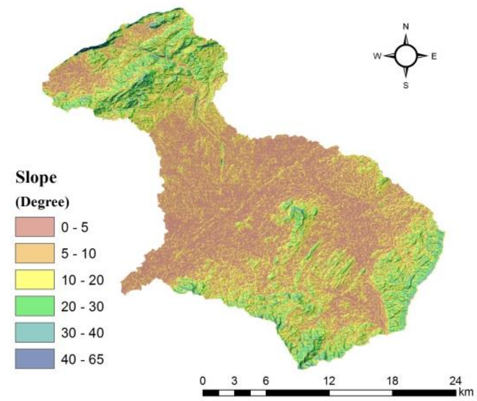

Fig. 5 Slope map of the Gardez Basin

Slope Length and Slope Steepness Factor (LS)

The LS factor has been used in a single index, which expresses the ration of soil as defined by Wischmeier and Smith, 1978.

$$LS = (X/22.1)^m (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065) \quad (5)$$

Where, X is slope length (m); θ is the angle of slope in degrees; and m is a constant dependent on the value of the slope gradient: 0.5 if the slope angle is greater than 2.86 degree, 0.4 on slope of 1.72 to 2.85 degrees, 0.3 on slope of 0.57 to 1.72 degrees, and 0.2 on slopes less than 0.57 degrees. Erosion increases as slope length and slope steepness increases. The slope length (L) and slope steepness (S) are combined in a single topographic index termed LS-factor was computed for the Gardez Basin by using spatial analyst extension in ArcGIS software has used to generate raster layers of the slope. The slope of Gardez Basin range values between 0 to 65 degree and was derived from the DEM as shown in Fig. 5.

First step, the elevation value was modified by filling the sinks in the grid. Second step Flow direction was generated from the fill grid. Third step the flow accumulation was calculated and generated from the flow direction. Flow accumulation tool identifies how much surface flow accumulates in each cell; cells with high accumulation values are usually stream or river channels and also recognizes local topographic feature such as mountain peaks and ridgelines. Finally, raster calculator function under Spatial Analyst tool was used to input the modified Eq. 5. To compute LS factor. The values between 0 to 175.64 as shown in Fig. 6.

Crop Management Factor (C)

The crop management factor (C) is the ratio of soil loss of a specific crop to the soil loss under the condition of continuous fallow (Renard et al., 1997). It measures the effect of canopy and ground cover on the hydraulics of raindrop impact and runoff.

Factor (C) is a relation between erosion on bare soil and erosion observed under a cropping system. It varies from 1 on bare soil to 1/1000 under dense forest, 1/100 under grasslands and plants and 1 to 4/10 under root and tuber crops (Morgan, 2005). Based on the national land cover map published by FAO-UN, 2016, the land cover classification of the Gardez basin has 11 classes. Therefore a crop management factor (C) was assigned for each land use type from the literature reviewed as shown in Fig. 7.

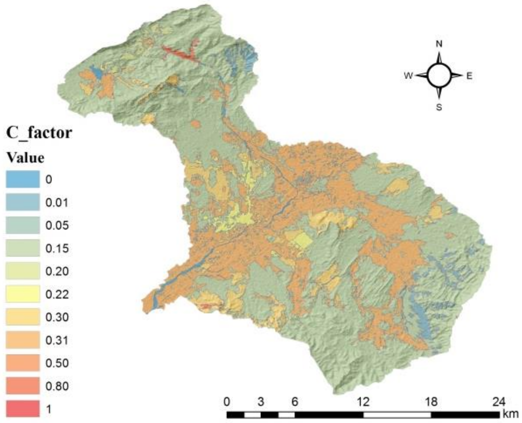

Fig. 7 C-factor map of Gardez Basin

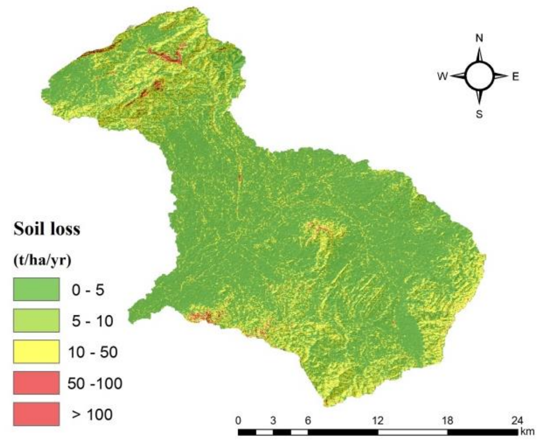

Fig. 8 Soil loss map of Gardez Basin

Conservation Practice Factor (P)

Factor P in USLE model expresses the effect of conservation practices that reduce the amount and rate of water runoff, which decrease erosion. It is the ratio of soil loss with specific support practice to corresponding soil loss with upslope and downslope parallel tillage (Renard et al, 1997 and Wischmeier and Smith, 1978). Currently, there are no support practices in the study area, hence P is assigned value of 1 in the calculation.

Estimated Soil Loss

The data layers (maps) extracted for R, K, LS and C factors of the USLE model were multiplied within the raster calculator of ArcGIS spatial analyst in order to generate the map of soil loss for Gardez Basin. The final map presents the annual soil loss t ha^{-1} y^{-1} a pixel level. The soil loss values estimated for Gardez basin ranges from 0 to > 100 t ha^{-1} y^{-1} which is shown in Fig. 8.

The annual soil loss map obtained was classified into five (5) classes. The results presented in Table 5 shows that about 64.31% of the study area is classified as slight erosion risk (0 – 5 t ha^{-1} y^{-1}), 13.95% of the area is classified as moderate soil erosion risk (5 – 10 t ha^{-1} y^{-1}), 19.76% of the area is classified as high soil erosion risk (10 – 50 t ha^{-1} y^{-1}), 1.76% of the area is classified as severe soil erosion risk (50 – 100 t ha^{-1} y^{-1}) and 0.22% of the area is classified as very severe soil erosion risk (greater than 100 t ha^{-1} y^{-1}). The higher soil loss is due to high slope steepness, very poor vegetation and no conservation practices which are the most prominent causes of soil erosion, severe and very severe soil erosion risk classes mainly located in mountains/foothills.

Table 5 Annual soil loss rate and risk categories

Soil loss (t ha^{-1} y^{-1})	Risk categories	Area (ha)	Area (%)
0 - 5	Slight	30,934	64.31
5 - 10	Moderate	6,713	13.95
10 - 50	High	9,503	19.76
50 - 100	Severe	847	1.76
> 100	Very severe	107	0.22
Total		48,104	100.00

(Morgan et al., 2004)

The land use map of country was developed by FAO-UN 1993 and subsequently updated in 2016 (FAO-UN). Land use classification map of Gardez basin consists of 11 classes as shown in Fig. 9, that are explained as follows; irrigated agricultural land, rainfed agricultural land, rangeland, rangeland/barren land, barren land, barren land/rangeland, forest and shrubs, fruit trees, vineyards, built up and water bodies and marshland. Rangeland is the most scattered land covering over 59% of the total area, irrigated agricultural land covers 24.5%, forest and shrubs covers 2.1% and built up areas covers 3.2% of the Gardez basin as shown in Table 6.

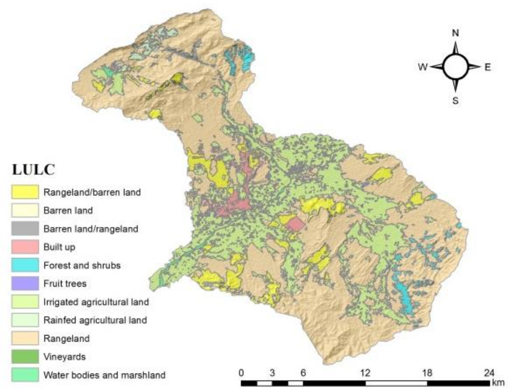

Fig. 9 land use map of Gardez Basin (FAO, 2016)

Table 6 Dominate land use/land cover in different mean annual soil loss rate

No	LULC	Area (ha)	Area (%)	Mean soil erosion (t ha^{-1} y^{-1})
1	Rangeland	28529	59.31	7.18
2	Rangeland/barren land	3731	7.76	11.26
3	Forest and shrubs	1045	2.17	2.21
4	Built-up	1687	3.51	2.67
5	Irrigated agriculture land	11806	24.54	3.48
6	Water bodies and marshland	427	0.89	2.77
7	Fruit trees	273	0.57	2.28
8	Vineyards	4	0.01	2.86
9	Rainfed agriculture land	409	0.85	6.39
10	Barren land	2	0.00	11.54
11	Barren land/rangeland	191	0.40	74.81

In order to identify average soil erosion rates for different land use classes of Gardez Basin, land use/land cover map of the study area was intersected with classified soil erosion map. From Table 6, it is clear that high levels of soil erosion classes are found on the fallow land, barren land/rangeland, barren land, rangeland/barren land, rangeland and rainfed agricultural land. The annual average soil erosion is lower in the forest/shrubs and fruit trees. Moreover, slight, moderate, high, severe and very severe soil loss area which was obtained based on land use map approximately, 30,933.96, 6,713.24, 9,503.04, 846.89 and 106.87 ha shown at Table 7, respectively. In addition, irrigated and rainfed agricultural lands area is about 12,215 ha of the total area and also most parts soil losses occur in slight to high soil loss categories. Since most of the agricultural lands are slight to high soil loss classes, immediate attention of soil conservation practices is required. To suggest site specific sustainable land use practices for controlling slight to high soil erosion risks, this result allows assessment of soil loss quantitatively, identify the risk zones and draw appropriate planning measure for implementing optimal land use management practices.

Table 7 Risk categories of Gardez Basin area (ha) based on land use/land cover

No	Risk categories	Slight	Moderate	High	Severe	Very severe	Total
	LULC	0 – 5 t ha^{-1} y^{-1}	5 – 10 t ha^{-1} y^{-1}	10 – 50 t ha^{-1} y^{-1}	50 – 100 t ha^{-1} y^{-1}	> 100 t ha^{-1} y^{-1}	
1	Rangeland	16804.82	3920.66	7215.25	570.58	17.73	28529.04
2	Rangeland/barren land	2089.36	511.15	893.20	210.80	26.49	3731.00
3	Forest and shrubs	909.15	46.29	89.35	0.16	0.00	1044.95
4	Built-up	1365.96	215.94	102.06	2.36	0.67	1687.00
5	Irrigated agriculture land	8813.18	1888.96	1074.35	27.15	2.36	11806.00
6	Water bodies and marshland	384.00	35.48	7.00	0.30	0.21	427.00
7	Fruit trees	259.00	12.99	0.79	0.22	0.00	273.00
8	Vineyards	3.80	0.20	0.00	0.00	0.00	4.00
9	Rainfed agriculture land	252.60	74.07	77.10	5.24	0.00	409.00
10	Barren land	0.00	0.00	2.00	0.00	0.00	2.00
11	Barren land/rangeland	52.09	7.49	41.94	30.08	59.40	191.00
	Total	30933.96	6713.24	9503.04	846.89	106.87	48103.99

CONCLUSION

The present study indicates that using GIS technologies for soil loss mapping, based on the USLE model provided satisfactory results. Different components of USLE model were used with mathematical equations; the rainfall erosivity R-factor calculated, using USLE method (rainfall in mm, intensity in mm hr^{-1}, maximum 30 minutes intensity in mm hr^{-1}) from daily automatic rain gauge is 217.5 MJ mm ha^{-1} hr^{-1} y^{-1} and the R-factor calculated based on annual rainfall amount using various equations, range between 157.58 to 199.72 MJ mm ha^{-1} hr^{-1} y^{-1}. However, the best fit was achieved between the R value from USLE method and annual rainfall for Gardez Basin. Soil erodibility factor (K) which was obtained from soil classification map range between 0.038 to 0.063 t ha hr ha^{-1} MJ^{-1} mm^{-1}. Slope length and slope steepness factor (LS) values obtained from DEM between 0 to 175.64. Crop management factor (C) values were obtained from land cover classification map range between 0 to 1.

The final map presents the annual soil loss, the values range from 0 to greater than 100 t ha^{-1} y^{-1}, and classified into five (5) classes; includes that about 64.31% of the study area is slight erosion risk (0 – 5 t ha^{-1} y^{-1}), 13.95% of the area is moderate soil erosion risk (5 – 10 t ha^{-1} y^{-1}), 19.76% of the area is high soil erosion risk (10 – 50 t ha^{-1} y^{-1}), 1.76% of the area is classified as severe soil erosion risk (50 – 100 t ha^{-1} y^{-1}) and 0.22% of the area is classified as very severe soil erosion risk (greater than 100 t ha^{-1} y^{-1}).

Most of the agricultural lands are classified slight to high soil loss. However, high soil erosion is found in the barren land, rangeland and rainfed agricultural land. The soil erosion risk is extremely higher on the steep slope and mountains/foothills. The land use map of the study area was prepared and the average annual soil loss for different land use will be highly useful in recognizing the priority areas for application of land use practices and soil conservation measures in Gardez Basin. The rainfed and irrigated agricultural lands require immediate attention for soil conservation practices. Based on the result of this study, the estimated soil loss and proposed land use map could be an effective input for the future planning and implementing soil conservation strategy in the eastern part of Afghanistan.

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Research article

Simplification of the Colorimetric Method to Detect Methanol Contamination in the Cambodian Local Rice Liquor

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Abstract Methanol, an alcohol, is known to be hazardous for human consumption. Methanol contamination in traditional rice liquor caused many deaths in local areas in Cambodia. Contamination happened in every steps of liquor manufacturing, distribution, and consumption. To avoid this problem, monitoring the quality of alcohol is important. However, only a few government institutes in the capital can detect the methanol contamination at an institutional level by colorimetric methods. To detect methanol contamination easily at the local level, a simplified method is urgently required. We tested the original colorimetric methods to determine the influence of the amount of chemical solutions, the time and the alcohol percentage to the color change. Further we checked the shelf life of the chemical solutions. The results showed that methanol was detectable at one-twenty of original volume after treatment 2-5 hours, and the alcohol percentage was not influence of the color changes. In addition, we tested 21 liquor samples collected from markets in Phnom Penh and 6 provinces with the simplified method, resulting that methanol was not detected in all samples.

Keywords local liquor, methanol, simplified methods

INTRODUCTION

Methanol, an alcohol, is known to be hazardous for human consumption. In the worst-case scenario, symptoms of methanol poisoning caused by inhalation or intake are blindness and death (Bennet et al. 1953). Recently, newspapers have reported that the contamination of methanol in traditional rice liquor caused many deaths in local areas of Cambodia (Gee & Martin 2012, The Cambodia Daily 2011). People bought cheap industrial alcohol at a high concentration, and mixed it as a loading fluid in every step of liquor manufacturing, distribution, and consumption.

Usually, when the equipment is available, the detection of methanol contamination is performed by gas chromatography, which is a quick and accurate method. However, due to high cost and shortage of human resources, this might be difficult to perform in developing countries.

In Cambodia, the Industrial Laboratory Center of Cambodia and CAMCONTROL in Phnom Penh have the resources to monitor the quality of alcohol at an institutional level using colorimetric methods. However, government agencies for the control of the quality of alcohol have not been established in other provinces. Therefore, the establishment of a simple method to detect methanol contamination based on the existing protocol is required promptly to decrease the number of fatal accidents occurring with traditional rice liquor in Cambodia or other developing countries.

OBJECTIVES

In this study, we improved some aspects of the conventional colorimetric method for detecting methanol by visual analysis. In order to simplify the colorimetric method, we aimed to modify the following 4 aspects: (1) detection sensitivity depending on reduced amount of chemical solutions, (2) optimum time to check the solution color after the final treatment, (3) detection sensitivity depending on the alcohol percentage, and (4) retention period of the chemical solutions. In addition, we conducted (5) methanol detection in rice liquors available in the local markets from 6 provinces.

METHODOLOGY

Original Method

We followed the colorimetric method reported by the Japan National Tax Agency in 1961(National Tax Agency of Japan 2007). A brief description of the method is reported below.

Preparation of chemical solutions: Solution A (500 mL): 15 g of potassium permanganate (VII) ($KMnO_4$) and 75 mL of phosphoric acid (H_3PO_4) were dissolved in distilled water and up to 500 mL, Solution B (500 mL): 25 g of oxalic acid dihydrate [$(COOH)_2 \cdot 2H_2O$] was dissolved in 500 mL 50% (v/v) sulfuric acid (H_2SO_4), Solution C (500 mL): 0.5 g of basic fuchsin was dissolved in about 300 mL of distilled water boiled at 100°C, and 5 g of sodium sulfite (Na_2SO_3) was dissolved in about 50 mL of distilled water. Fuchsin solution was mixed with Na_2SO_3 solution and 5 mL of hydrochloric acid (HCl) was added. Then, the final solution was diluted to 500 mL with distilled water. Finally, 40 mL of 10N H_2SO_4 was added, and the solution was kept at room temperature for more than 5 h. The color often became light brown after adding HCl. Although it should be used after the color of fuchsin disappear, it could be a pale yellow color solution. The all chemicals were purchased from Wako Pure Chemical Industries.

Preparation of standard solutions: The standard solutions were prepared with 99.5% ethanol and methanol (Wako Pure Chemical Industries, Ltd). Ethanol was adjusted to 40% (v/v) with distilled water, and 0, 5, and 15μL methanol was added into 10 mL of 40% ethanol to make the 0, 0.05, and 0.15% (v/v) methanol artificial contaminated solutions since the Cambodian government set 0.15% is the highest standard level of methanol contamination in the original liquor. Finally these mixtures were 8 times diluted to prepare the 5% alcohol percentage for testing.

Test procedures according to original method: The sample solution (5 mL) was mixed in a test tube with 2 mL of solution A and left for 10 min. Then, 2 mL of solution B and 5 mL of solution C were added in this order and mixed well. After 30 min, the color of the solution was checked and the absorbance was determined at 590 nm with a spectrophotometer (U-2000A, HITACHI) (Hayashibe 1955) using low volume cell. Checking the absorption wavelength of standard solution determined the peak at 580-600 nm, hence we adopted 590 nm as the wavelength for the measurement. The colors of mixture turned from clear and colorless (0%), weak purple (0.15%) to purple (over 0.8%) according to the trial experiment.

Simplification of the Original Method

The 40% ethanol with methanol 0, 0.05 and 0.15% (v/v) was diluted into 5% as the standard solutions. All steps were conducted under the room temperature (about 22–25°C).

Dose reduction of the chemicals: Various total amounts of standard and chemical solutions (i.e., 1, 1/2, 1/5, 1/10 and 1/20 of the amount indicated in the original protocol) were used to detect the methanol contamination in standard solutions. The color of the solution was assessed by visual analysis and spectrophotometer (590 nm) in following analyses.

Optimum time to check the color of the solution: The change of color was assessed 0.5, 1, 2, 3, 5, and 24 h after adding the final solution C. The amounts of solution were as follows: standard 0.25 mL, solution A 0.1 mL, solution B 0.1 mL, and solution C 0.25 mL.

Difference in the sensitivity depending on the percentage of alcohol in the sample solution: We compared the sensitivity of the colorimetric method between ethanol standard solutions (5%) and original solutions (40%) respectively. Further, rice liquor samples produced in Cambodia (Sraa Takeo 40% alcohol/volume, Royal University of Agriculture, Phnom Penh, Cambodia) were used; original percentage of the liquors (40%) with 0, 0.05 and 0.15% methanol artificial contamination, and its 5% diluted solutions. The amounts of solution were as follows: ethanol/liquor solutions (40% or 5%) 0.25 mL, solution A 0.1 mL, solution B 0.1 mL, solution C 0.25 mL. The color was checked 3 h after treatment.

Expiration period of chemical solutions: Test solutions were kept for 2 and 4 weeks at room temperature (about 22–25°C) and, then, were tested in comparison with fresh solutions. The combination of the solutions is shown in Table 1; N: fresh solution and O: 2 or 4 weeks old solutions. The amounts of the solutions were as follows: standard solutions 0.25 mL, solution A 0.1 mL, solution B 0.1 mL, and solution C 0.25 mL. The color was checked 3 h after treatment.

Table 1 The combinations between fresh and old solutions

Test solution	Combinations*							
	1	2	3	4	5	6	7	8
A	N	O	N	N	O	O	N	O
B	N	N	O	N	O	N	O	O
C	N	N	N	O	N	O	O	O

** N: fresh solutions, O: 2 or 4 weeks old solutions*

Detection of methanol from the local rice liquors: Rice liquors collected from the local market in Phnom Penh and 6 provinces (Battambong, Kompong Chhunang, Prey Veng, Pursat, Svay Rieng, Takeo) were used as liquor samples; 3 samples/province and 21 samples in total. Rice liquors were clear and colorless and the original liquors were diluted into 5% for testing. The amounts of the solutions were as follows: liquor 0.25 mL, solution A 0.1 mL, solution B 0.1 mL, and solution C 0.25 mL. The color was checked 3 h after treatment.

Data analysis: The data was analyzed using with Excel statistical analysis add-in software (Excel statistic 2012; Social Survey Research Information Co., Ltd., Tokyo, Japan).

RESULTS AND DISCUSSION

The methanol percentage in the all figures indicated the methanol percentage in the original concentration (0, 0.05 and 0.15%), and the absorbance values of solutions (original/5% diluted) were shown without change.

Scale-down of the Amount of Chemical Solutions: The reduction of the waste chemical solutions is required because the disposal of the toxic waste in Cambodia is not yet well-implemented and heavy metal such as $KMnO_4$ pollutes the environment when discarded without treatment. We could recognized the difference between 0 and 0.15% methanol contamination by eyes in every total amount, and the absorbance among 0, 0.05, and 0. 15% methanol were significantly different in 1/20 of the amount in the original protocol (Fig. 1). It shows that methanol contaminations in the smallest amount of chemical solutions (ethanol standard: 0.25 mL, A: 0.1 mL, B: 0.1 mL and C: 0.25 mL) could be detected as same as original amount.

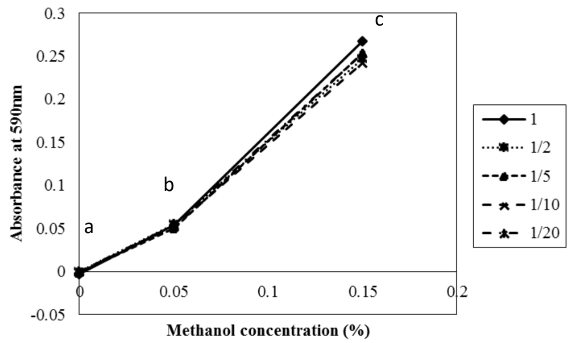

Fig. 1 Scale-down of the amount of chemical solutions

Significant differences among each methanol concentration of 1/20 of the initial solution were determined by one way-ANOVA. The same letters (a-c) mean no significant difference ($p<0.01$).

Optimum Time for Detecting the Color of the Solution: The optimum time for comparing the color by visual judgment was determined. 0.15% methanol, the highest allowed level of methanol contamination decided by the Cambodian government, was visually detected 0.5 h after adding the final solution. Two hours later, the differences of the color between 0% and 0.15% methanol could be observed easier, while no difference could be detected visually between 0% and 0.05% samples. However, after 24 h, although the difference of absorbance was detected by spectrophotometer, no discernible difference could be observed. Therefore, we can check the color of the solutions 2–5 h after treatment (Fig. 2).

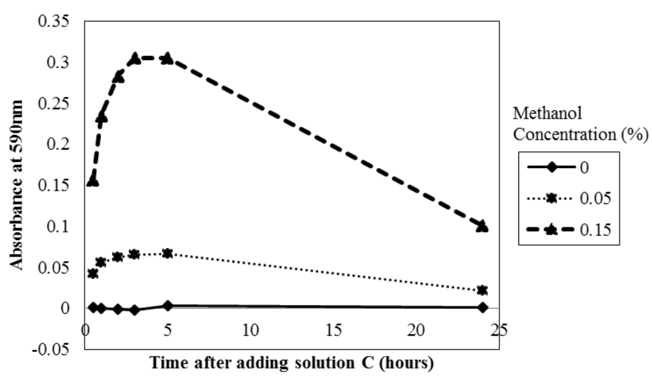

Fig. 2 Optimum time for detecting the color of the solution

Detection Sensitivity for Methanol Contamination Depending on the Alcohol Percentage: The detection sensitivity of the 40% ethanol/rice liquor were compared with 5% diluted ethanol/ rice liquor to know whether methanol contamination can be detected in the original percentage. We could not recognize visually the difference between 0 and 0.05% methanol in both samples, however between

0% and 0.15%, it was detectable the difference by naked eyes though the absorbance was lower in original percentage than in 5% diluted one of both ethanol and liquor solutions (Fig. 3). To detect the accurate amount of methanol in alcoholic beverage, though gas chromatography is so convenience (Wang et al. 2004), the method shown in this study makes us possible to quick detection and visual discrimination if concentration of methanol included in the beverage is higher than specified safety level without using special equipments.

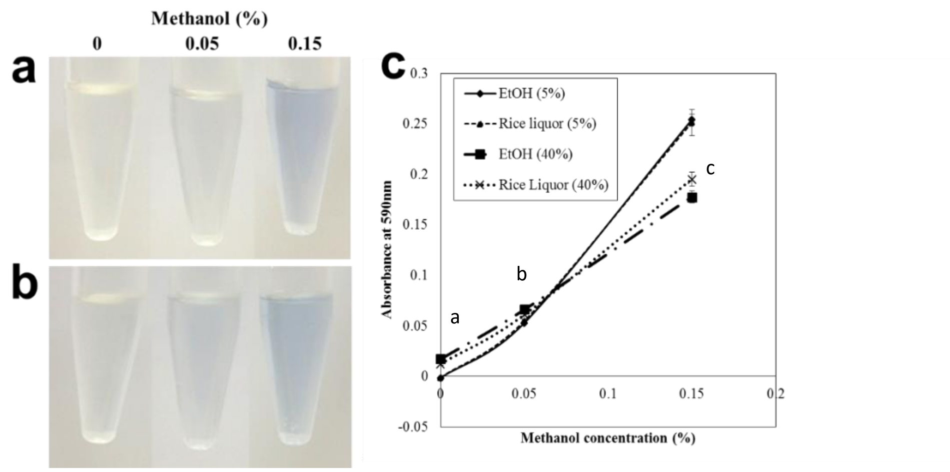

Fig. 3 Difference of detection sensitivity for methanol contamination depending on the alcohol percentage

Concentration-dependent change of solution color of (a) ethanol standard (5%) and (b) rice liquor (40%) with 0, 0.05, and 0.15% methanol contaminations from left to right, (c) concentration-dependent change of absorbance among 0, 0.05, and 0.15% methanol contaminations in 5% and 40% ethanol/rice liquor. The same letters (a-c) mean no significant difference ($p<0.01$) of the 40% rice liquor among each methanol concentrations as determined by one-way ANOVA.

Expiration Period of the Chemical Solutions: To save time for the preparation of the chemicals, the retention period of chemical solutions was determined. The combination of fresh chemicals with old solutions was tested at 2 and 4 weeks after preparation. The detection sensitivity of the chemical solutions was not changed after 2 weeks. However, after 4 weeks, a difference could be observed and the detection sensitivity became lower in conditions 2, 4, 5, 6, 7, and 8, which include old A and C solutions. On the other hand, in condition 3, which includes old B solution, the color was the same as that of the normal fresh condition (Table 1, Fig. 4).

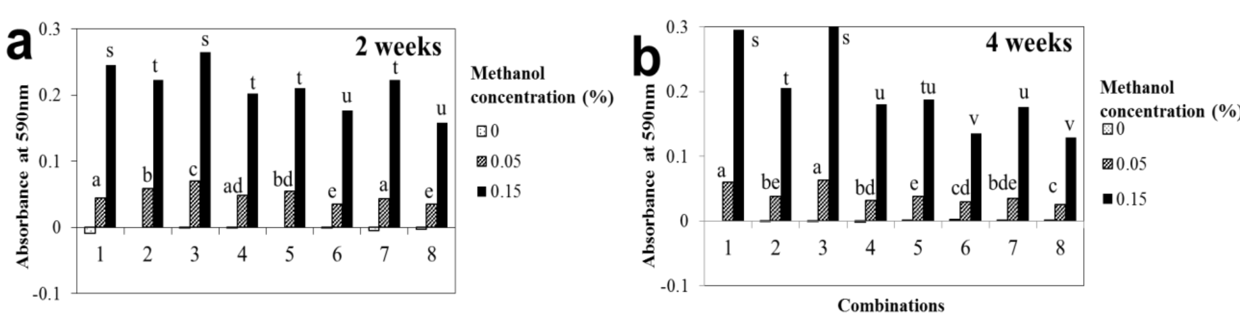

Fig. 4 Expiration period of each chemical solution affecting detection sensitivity

Dot, diagonal line, and black bars represent the absorbance of the 5% ethanol solution containing 0, 0.05, and 0.15% methanol, respectively. Conditions 1–8 show different combinations with fresh and old chemicals of A, B, and C (Table 1). Significant differences among conditions in (a) fresh and 2-week-old solutions, (b) fresh and 4-week-old solutions were calculated with one-way ANOVA respectively. The same letters mean no significant difference ($p<0.05$): 0.05% (a-e) and 0.15% methanol (s-v) among condition 1-8.

Detection of Methanol from the Local Rice Liquors: The 21 local rice liquor samples were tested by the simplified method. No methanol contamination was detected from those samples.

Table 2 Detection of methanol contamination from local rice liquors

Province	Number of sample	Methanol contamination
Battambong	3	No detect
Pursat	3	No detect
Kompong Chhunang	3	No detect
Phnom Penh	3	No detect
Prey Veng	3	No detect
Svay Rieng	3	No detect
Takeo	3	No detect
Total	21	

CONCLUSION

Based on our observations, we conclude that: (1) the amount of solutions can be reduced to a total volume of 0.7 mL (standard 0.25 mL, solution A 0.1 mL, solution B 0.1 mL, and solution C 0.25 mL); (2) the difference of color can be detected easily 2–5 h after the final treatment; (3) Moreover, the methanol contamination was detected without dilutions, and all the degrees of methanol contamination could be identified by comparison with 0% methanol standard solution though the detection ability was higher in 5% diluted solutions; (4) The degradation of the solutions increased with time, especially for solution C; therefore, the results indicated that solutions A and C could be used for 2 weeks, and solution B for 4 weeks. It is preferable to prepare fresh solutions within 2 weeks considering that the volatile substances in the solutions are hazardous; (5) Furthermore, this method can be used for rice liquor from local markets. Our results suggested that the simplified methods could identify the methanol contamination over the highest standard level by visual though it couldn't be measured accurate percentage of methanol contamination. Once the contamination is detected, the rice liquor is required to be analyzed in detail by laboratory experiments.

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Research article

Pre and Postharvest Losses and Marketing of Grapes in Afghanistan: Case Study in Mirbachakot, Shakardara and Kalakan Districts of Kabul

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Abstract Grape is one of the most commonly produced and globally well-known fruit crops. And also grape is the major fruit species grown in Afghanistan that accounts 48% of the total fruit growing area. Reduction of post-harvest losses is the indispensable challenge in the country, hence to increase the availability of fruits and vegetables. However, the purpose of this study is to determine the pre and post-harvest losses of grape at stages of marketing and distribution. A questionnaire survey was conducted in Mirbachakot, Shakardara and Kalakan districts of Kabul province, Afghanistan. A total 60 farmers, including contractors, wholesalers and retailer were randomly selected and interviewed across in the study areas, using structured and semi-structured questionnaire sheet during the months of August-September in 2016. Based on the result of questionnaire, pre-harvest loss of grape from large, medium and small by 14%, 13 and 12%, respectively. Similarly, total post-harvest losses of grapes; Contractor loss, 9.0%, Wholesaler loss, 10.3% and Retailer loses 12.0%. In addition, there are many other causes such as, insect attack, diseases, dropping, mummification, water berries, improper packing and transportation. All these factors contribute and significantly declining the grape production. It can be suggested that grape growers would be trained on the subject of pre and post-harvest management and marketing practices.

Keywords pre and post-harvest loss, marketing, grape, Afghanistan

INTRODUCTION

It is acknowledged that grape is one of the most important fruit crops of the world and it contains many of the most valuable elements necessary for life. In Afghanistan 48% of the total fruit growing area is under grape vine equivalent to 82,450 hectares with estimated 874,500 tons production (CSO, 2016).The outputs of all agricultural commodities produced in the field have to undergo a series of operations such as harvesting, packing, transportation, processing, storage and exchange before they reach the consumer, and there are substantial losses occur during pre-harvest and post-harvest stages (Kader et al., 2004). The information on the extent of losses at these stages are important not only for agricultural scientists, but it would be useful for the policy makers as well. The agricultural scientist and technologist will be guided by these findings in improvements in the crops production and post-harvest technologies aimed at minimizing these losses. The sum quantity of outputs loss in these operations at all of these stages is referred to as post-harvest losses (FAO, 1980). One of the main reasons attributed to lower availability food is plenty of post-harvest losses that occur at various stages of marketing which ranges from 15% to 50% (FAO, 1981 and Roy, 1989).

Pre-harvest factors greatly influence the crop conditions on the stage of harvest, storage, and nutritive potential. There are many pre-harvest factors have known that affect storage quality, including genotype, cultivar selection, and stage of maturity at harvest has a very important influence on subsequent storage life, soil texture and fertility, fertilizer application, climate conditions such as temperature, light intensity, and rainfall amount (Watada et al., 1984).

Evaluating pre-harvest conditions indicated the most influence on the postharvest fruit quality (De long et al., 2003; Stanle et al., 1999; Robert, et al., 1996). The importance of post-harvest losses has been discussed at several national and international levels. Many studies and researches have been conducted in developed and developing countries for estimating the post-harvest losses, but the importance of post-harvest losses in agricultural commodities have not fully recognized yet. However, studied by USAID, 2012 and ROP, 2009 the agricultural production in Afghanistan has not fully linked to marketing. The number of scientists involved in production research in these countries is significantly higher than those concerned with post-harvest losses in agricultural commodities. Unfortunately, much time and money are being spent to cultivate crops, irrigation, fertilization and protection. Nevertheless, has received little attention and resources devoted to the issues related to pre and post-harvest losses resulting in failure, to meet food requirement, thereby millions of people now suffer from hunger throughout the nation (FAO, 1980 and FAO, 2011).

In developing countries, it is not only the problem of production, but it is equally important to save whatever is produced. Therefore, knowledge regarding to the magnitude of losses at various stages of handling and storage is considered to be very important to introduce necessary improvement for saving and preserving production (FAO, 1980). The purpose of this study is to determine the pre and post-harvest losses of grape at various stages and marketing practices in the Mirbachakot, Shakardara and Kalakan districts of Kabul province, Afghanistan.

METHODOLOGY

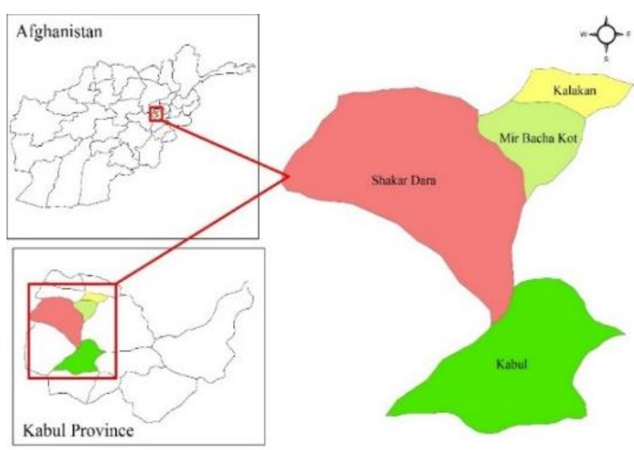

Fig. 1 Map of the study area

In order to identify the pre and post-harvest losses and marketing of grape a survey was conducted in Mirbachakot, Kalakan and Shakardara districts of Kabul province, Afghanistan as shown in Fig.1. A total 60 farmers were randomly selected across the entire study area and interviewed using structured and semi-structured questionnaire in the survey. Farmers were categorized into six groups; large, medium, small grape growers, pre-harvest contractor, wholesaler and retailer based on their trade and characteristics (production, farm size of vineyard). In addition, two kinds of data were collected as primary and secondary during the grape harvesting and marketing season. Primary data included information, face to face interview with grape growers, local authorities of villages and NGO. Secondary data were assigned from scientific papers, journals, and books. Data were calculated for average and percentages of pre and post-harvest losses and marketing channels. Likewise, primary data were recorded for various parameters were subjected to statistical analysis, Critical Difference (CD) at the 5% level of probability and used Statistic Package for Social Science (SPSS) software.

RESULTS AND DIACUSSION

Pre-harvest Losses

The pre-harvest losses defines from production to the farm gate, which includes growing, harvesting and on-farm handling (COMCEC, 2016). Although, estimates of losses in developing countries are hard to judge, evaluating pre-harvest conditions exert the most influence on post-harvest quality. However, based on the survey conducted, the pre-harvest losses of fresh grapes are due to several common factors like insect attack, disease, birds, droppings, water berries, short berries, mummification, poor water management and drought, and cultural practices (pruning, fertilizing, and pesticide spraying). Insect attack and diseases were contributed the maximum loss, 3.2% and 3% in large and medium farmers respectively. Similarly, in the small grape farmers maximum loss was reduced by 2.7%. The total pre-harvest of grape loss was 14% from large farmers, 13% from medium farmers and 12% from small farmers. The result showed that the severe pre-harvest loss was by insect attack, diseases and dropping among three categories of farmers as shown in Table 1.

Reported by COMCCE, 2016 loss of the agricultural production ranges 23% to 39% in Africa, Asia and the Middle East, high percentage of loss is recorded for fruits and vegetables. In Developing countries the agriculture production losses and waste are mostly, financial, managerial and technical limitations, but developed countries, mostly related to consumer attitude (FAO, 2011). Thus pre-harvest losses could be significant impacts on production and post-harvest process leading to lost revenue, lower yields and waste of resources.

Table 1 Pre-harvest losses of grapes at large, medium and small level of farmers

Stage of losses	Large farmers			Medium farmers			Small farmers		
	Qty (kg)	Loss%	Value (AFN)	Qty (kg)	Loss%	Value (AFN)	Qty (kg)	Loss%	Value (AFN)
Quantity harvested	1,000	100	20,000	1,000	100	20,000	1000	100	20000
Dropping	28	2.8	560	27	2.7	540	27	2.7	540
Water berries	26	2.6	520	25	2.5	500	22	2.2	440
Shot berries	24	2.4	480	23	2.3	460	24	2.4	480
Mummification	26	2.6	520	24	2.4	480	22	2.2	440
Insect and diseases	32	3.2	640	30	3.0	600	26	2.6	520
Total	136	14	2,720	129	13	2,580	121	12	2,420
Quantity Remaining	864	86	17,280	871	87	17,420	879	88	17,580

(USD 1 = 66.5 Afghani)

Fig. 2 Packing, transportation and marketing grapes system in Afghanistan

Most of the fruit losses occur between leaving the farm and reaching the consumer. The grapes normally harvests in the farm. After that removing the damaged bunches and berries, packed in plastic bags or cartons, then transporting to market by vehicles as shown in Fig. 2. It was observed that poor packing and faulty transporting the main factors for loss of agricultural production, particularly fruits in the study site.

Postharvest Losses

Over the past decades, 95% of the research investments were reported to have focused on increasing productivity and only 5% directed towards reducing losses (Kader, 2005; Kader and Roller, 2004; WFLO, 2010). Food production is currently being challenged by limited land, water and increased weather variability due to climate change. To sustainably achieve the goals of food security, food availability needs to be also increased through reductions in the post-harvest process at farm, retail and consumer levels. Based on Table 2, the loss at contractor, wholesaler and retailer level were 9%, 10.3% and 12% respectively, due to handling and packing, loading and unloading, poor transportation, and faulty storage. The maximum loss during the transportation and storage were 2.3% and 2%, respectively.

Other researchers found that the high losses occur during on-farm and postharvest stages in developing countries (COMCEC, 2016). In Pakistan about 21% the grapes grown (9.8 thousand tons amounting $3.25 million) lost and wasted of grape due to gaps in the cold chain, unavailability of cold storage and poor transportation (Khalid et al., 2011). On the other hand field management practices; genotype, cultivar selection, soil texture and fertility, fertilizer application, pruning, irrigation, pest control, and stage of maturity play a very important role in determining quality attributes size, color, flavor, texture, and nutritional values. Understanding the effect of pre-harvest factors would contribute minimize losses and maintain the quality of the grape.

Table 2 Post-harvest losses of grapes at different level

Stages of losses	Contractor loss (%)	Wholesaler loss (%)	Retailer loss (%)
Quantity purchased	100	100	100
Transportation	2.3	2.5	2.5
Handling and packing	1.9	1.5	2.3
Loading and unloading	1.8	2.3	2.2
Storage	2.0	3.0	3.0
Others	1.0	1.0	2.0
Total losses	9.0	10.3	12.0
Quantity Remaining	91.5	89.7	88.0

It observed from Table 1, that there was negligible different grape loss between large, medium and small farmers, But at the field level, the dropping, insect attack and diseases accounted for the highest percentage of loss. Based on Table 2, the total postharvest loss in grapes in pre-harvest contractor was found to be 9% .The wholesale level loss was found to be 10.3% and loss at the retailer level was slightly higher at 12%. At the pre-harvest, wholesaler and retailer level, the storage and transportation were found to contribute more toward the loss. Due to, insufficient storage, poor roads and no specialized transportation vehicles exclusively for fruits were used in the study site.

According to the Fig. 3 post-harvest losses from point of harvesting to consumption worked out to be 43.3% comprising of 13% at the farm, 9% in pre-harvest contract, 10.3% in wholesaler, and 12% at the retailer level respectively. Based on table 4, findings indicated, that the maximum grape loss occurred was due to insect attack, diseases and dropping at farm level.

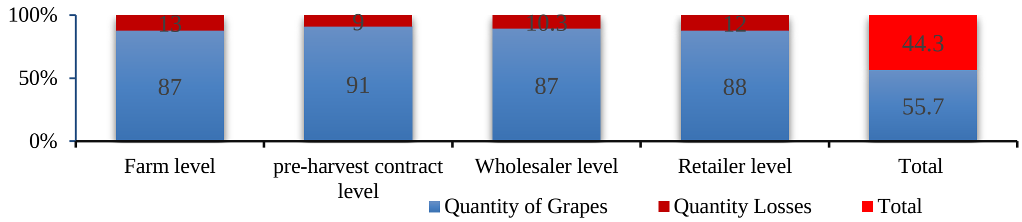

Fig. 3 Pre and post-harvest losses percentage of grapes in different stages

Marketing Channels

The marketing of grapes begins when the produce leaves the farm and ends when it reaches to the final consumers. It is rather a series of important business activities that transform a farm producer`s product into a number of finished products desired by the consumer. The results indicated that 60% of the grape growers sell their yield at a lower price to channel 1, due to non-availability of cold storage, followed by 25% farmers market through direct sale of the products to the channel 2, because direct sales benefit the producers more than contract sales. While remaining 15% farmers' sale their product to commission agents. It is found that grape growers in the study area follow several marketing channels.

Channel 1 ⇒ Producer ⇒ Pre-harvest contractor ⇒ Wholesaler ⇒ Retailer ⇒ Consumer

Channel 2 ⇒ Producer ⇒ Wholesaler ⇒ Retailer ⇒ Consumer

Channel 3 ⇒ Producer ⇒ Commission agent ⇒ Wholesaler ⇒ Retailer ⇒ Consumer

Table 3 Coefficient of Variation = 5.16

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F calculated	F probability
Replications	2	22.53	11.26	6.373	0.020
Treatments	4	74.26	18.56	10.50	0.008
Error	8	14.13	1.766	-	-
Total	14	-	-	-	-

Table 4 Statistical analysis (ANOVA)

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F calculated	F probability
Replications	2	41.2	20.6	2.22	0.177
Treatments	4	495.0	123.7	13.351	0.002
Error	8	74.13	9.2	-	-
Total	14	-	-	-	-

Treatment No.	T 4	T 1	T 3	T 2	T 5	P 5	P 1	P 2	P 4	P 3
Treatment Average	26.6	24.3	21.0	19.0	10.0	29.3	27.3	24.3	24.0	23.6
Critical Difference (CD) Compared	a	ab	ab	b	c	a	a	b	b	b

(T1-T5 show critical difference at large, medium, small farmers and P1-P5 critical difference at pre-harvest contract, wholesaler and retailer level). Significant difference at $p<0.05$

CONCLUSION

Despite the global progress in the food loss reduction there remain many gaps in the Knowledge regarding the quantity of losses at pre and postharvest stages and marketing practices are considered very useful to introduce necessary improvement to enhance quality and quantity of production. Pre and postharvest losses are a complex problem in Afghanistan, it is one of the big challenges for the farmers particularly for fruit growers. Due to improper management and poor knowledge of growers about 30% to 40% losses of agriculture production. However, grape is the most important fruit in Afghanistan, it covers 48% of total fruit growing areas and annual production is about 874,500 tons. The questionnaire survey was conducted in Mirbachakot, Shakardara and Kalakan districts of Kabul province. To determine the pre and post-harvest losses of grape at stages of marketing and distribution. A total of 60 (farmers, contractors, wholesalers and retailer) was randomly selected across the entire study area and interviewed in the survey. Based on the result of questionnaire, pre-harvest loss of grape from large, medium and small by 14%, 13% and 12%, respectively. Similarly, total post-harvest losses of grapes; Contractor loss, 9.0%, Wholesaler loss, 10.3% and Retailer loss 12.0%. In addition, there are many other causes identified such as, insect attack, diseases, dropping, mummification, water berries, improper packing and transportation. Meanwhile, the majority of the farmers live on the margin of food insecurity, so reduction grape losses could have an immediate and significant impact on their sustainable livelihoods. It can be suggested that grape growers would be trained on the subject of pre and post-harvest management and marketing practices. Thereby, using better agricultural practices and adequate technologies can significantly reduce the losses and help in strengthening food security and poverty.

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Research article

Determining Crop Insurance Participation in Laguna, Philippines Using Subsidy and Asymmetric Information Incentives

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Abstract The Philippines is susceptible to tropical cyclones which threaten the production of agricultural crops. To help farmers cover their losses, financial protection through crop insurance can be employed. This paper studied the effects of Philippine multi-peril crop insurance on mean returns per acre. Data on *palay* (unhusked rice) yields in the province of Laguna were gathered from 1978 to 2015. Using classical decomposition, the time series data was decomposed into trend-cycle, seasonality and irregularity components to compute for the Actual Production History (APH) yield and to forecast the APH yield for 2016. Using the crop insurance incentives model of Just et. al., the data were used to explore the subsidy and asymmetric information incentives for insurance participation for both wet and dry seasons. Three risk classes were considered: low, medium and high, while four insurance guarantee levels were considered: 100%, 90%, 10% and 0%. It was found that as yield guarantee increases, the effect of insurance on mean returns also increases. Additionally, as insurance premium increases, the effect of insurance on mean returns per acre decreases. Results also indicate that effects of crop insurance on mean returns per acre are highest when risk class is low and yield guarantee is high.

Keywords crop insurance, subsidy incentive, asymmetric information incentive

INTRODUCTION

The Philippine government has been helping farmers, who are amongst the poorest citizen in the country, cover their production losses by offering financial protection through crop insurance. These insurance products pay the farmer the cost of production input when a partial or total loss is experienced. A loss is considered partial if the loss is between 10% and 90%; otherwise, if the loss is above 90%, it is considered a total loss. While some insurance products from the government are free, farmers are required to pay a premium for these insurance products. The insurance premium varies according to the season and risk classification. There are two main planting seasons in the country, the wet and the dry season. While there are three risk classes: low-risk, medium-risk or high-risk, which is classified according to the riskiness of planting rice in that area. The farmer can choose the amount of cover or guarantee level.

The government heavily subsidizes the premium to help the farmers. This is a great aid to many low-income farmers, who still finds it difficult to purchase the insurance despite the subsidy. However, this may also attract opportunistic agricultural producers who use information advantages to obtain more profits. Though extensive studies are conducted by the insurance providers, farmers are often more knowledgeable about the risk in planting. Some studies conducted by Just, Calvin and Quiggin (1999), Walters, Shumway, Chouinard and Wandschneider (2014), and Wang, Hanson and Black (2003) suggest the presence of adverse selection and moral hazard in insurance. Profit-maximizing in adverse selection occurs when there is information asymmetry between two parties before the agreement, whereas profit-maximizing in moral hazard occurs when there is a change in behavior after the agreement (Nickolas, 2016). If premiums paid are not able to cover the indemnities, this may render the insurance product unsustainable.

Many studies identifying factors affecting farmer participation in crop insurance have been conducted. According to some literatures, a set of factors that impact farmer participation decisions include farmer-specific attributes, region-specific attributes and economic factors. Farmer-specific attributes include age, experience, education and income. Region-specific attributes involve farm size, location and soil quality. Economic factors consist of the insurance premiums and indemnity payments.

Sai, Yulian and Xiaofeng (2010) found that in China household size, agricultural land, farmer's education, production capacity and the transaction costs of households are particularly significant factors for families in rural areas to enroll in crop insurance programs. A study performed in the United States verified the idea that decreasing transaction cost improves crop insurance. According to Ker and Ergun (2003), when transaction cost is reduced through efficient delivery channels, greater insurance participation can be elicited. A research by Cabas, Leiva and Weersink (2008) found that that farmer participation in insurance is largely determined by price variables.

In this study, it will be determined if adverse selection is present in the crop insurance program to aid the insurers in safeguarding the sustainability of their insurance products. This study can also be useful for farmers who are on a tight budget and are picking only the likely situation where insurance can help them in safeguarding their income.

OBJECTIVE

The primary aim of this study is to estimate the effects of insurance, particularly the multi-peril rice insurance, on mean returns (bushels per acre) to the farmer and to look into the influence of subsidy and asymmetric information in the decision of farmers to participate in crop insurance programs.

METHODOLOGY

In this study, an analysis is made by applying the crop insurance incentives model built by Just, Calvin and Quiggin (1999). Data are collected from two sources: Regional Office of the Department of Agriculture (DA), and the Philippine Statistics Authority. The data on rice production are collected from the Regional Office of the Department of Agriculture (DA) in Calauan, Laguna. These included harvest area, average yield (in metric tons per hectare) and yield production (in metric tons) in 2014 and 2015 during wet and dry seasons. There data collected from the Philippine Statistics Authority - Bureau of Agricultural Statistics are downloaded from the website. These data are statistics on the quarterly area and volume of *palay*, and monthly farm-gate prices of *palay* in Laguna from the years 2006 to 2015.

The analysis uses data on rice production of Filipino farmers in Laguna to identify crop insurance effects on mean returns per acre. The insurance effects on mean returns are then decomposed into asymmetric information and subsidy incentives. Subsequently, the crop insurance effects are forecasted for the following year using forecasted values of the Actual Production History (APH) yield and using forecasted values of the *palay* price. Forecasting of APH yield and *palay* price for 2016 is employed to predict insurance effects on mean returns per acre and to predict the changes in the subsidy and the asymmetric information effects for 2016.

RESULTS AND DISCUSSION

Decomposition of Data Collected

Upon applying classical decomposition, the data collected on production shows that *palay* production in the Philippines has an increasing trend (Figure 1), except for the drop experienced in the first quarter of 2010, which can be attributed to the *palay* damaged due to spread of tungro, rice blasts, black bug, as well as the onset of El Niño. Another observation from the seasonality component (Figure 2) of the data is that yields are highest during the wet season and lowest during the dry season. This observation is necessary in determining the periods when insurance participations are most effective.

Computing the effect of insurance on mean returns per acre shows that as the premium increases, the effect of insurance to the farmer's mean return decreases. However, the effect of insurance increases as the loss increases. This implies that adverse selection can happen for farms in high-risk area. These results are summarized Table 1, Figures 3 and 4. Figure 3 shows that as insurance premium increases, the effect of insurance on mean return decreases. Figure 4 shows that the effect of insurance on mean returns increase for higher than 70% of loss.

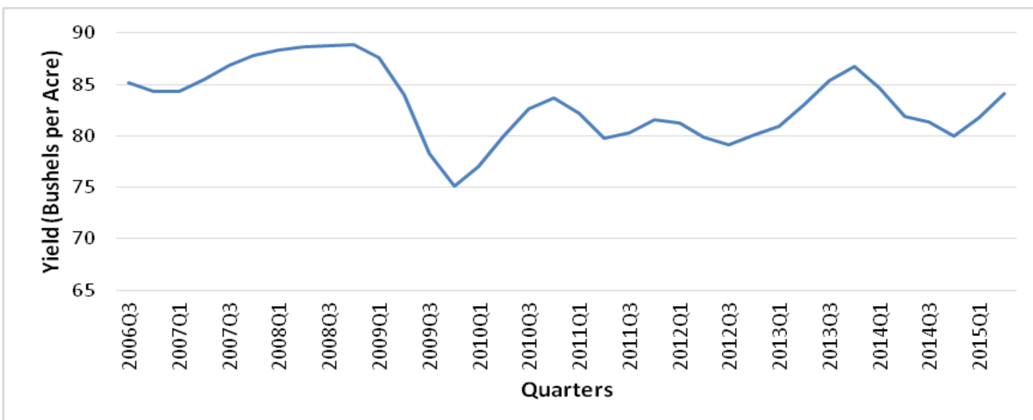

Fig. 1 Trend-Cycle Component of *Palay* Yield on a Quarterly Basis from 2006 to 2015

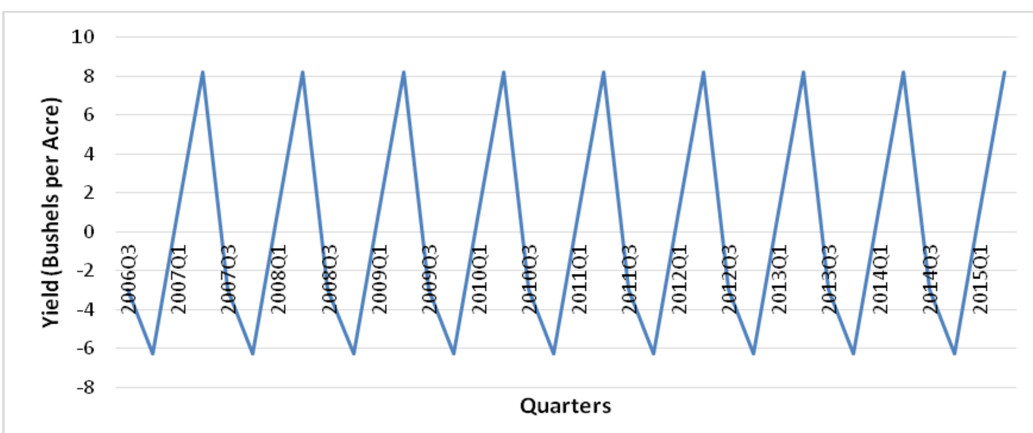

Fig. 2 Seasonality Component of *Palay* Yield on a Quarterly Basis from 2006 to 2015

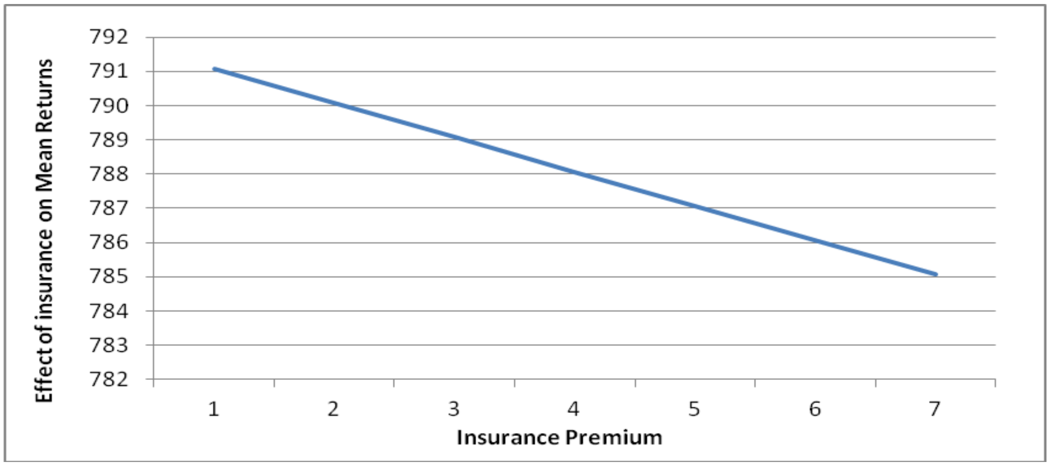

Fig. 3 Relationship between Insurance Premium and Effect of Insurance on Mean Returns per Acre during the Wet Season when there is Total Loss

Table 1 Effect of Insurance on Mean Returns Per Acre

Multi-Risk Cover	Effect of Insurance on Mean Returns per Acre					
	Wet Season			Dry Season		
	Low	Medium	High	Low	Medium	High
Total Loss	390.02 to 790.74	387.43 to 788.15	384.83 to 785.55	-10.40 to -2.55	-12.73 to -4.88	-15.06 to -7.21
Partial Loss	-14.25 to 390.02	-16.84 to 387.43	-19.44 to 384.83	-12.87 to -10.40	-15.20 to -12.73	-17.53 to -15.06
No Loss	-14.31 to -14.25	-16.90 to -16.84	-19.50 to -19.44	12.87	-15.20	-17.53

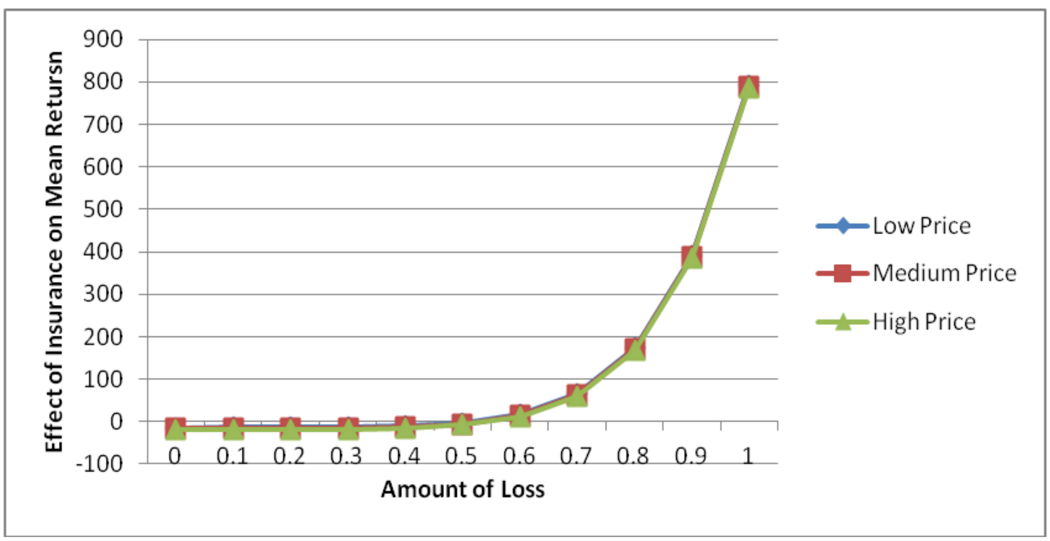

Fig. 4 Relationship between Amount of Loss and Effect of Insurance on Mean Returns per Acre during Wet Season (Original and Forecasted Price)

Analysis of the Subsidy and Asymmetric Information Incentives

This effect is decomposed into subsidy and asymmetric information incentives. Subsidy incentive refers to the financial aid given by the government to increase farmer participation in crop insurance programs, whereas the asymmetric information incentive is defined to be the incentive associated with the inaccuracies in insurance underwriting because of asymmetry of information.

Table 2 Subsidy Effect of Insurance

Yield Guarantee	Subsidy Effect of Insurance					
	Wet Season			Dry Season		
	Low	Medium	High	Low	Medium	High
> 90%	-13.55 to 585.63	-16.14 to 583.04	-18.74 to 580.44	-12.09 to 587.09	-14.42 to 584.76	-16.75 to 582.43
10% to 90%	-14.33 to -13.55	-16.92 to -16.14	-19.52 to -18.74	-12.87 to -12.09	-15.20 to -14.42	-17.53 to -16.75
< 10%	-14.33	-16.92	-19.52	-12.87	-15.20	-17.53

The subsidy effect of insurance on mean net income of farmers is presented in Table 2. Results show that for both cropping seasons, the subsidy effect on mean net income is very high in low-risk area and at > 90% loss, while the least effect appears in high-risk area and at < 10% loss. This suggests that the largest increase of mean net income due to subsidy occurs when a farmer from a low-risk area experiences a total loss. This implies that a farmer will benefit from the insurance if he is from a low-risk area and he sees that for that cropping season losses are likely to occur. However, it is also seen that adverse selection is greater during the dry season than during the wet season. As for the insurer, this means that he should be more careful in underwriting the insurance product during the dry season.

By comparing subsidy effects across yield guarantees for both wet and dry seasons, high positive mean subsidy effects of crop insurance are perceived for some yield guarantees between 90% to 100%. This means that for these yield guarantees, the subsidy greatly increases mean net income when agricultural loss is at least 90%. It can also be perceived that low negative mean subsidy effects are at yield guarantees from 0% to 90%. This means that insurance subsidy causes a slight decrease on mean net income for yield guarantees 0% to 90%.

By comparing the values obtained by cropping season, it can be identified that the values for the dry season are greater than that of the wet season. Higher mean net income effects are expected during the dry season because there are less storms and typhoons that hinder the growth of *palay*. It is seen that adverse selection is greater during the dry season than during the wet season.

Another significant observation is that when the yield guarantee is low, the subsidy effect of insurance on mean returns per acre is also low. This implies that there is a positive association between these two. It is determined that as the premium increases, the effect of insurance on mean returns per acre decreases linearly.

As for asymmetric information effects (Table 3), calculations show that for dry season the mean effect on income is negative when farmer, in any area, chooses the highest guarantee level. This means that farmers cannot exploit the insurer for insufficient information, or that adverse selection is greater during the wet season than during the dry season. This implies that farmers are less likely to insurance during dry season, as if less likely to choose maximum coverage during this season.

By comparing asymmetric information effects across yield guarantees for both cropping seasons, it can be observed that the mean net income effect is very high when yield guarantee is 90%, while it is very low when guarantee is 10%. When yield guarantee is 100%, negative asymmetric information effects are also very high. However, for other yield guarantees 10% and 90%, positive asymmetric information effects are very low. It can be deduced here that for dry seasons, farmer cannot fully exploit the insurers for insufficient information.

Table 3 Asymmetric Information Effect of Insurance

Yield Guarantee	Asymmetric Information Effect of Insurance					
	Wet Season			Dry Season		
	Low	Medium	High	Low	Medium	High
100%	205. 11	205.11	205.11	-589.64	-589.64	-589.64
90%	403.57	403.57	403.57	1.70	1.70	1.70
10%	0.07	0.07	0.07	0.00	0.00	0.00

By comparing the asymmetric information across cropping seasons, it can be identified that the values for the dry season are less than that of the wet season. This means that higher mean net income effects due to asymmetric information are expected during the wet season. It is seen that adverse selection due to asymmetry of information is greater during the wet season than during the dry season.

CONCLUSION

In conclusion, this study finds that adverse selection due to subsidy and asymmetric information incentives is existent in the multi-risk crop insurance product. The results support that the adverse selection is highest when yield guarantee is high. In most cases, adverse selection is highest when risk is low and the yield guarantee is high. For the farmer, he will benefit if he is from a low-risk area and insures when he expects that there will be losses for a certain cropping season.

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Research article

Event-based Rainfall-runoff Simulations using GETFLOWS for Kourtimalei Catchment in Djibouti

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Abstract This work was focused on the simulation of a surface terrestrial water flow process model in the area of Kourtimalei in Djibouti using GIS, RS and GETFLOWS, a physics-based surface and subsurface fully coupled fluids flow code. A trial and error were used to calibrate the model using observed surface water level of the pond. The manual calibration was performed until the surface water level of the pond RMSE to be 0.40 m with r^2=0.99. Furthermore kappa coefficient was used to evaluate the agreement between the pond areas extents derived from available LANDSAT-8 images during the simulation period with the pond area extents results of GETFLOWS simulation. The analysis showed that GETFLOWS successfully simulated the surface water flow process. We conclude that the use satellite derived datasets can help calibrate and evaluate GEFTLOWS hydrologic model for an ungauged watershed like in the present case..

Keywords Djibouti, GETFLOWS, LANDSAT-8, simulation, surface runoff

INTRODUCTION

Djibouti is a typical arid country located in the horn of Africa with fluctuating and low rainfall (less than 200 mm yr^{-1}) and high temperature in summer (June to August). However, intensive rainfall has sometimes caused abrupt runoff on bare land surface, resulting in heavy flood damages along the alluvial fan. When such rainfall occurs in the closed watershed, rainfall water accumulates at the lowest point in the watershed and the ponding area can stay up for several months sometimes. Usually that ponding water is lost through evaporation and seepage in a three to six months period. Kourtimalei catchment at Grand Bara desert is a good example of a closed watershed where ponding water appears during intensive rainfall. For a period of two years (May 2012-August 2014) the local government put in place a pilot farm project in the area investigating suitable of irrigation techniques and cultivation techniques. In this project, source of the irrigation water was set to be a pond collected from surface runoff of the catchment water.

The purpose of this work is to characterize the runoff process of the watershed by applying observed precipitation (and other meteorological variables), at scale of hourly interval. Therefore we created a 3D model simulating the surface flow process on the basis of spatial data (DEM, land cover, geology) along with hydrogeological and hydrological parameters and integrating into the flow computer code GETFLOWS (General purpose terrestrial fluid-flow simulator) (Tosaka et al., 2000).

METHODOLOGY

Study Area

Located near the Grand Bara desert in the southern part of Djibouti, Kourtimalei watershed records an annual precipitation that ranges approximately from 150 to 200 mm yr^{-1}. The land cover distribution covers mostly bare land with sparse shrubs (Acacias), rocks, and alluvial fan surfaces on the steep hill area. The geology of the area is comprised of alluvium sediment group along the alluvial fan or in the Petit-Grand Bara desert and of basaltic rocks like Dalha basalts (3.4-9 Myr) Stratoid basalts (1.5-3.4 Myr) (Jalludin et al., 2003) (Fig. 1). The alluvium was found to be comprised of loam, sandy loam and gravel deposit which has various grain sizes. The topography influences best explains the observable differences of the soil texture and in the infiltration capacity seen tin the catchment (Toyoda et al., 2015).

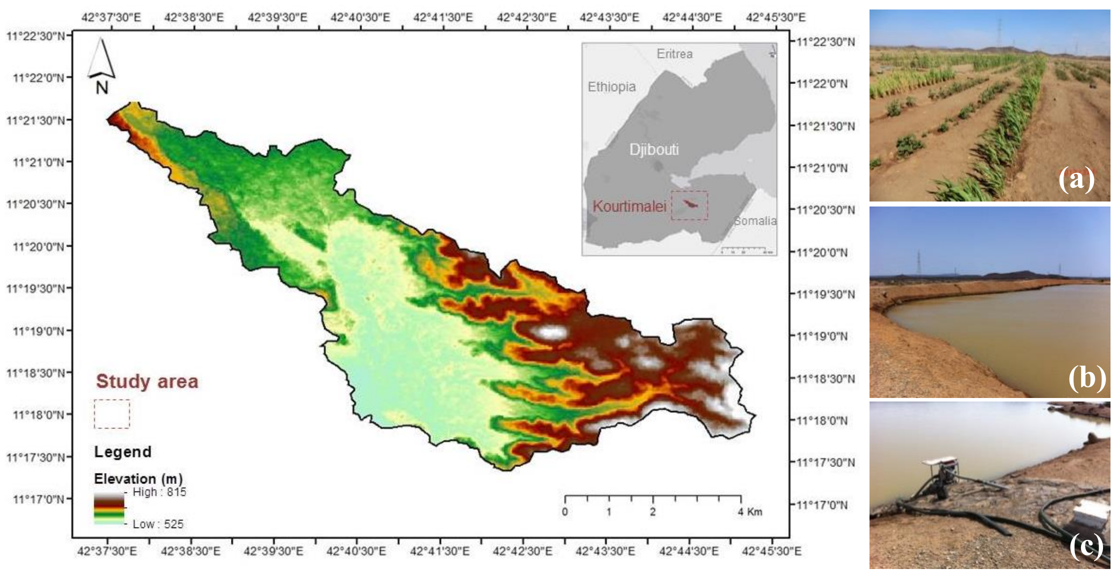

Fig. 1 Location of the Study area; (a) pilot farm near Kourtimalei pond; (b) Kourtimalei pond; (c) pumping engine

As in Djibouti, precipitation is sometimes intense and causes floods therefore the government of Djibouti has decided to promote the active mobilization of surface water for agriculture. Therefore, around Kourtimalei, a pond reservoir was created (volume capacity 5,400 m^3) (Fig. 1.b) and irrigated crops have started on a small scale (pilot farm of 0.65 ha) (Fig. 1.a) with a small pumping engine (Fig. 1.c). The major problem of this source of irrigation remains the instability of the reservoir volumes. Most of the water is lost either through evaporation or seepage (JICA, 2014).

Data Collection

The key datasets enabling the implementation and testing of the numerical model are based on the widely published information but also site investigation data in the Kourtimalei basin. It includes the following:

1) In this work, we used 4 LANDSAT-8 images (July 28, September 14 and 30, and December 03)

for the pond extent mapping and the area measurements. The images represent also a crucial part of the validation phase of the simulation. It offers a good combination of two months coverage with an acceptable spatial resolution (30 m pixels).

2) ASTER GDEM data (30 m resolution DEM) published by NASA and The Ministry of Economy, Trade, and Industry (METI) of Japan was used as elevation data for the watershed area. The vertical accuracy was improved by modifying with point elevation data from ground survey in the reservoir area.
3) Observed precipitation records at different location in the watershed indicating an average of less 100 mm month^{-1}. Although the small scale of the area, it was found that the amount of rainfall isn't homogenously distributed (Toyoda et al., 2015). Evapotranspiration was estimated from potential evapotranspiration and represents 84% of the annual average precipitation.
4) Hourly record of the water level of pond collected from sensors within Kourtimalei reservoir.
5) The surface geology is from the national geology map (ORSTOM, 1986)
6) The land cover map with 3 classes (rock, soil and vegetation) was derived from LANDSAT-8 images by unsupervised classification (Fig. 1).
7) The fluid properties of water and air are represented by the typical value in the standard conditions. The soil is mainly comprised of loamy and sandy loam. The loam soil hydraulic conductivity ranges from 50 to 100 mm h^{-1}, while for the sandy loam soil texture, larger ranges (160-190 mm h^{-1}) were recorded (Toyoda *et al.*, 2015). The permeability of basaltic rock, weathered rock on the surface was estimated by pumping test and considered to be small as shown in Table 1 (Jalludin and Razack, 1994)

Table 1 Hydraulic parameters used

Geology	Intrinsic Permeability (cm/s)	Porosity (%)
Loamy soil	5.63 x 10^{-2}	40
Alluvium deposit	1.00 x 10^{-2}	40
Weathered rock	1.00 x 10^{-6}	10
Basalts	1.00 x 10^{-5}	10

GETFLOWS Modeling and Verifications

The General purpose terrestrial fluid-flow simulator (GETFLOWS), developed by Tosaka et al. (2000), was used to simulate rainfall runoff events at the study site. It is a physically based model that solves both the surface and subsurface systems simultaneously by employing an integral finite difference method approach for solving the governing equations. The natural system is discretized into small cells in order to obtain exact solutions (Magnus et al., 2011). The governing equation for air/water two-phase fluid flow in GETFLOWS is expressed by the following equation of mass conservation (Eq. 1).

$$-\nabla\left(\rho_p\, u_p\right) - \rho_p q_p = \frac{\partial}{\partial_t}\left(\rho_p\, \emptyset S_p\right) \qquad (p = water, air) \qquad (1)$$

Where u_p is the fluid flow velocity (m s^{-1}), ρ_p is the fluid density (kg m^{-3}), q_p is the production and/or injection rate (m^3 m^{-3} s^{-1}), $\emptyset$ is effective porosity (-), S_p is saturation degree (m^3 m^{-3}) and p is a subscripts that indicate quantities on each fluids phases. In the surface GETFLOWS solves the Manning's equation for the horizontal surface water flow by using the linearized-diffusion-wave approximation equations (Tosaka et al., 2000). The flow in the subsurface and the vertical flow in the surface are expressed with the Darcy's equation .GETFLOWS solves the saturated, unsaturated subsurface flow and surface flow in a continuum approach within a single matrix. Nonlinear interactions between all components of the system are simulated without a priori specification of the coupling between surface and subsurface flow. Therefore streams formation are purely based on hydrodynamic principles governed by recharge, topography, hydraulic conductivity and flow parameters (when water is ponded due to surfaces flux exceeding the infiltration capacity of the soil or due to excess from subsurface soil saturation).

The study area was discretized spatially in 2D plane by grid blocks of approximately 30 m. The secondary data (i.e. elevation, geology. land cover) were assigned into the corner-point coordinate of the 2D grid blocks. Then the 2D plane grid-block system was enlarged into depth direction and discretized again along Z axis to generate the 3D grid-block system. The total number of grid cells recorded to be 100,890 cells (Fig. 2).

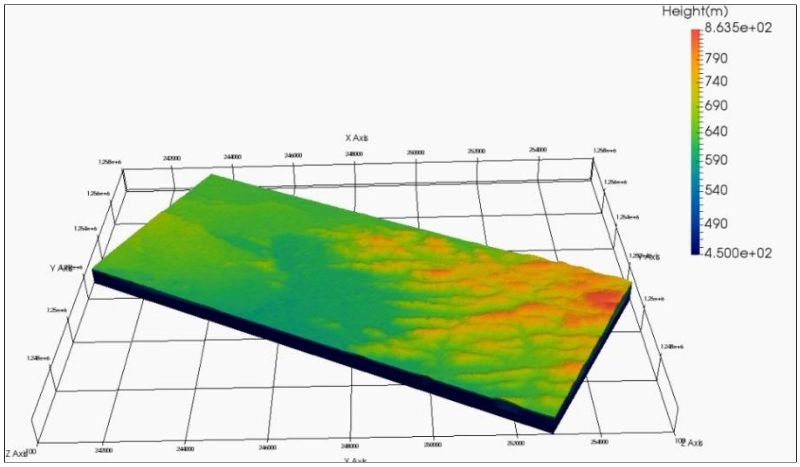

Fig.2 Three dimensional model (topography)

Our aim is to analyze the runoff characteristic of the watershed that creates the Kourtimalei pond during intense precipitation events. Thus the model was used for a short-term reproduction of the rainfall events of August 01 to December 03, 2013. Recorded daily fluctuations of meteorological conditions were constrained onto the model. Then, GETFLOWS was calibrated using the available daily pond water elevations observations for the period between August 01 and December 03, 2013 in Kourtimalei. RMSE indicator is used to assess model accuracy in matching the model-simulated runoff with observations of the differences in water level records of the pond. The criterion is used as an objective functions for the calibration. Furthermore the Kappa coefficient is used to assess the accuracy of the model by comparing the pond area extent derived from LANDSAT-8 satellite images during the simulated period with GETFLOWS simulation result at the 4 times when clear LANDSAT-8 images were available (i.e., 10 am on August 29, September 14 and 30, and December 12, 2013) (Fig. 3).

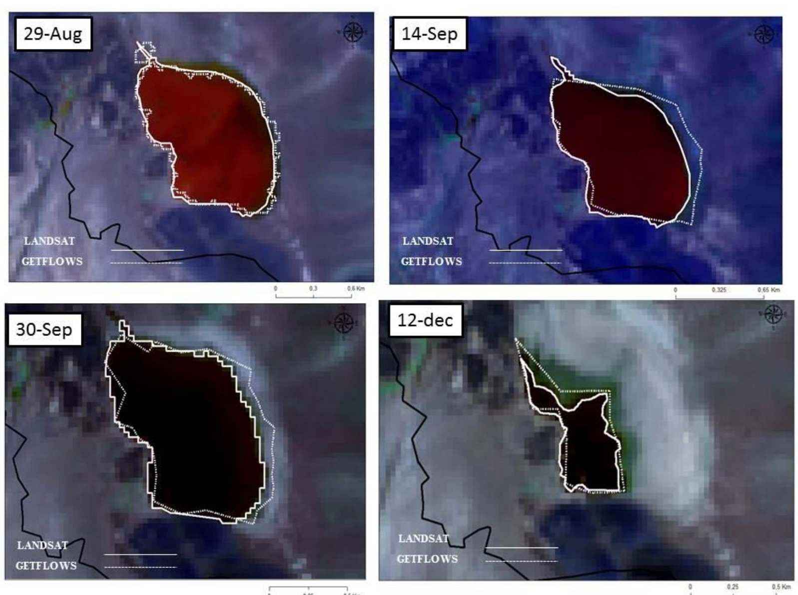

Fig. 3 LANDSAT-8 in false color (5:4:3) pond extents in August 29th, September 14, September 30 and December 12th 2013

RESULTS AND DISCUSSION

In this section, we present the results of the calibration process of GETFLOWS. The Root mean squared error (RMSE) has been used for comparison of simulated pond water levels with observed water levels for the period of August to December.

The trial and error method yielded for an optimized parameter combination that had a RMSE of 0.40 m (Fig. 4). The Comparison of GETFLOWS-simulated spatial extent of the pond with satellite-based observations images (LANDSAT-8) (Fig3) was to provide a further evaluation of the GETFLOWS performance in simulating the spatiotemporal evolution of the pond extent during the calibration period. Fig. 5 shows the statistical comparison between GETFLOWS and LANDSAT-8 which indicates that a rather good agreement between the obtained pond spatial extents of GETFLOWS and LANDSAT-8.

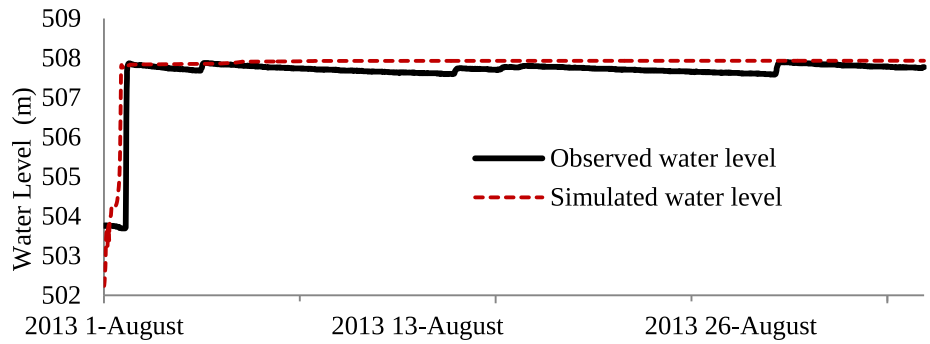

Fig. 4 Comparison between the observed and simulated Water levels during the month of August, 2013

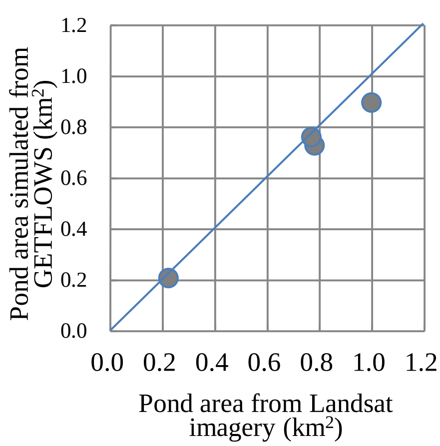

Fig. 5 Comparison of the surface pond area extent between LANDSAT vs GETFLOWS

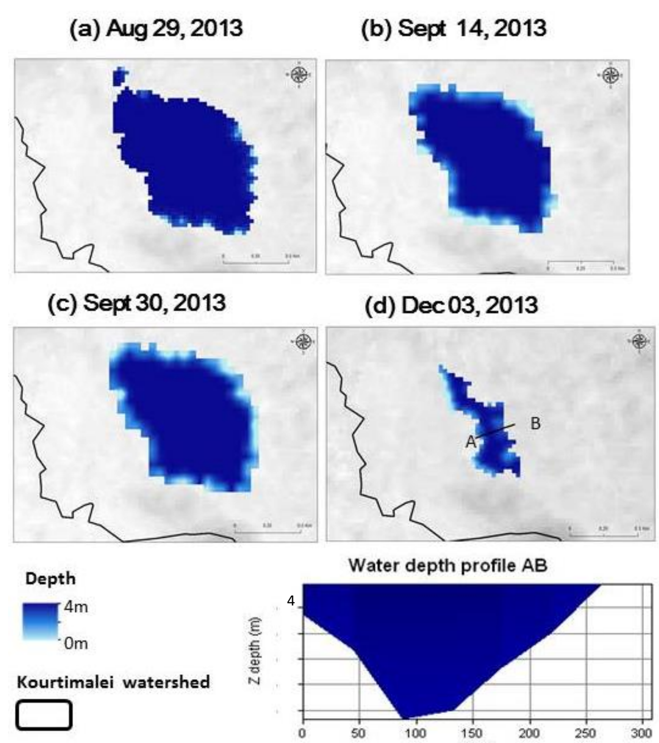

Fig. 6 Simulated water depths of Kourtimalei pond at four time step with pond profile on Dec 03

For further verification of GETFLOWS simulations results, the objective function selected to guide to assess the agreement fit between satellite-based pond extent and GETFLOWS modeled extents was the Kappa coefficient as shown in Table 2. Overall, GETFLOWS could recreate the rainfall-runoff process successfully for each of the date. More 80% of the simulated pond extent matches the spatial extent detected by LANDSAT-8 at the given date. Less than 20% of the simulated spatial extent of the pond was either misclassified as flooded area (false) or either classified as non-flooded not all (missed).

Table 2 Comparison between GETFLOWS and LANDSAT simulated area vs derived area

Date of events	LANDSAT detected area (km^2)	GETFLOWS				Kappa Statistic *K*
		simulated area (km^2)	Correct (%)	Missed (%)	False (%)	
29/AUG	1.00	0.90	85.64	12.16	2.20	0.88
14/SEP	0.86	0.73	80.00	13.16	6.83	0.84
30/SEP	0.77	0.76	78.86	11.03	10.10	0.83
12/DEC	0.22	0.21	71.22	6.80	21.99	0.82

CONCLUSION

In this work, we have run a rainfall-runoff simulation with GETFLOWS of the Kourtimalei watershed, and calibrated the model by using both water levels observations data, and then validated with satellite derived datasets of the spatial extents of Kourtimalei pond. GETFLOWS model was able to reproduce the rainfall-runoff process of the watershed fairly with RMSE of 0.40 m and a coefficient of determination of r^2= 0.989. This approach is in contrast with the conventional method of runoff modelling technique. The proposed approach implements a distributed hydrologic model and further calibrates the model parameters through satellite derived datasets that are freely available in the public domain. The impact of such a demonstrated technique is to provide a cost-effective tool in poorly gauged or ungauged watershed like in this case study.

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Research article

Certification Schemes for Alternative Agriculture in Japan

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Abstract Conventional agriculture, also known as modern or industrial agriculture, which main aim is to maximize production, is currently prevalent in the world. Negative consequences of such approach include environmental impacts such as soil degradation, groundwater pollution and GHGs emissions. Along with environmental problems, the use of chemical pesticides and fertilizers in conventional agriculture may cause problems to human health, both of producers and consumers. To alleviate negative impacts of conventional agriculture, the Japanese government has undertaken attempts to promote alternative agriculture. Laws, guidelines and certification schemes for promotion of alternative agriculture have been introduced in late 1990s and early 2000s. Today there are three national level certification schemes: "JAS (Japanese Agricultural Standard) Organic", "Eco-Farmer" certifications and "Specially Cultivated Products" certification. This review takes a look into the history of developing these certification schemes in Japan as well as the differences in the requirements for obtaining the certifications. The literature suggests that the role of national, regional and municipal governments vary regarding the procedure of introducing and issuing the certifications of each type. The possibility of negative economic impact on uncertified farmers practicing alternative agriculture is discussed. Authors argue that a simplified labeling system is preferred to increase customers' awareness and understanding of alternative agriculture certification schemes.

Keywords alternative agriculture, certification schemes, organic farming, eco-farmer, specially cultivated agricultural products

INTRODUCTION

The discussion on conventional versus alternative agricultural paradigm was underpinned by Beus and Dunlap in 1990. Conventional agriculture, which is also referred to as modern, industrial or intensive, is characterized by large-scale single crop production dependent on input of synthetic fertilizers and pesticides (Beus & Dunlap, 1990). Conventional agriculture, also known as modern or industrial agriculture, which main aim is to maximize production, is currently prevalent in the world. Negative consequences of such approach include environmental impacts such as soil degradation, groundwater pollution and GHGs emissions. Along with environmental problems, the use of chemical pesticides and fertilizers in conventional agriculture may cause problems to human health, both of producers and consumers. Organic farming is an example most often used as an agricultural practice opposite to conventional farming. However, a large variety of agricultural practices having a potential to alleviate negative impacts of conventional agriculture on natural environment and human health exist. This paper refers to these practices as alternative agriculture and is investigating its state in Japan.

To alleviate negative impacts of conventional agriculture, the Japanese Government has undertaken attempts to promote alternative agriculture. Laws, guidelines and certification schemes for promotion of alternative agriculture have been introduced in late 1990s and early 2000s. An umbrella term that is often used in policy discourse in Japanese is *kankyo hozengata nogyo*, which can be translated as environmentally friendly agriculture. However, the authors are using a broader term "alternative agriculture" and the initiatives introduced in this paper will be viewed as a part of it. The term 'alternative agriculture' is used here as an umbrella definition for different types of agricultural practices that put effort into limiting its impact on natural environment. In this paper authors include "JAS Organic Certification", "Specially Cultivated Agricultural Products Certification" and "Eco-farmers Certification" under the common definition of alternative agriculture. Authors intentionally avoid using term "sustainable agriculture" (although this term is used in official English translation of relevant legislative acts), as the paper does not put focus on evaluating long-term sustainability of each practice and certification scheme. The focus of this paper is on the agricultural practices and products, and excludes animal husbandry and livestock products.

In 2010, the tenth meeting of the Conference of the Parties (COP 10) was held in Nagoya, Aichi Prefecture, Japan. In the light of this even, the concept of biodiversity conservation became widely known among policymakers, citizens and industry. In March of the same year, the Prime Minister Cabinet Decision approved the new "The National Biodiversity Strategy of Japan 2010". One of the recognized methods for protecting biodiversity is Payment for Ecosystem Services (PES). It is also applicable to agricultural products, and eco-labels are playing important role in communicating necessary information from producers to consumers (Watanabe, 2012).

Importance of taking environmental aspects into consideration during agricultural production were introduced in Food, Agriculture and Rural Basic Act of 1999 and later elaborated in Environmental Norms for Agricultural Activities of 2005. Later additional laws and guidelines were issued to introduce certification schemes and eco-labels to promote various types of alternative agriculture. Main legislation acts for alternative agriculture in Japan are summarized in Table 1. Currently, there are three national level certification schemes: "JAS (Japanese Agricultural Standard) Organic", "Eco-Farmer" certification and "Specially Cultivated Products" certification. Certification schemes and eco-labels are known to be an effective instrument for providing information to consumers and thus have potential to contribute to protection of environment, biodiversity and help promoting local products through marketing them (McCluskey & Loureiro, 2003). Thus, main focus of this paper is on three certification schemes introduced by Japanese government.

With the trend for urban migration and shrinking and aging of rural population, the number of population involved in farming activities in Japan is on decline, which is also influencing the degree of alternative farming penetration.

OBJECTIVE

The objective of the paper is to summarize available information on national schemes for alternative agriculture certifications, namely "JAS Organic", "Eco-Farmer" certification and "Specially Cultivated Agricultural Products" certification. Historical background, related legislation, level of penetration and level of recognition by consumers are reviewed. Obstacles towards further dispersion of each practice will be identified.

METHODOLOGY

The review of three national certification schemes for alternative agriculture is based on secondary data. Research articles, book chapters, documents issued by the government and national statistical databases served as main source of information.

Table 2 Main Legislation for Alternative Agriculture in Japan

Year	Act/Law/Guideline
1999	Food, Agriculture and Rural Basic Act
	Law for Promoting the Introduction of Sustainable Agricultural Practices (Eco-farmers certification)
2001	Specially Cultivated Agricultural Products Guideline
2005	Environmental Norms for Agricultural Activities
2006	Act on Promotion of Organic Agriculture
2011	Direct Support Measures for Alternative Agriculture

RESULTS AND DISCUSSION

Overview

The application of synthetic chemicals in agriculture has sharply increased after the Second World War and brought about benefits of less labor demand and higher yields. On the other hand, the cases of farmers' poisoning by the chemicals also became widespread (Nishigaki et. al., 2002). It was during and soon after the period of Rapid Economic Growth (1955-1973), when industrial pollution was proved to cause harm to human health (e.g. Minamata disease and Itai-itai disease). In the result, public concerns towards the use of chemicals and environmental issues linked to its use started to grow. Although different types of alternative agriculture, such as natural farming, were developed by Mokichi Okada and Masanobu Fukuoka as early as 1930-1940s (Kristiansen et al, 2006), it was not until 1970s that a solid social movement supporting alternative agriculture was formed.

During the period of Rapid Economic Growth in Japan, a lot of environmental pollution and degradation was happening and causing harm to human health (e.g., Minamata disease, Itai-itai disease, Yokkaichi Asthma). In this regard, the public concern over environmental issues started to grow. Environmental movements environmentally friendly lifestyle and safe consumption also started to emerge. Green consumerism movement and the organic farming movement can be raised as examples. The organic farming movement in Japan emerged in the 1960s. Main concerns during that time were environmental degradation and health risks caused by synthetic pesticides and chemical fertilizers used in conventional agriculture (Funato, 2010). The movement was lead by the Japan Organic Agriculture Association (JOAA) that recognized the necessity of spreading awareness about food safety and eating habits among urban consumers (Minamida, 1995). In 1978, JOAA introduced the document "Ten Principles of Co-partnership", which later evolved into so-called TEIKEI (Minamida, 1995). TEIKEI is an alternative distribution system of agricultural products directly from a farmer to a consumer based on mutual understanding and trust. Another outcome of the movement was a change in policy that led to the introduction of labeling systems. Japanese Consumers' Co-operative Union (JCCU, often referred to as COOP) also played important role as a distribution channel for alternative agriculture products. The three national labeling schemes are introduced below in detail and summarized in Table 2.

"JAS Organic" Certification

First law introducing organic agriculture labeling system was issued in 2000 and the certification scheme that was established is referred to as JAS (Japanese Agricultural Standard) Organic ("*JAS Yūk*i" in Japanese). Currently "JAS Organic" certification is divided into four types: organic plants, processed food (e.g., drinks, spices, flour etc.), feed and organic livestock products (the later is excluded from the scope of this paper for the sake of making comparison with other certification types). Prefectural governments and municipal governments are in charge of establishing promotion strategy and plan for their areas.

The requirements for receiving certification are summarized in the text of "Japanese Agricultural Standard for Organic Plants". The Standard presents a list of prohibited substances that include chemical pesticides and fertilizers. The listed substances are not allowed on the agricultural land for at least two years before sowing or planting as well as during production.

Table 3 Alternative Agriculture Labels and Certification Requirements

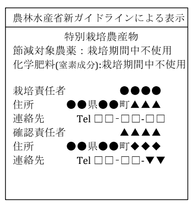
Certification name	Label	Certification Requirements	Certification authority
"JAS Organic"		No chemical fertilizers and pesticides No GMOs Use of compost	Authorized private certification centers (certified by land)
"Specially Cultivated Agricultural Products"	 Design can be modified by each prefecture	50% decrease in use of chemical fertilizers (by amount) and pesticides (by frequency) based on conventional level of each prefecture	Authorized private certification centers (certified by crop type)
"Eco-Farmer"	 Design can be modified by each prefecture	Submission of a 5-year plan for reduction of chemical fertilizers and pesticides use, and use of compost	Prefectural Governor (certified by crop type)

Image Sources: 1) "JAS Organic" Label – picture taken by author;
2) "Specially Cultivated Agricultural Products" Label – recreated by author
3) "Eco-farmer" Label – Chiba Prefecture Website. https://www.pref.chiba.lg.jp/annou/chibaeco/newlogomark.html

The Standard regulations also do not allow the use of Genetically Modified Organisms and encourages the use of compost. Moreover, necessary measures are required to prevent prohibited substances from drifting or flowing to the land. There are rules that need to be followed at all stages of production process. They include regulations regarding: cultivation sites, collection area, seeds or seedlings to be used in fields, fungus spawn, manure practice on the land, cultivation management in cultivation sites, control of noxious animals and plants in fields or cultivation sites, general management, management concerning harvest, transportation, selection, processing, cleaning, storage, packaging and other post-harvest processes.

In order to receive a certification, the producers are required to apply to private certification centers authorized by Ministry of Agriculture Forestry and Fishery (MAFF). The certification inspection is conducted by land units, without regard to the number of crops grown on the land. Thus unit of certification is a plot, not crop type, which means that one certification can cover several crop types harvested from the same plot. As of July 2016, there are fifty-six registered certifying bodies within Japan. Sixteen certification centers among them certify not only domestic producers but overseas ones as well. After the inspection is conducted, certified producers are granted permission to use "JAS Organic" label (see Tab. 2). A number of certification centers has to be mentioned on the label. Despite the efforts to promote "JAS Organic" certification, the number of certified households has been on decrease since 2012. Nevertheless, the size of farming area keeps on increasing steadily (see Figure 1).

This implies that the size of farming area per certified household is increasing, and that a farming household certified as "JAS Organic" in the past can be converting additional plots into organic practices in subsequent years.

In 2016, a number of farming households certified as "JAS Organic" reached 3,660 households. At the same time, the number of the farmers practicing organic agriculture without obtaining "JAS Organic" certification is double of that, around 8,000 households (MAFF, 2016a). Those uncertified produces are not allowed to place word "organic" on their products, which might negatively influence their sales.

According to the customers' survey conducted by JOAA, more that 90% are familiar with the term "organic farming". Nevertheless, 54% of respondents were not familiar with "JAS Organic" label that is placed on the products (see Tab. 2) and only 5% knew the details of "JAS Organic" certification process (JOAA, 2011).

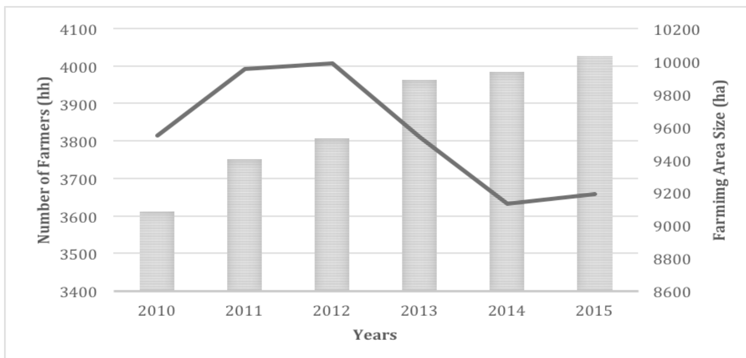


Fig. 1. Number of farming households and farming area size certified as "JAS Organic" (2010-2016). Based on data published on MAFF Website.

"Eco-Farmer" Certification

"Eco-Farmer" certification was established in 1999 with enacting of the Law for Promoting the Introduction of Sustainable Agricultural Practices. This certification scheme is encouraging to decrease the use of chemical pesticides and synthetic fertilizers on farms and promote the use of compost. In order to receive certification, the applicant has to submit a 5-year plan for reducing of chemicals input. Unlike "JAS Organic", "Eco-Farmer" certification is issues by crop type, and not by agricultural plot. The certification process is organized via prefectural government and governor approves applications.

The certification is valid for 5 years and has to be renewed after that. With the average age of farmers rising (66.4 years old in 2015) and the share of farmers over 65 years old growing (63.5%) (MAFF, 2015), it is often the case that once certified farmers do not renew the certification after 5 years since retirement is approaching.

After the certification process if successfully completed, certified farmers are allowed to place an "Eco-farmer" label (see Tab. 2) on their products. This label used to be universal for all prefectures until 2011. After that only eleven out of forty-seven prefectures have continued to use the same label, whereas the rest of prefectures have designed their own unique labels. Although it might help in promoting local brands of each prefecture, it might also have negative impact on the level of recognition of the label by consumers. According to a consumers' survey conducted in 2005 only 42% of consumers interested in purchasing alternative agricultural products replied that they are familiar (or have seen before) "Eco-Famer" label (Mibu & Okubo, 2005).

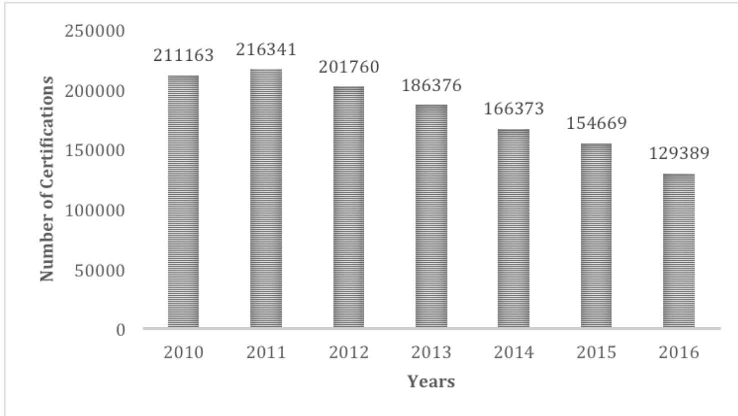


Fig. 2 Number of issued "Eco-farmer" Certifications (2010-2016)
Based on data published on MAFF Website

Although the number of "Eco-Farmer" certifications issued increased sharply from 19 cases in 1999 to 216,341 cases in 2011 when it reached its peak, it then has then fallen to 154,669 cases in 2015 (MAFF, 2016b). One of the reasons is that the financial return is not balanced with the cost of transition and labor demand (MAFF, 2015). To overcome these obstacles, it was made possible for "Eco-Farmer" certified farming units to receive support in a form of Direct Payments and employ extended periods for the return of loans granted for the improvement of agricultural practices.

"Specially Cultivated Agricultural Products" Certification

In terms of requirements towards the producers, "Specially Cultivated Agricultural Products" (*Tokubetsu Saibai Nosanbutsu* in Japanese) certification scheme lies somewhere in between "JAS Organic" and "Eco-farmer" Certifications. The guideline that is establishing the rules for the proper labeling of such products was introduced in 2001 and then amended in 2003. To use this label, the producers are required to reduce the use of chemical fertilizers (by amount) and pesticides (by frequency of application) by 50% towards the conventional level of the region.

Similar with "Eco-farmer" scheme, the design of the label can be changed by each prefecture, which potentially decreases the level of its recognition by the consumers. Mibu and Okubo (2005) argue that in comparison with "JAS Organic", "Specially Cultivated Agricultural Products" labels lack credibility and thus the market price of such products is lower than those labeled "JAS Organic" (Mibu and Okubo, 2005). This is one of potential reasons why the number of certified farmers is stagnant (around 45,000 households in 2015), as the financial benefits do not fully cover the cost of transition (MAFF, 2015).

DISCUSSION

This paper looked into three national level schemes for certification of alternative agricultural products, namely "JAS Organic", "Eco-farmer" and "Specially Cultivated Agricultural Products" schemes. Although the number of certified farmers and size of certified agricultural land is monitored annually, the studies that analyze the reasons behind low penetration of alternative agriculture in Japan. A thorough study surveying certified producers about the benefits and demerits they experienced on obtaining certification, distribution and information channels they use as well as their opinion on the certification schemes will help to shed the light on potential reasons for farmers' lack of interest in obtaining the certification. At the same time, additional consumers' survey about their knowledge of labels and willingness to purchase certified agricultural products would help in analyzing whether demand for such products exists on Japanese market.

CONCLUSION

After the introduction of alternative agriculture certification schemes in late 1990s early 2000s, the number of farming households certified under each scheme increased sharply during the first years. However, in 2011-2012 after reaching a tipping point, both the number of “Eco-Farmer” and “JAS Organic” certified farmers started to decline. The number of households certified under “Specially Cultivated Agricultural Products” scheme is also stagnant lately. High cost of transition and insufficient financial return as well as aging and shrinking of the farming population are among the factors that are hindering further dispersion of alternative agriculture certifications. The recognition level of the labels among consumers is low and simplification of current system might help in improving consumers’ awareness and increasing their willingness to purchase such products. Educating consumers about food safety can also be a useful method for promoting more understanding towards alternative agricultural products. Lastly, a more inclusive certification system is recommended for alleviating negative economic impacts experienced by non-certified farmers practicing alternative agriculture, as they are currently not allowed to use term ‘organic’ for their products.

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Research article

Current Agricultural Status and Problems faced in Paghman District of Kabul Province, Afghanistan

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Abstract Afghanistan, an agricultural and land locked country, located in the heart of Asia. More than 75% of country's population is living in rural areas. Paghman District located in the Kabul Province of Afghanistan was selected for conducting this research. In Paghman District, there are some severe problems regarding agricultural land use, water resource conservation, and utilization. The objective of this study is to identify current agriculture status and problems faced in Paghman District for conserving water environment of the Qargha Reservoir qualitatively and quantitatively. To achieve the objectives, a questionnaire survey was conducted to find out the current agricultural status and problems faced in Paghman District. One or more local farmers (representatives) were selected from each of the 15 different villages in Qargha Reservoir watershed of Paghman District. The results indicated that water shortage, soil erosion, and low fertility were the major factors causing low agricultural productivity. Majority of the local farmers perceived water shortage magnitude as severe and very severe at 33%, respectively. Local farmers' awareness about soil erosion effects on their cultivated lands were minor. About 54% of the local farmers were not aware of the soil erosion effects on their lands. The correlation analysis showed that water shortage and soil erosion negatively affected the yields. The development of proper conservation strategies as well as farmers education on proper soil and water resource management is needed to achieve sustainable agriculture in Paghman District of Kabul Province, Afghanistan.

Keywords Paghman, Afghanistan, sustainable agriculture, low fertility, land use, water resource management

INTRODUCTION

Afghanistan is a country with majority of the population involved in agricultural activities and is located in the center of Asia. Afghanistan is bordered by Pakistan in the south and the east, Iran in the west, Turkmenistan, Uzbekistan and Tajikistan in the north, and China in the far northeast. More than 75% of country's population is living in rural areas, and 50% or more of the GDP is generated by agriculture and related sectors in rural areas. By far, the greatest part of the land surface of Afghanistan is extensive grazing land, desert, and semi-desert or high or Steep Mountain, only about 40% is said to be suitable for winter grazing (Thieme, 2006).

Afghanistan faces problems of effective use of water resource, an increase of irrigation area, and improvement of irrigation method (Kawasaki et al., 2012). Rainfall varies from a low 75 mm in Farah Province to 1,170 mm in south Salang, occurs mostly in the winter months and particularly in the February/April period. The wet season is concentrated in winter and spring when the vegetative cover is low. In higher elevation, precipitation falls in the form of snow that is highly critical for river flow and irrigation in summer. From June to October, Afghanistan receives hardly any precipitation. The Afghan climate is continental with temperatures ranging from above 30° C in summer to below -20° C in winter. In spring, late frost can affect fruit production (Favre and Kamal, 2004). According to Saba et al., (2001), only 6% of the 15% of land in Afghanistan is usable. Due to the nature of the topography and the arid climate, vast areas are subject to soil erosion. The annual average soil loss rate of Kabul River Basin was estimated to be 19 tons/acre/year (4748 tons/km^2/year) (Sahaar, 2013). Agriculture production has been considered as a key sector for the revival of the economy and well-being of the people in the country, but it is not enough level to achieve the food self-sufficiency and to export of agricultural products (Kawasaki et al., 2012). The objective of this study is to identify current agricultural status and problems faced in Paghman District of Kabul Province, Afghanistan for conserving Qargha Reservoir water environment qualitatively and quantitatively by reducing sediment yield, nutrient loss, and irrigation water shortage.

METHODOLOGY

Paghman District is located in west part of Kabul Province of Afghanistan, total of the area is 361 km^2, and average annual rainfall is 473 mm. Qargha Reservoir is located in Paghman District. Qargha Reservoir is used for irrigation and recreational purposes. Furthermore, Qargha Reservoir provides irrigation water for more than 2,000 hectares of farmland. Only seven extension workers are responsible for managing agriculture in the whole study area with more than 150,000 population.

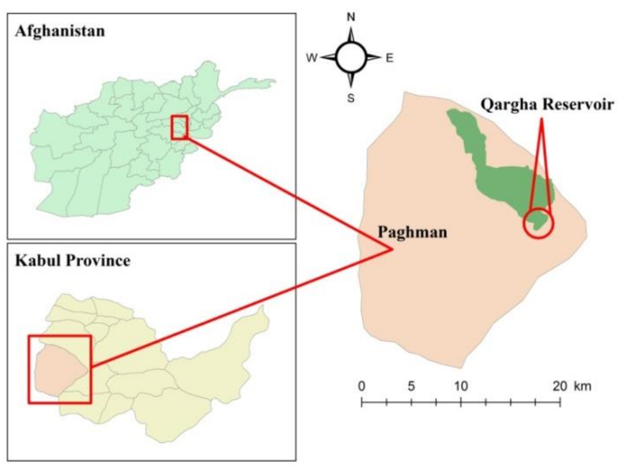


Fig. 1 Location of Qargha Reservoir Paghman District, Kabul, Afghanistan

Table 1 Land cover and land use classification in Paghman District (FAO, 2016)

Irrigated land (ha)	Fruit trees (ha)	Vineland (ha)	Barren land (ha)	Forest shrubs (ha)	Rangeland (ha)	Build up (ha)	Water bodies (ha)	Total (ha)
8,080. 63	1,419.50	31.5	456,59	99.93	24,587.40	907.9	537.4	36,120
22.37%	3.93%	0.09%	1.26%	0.28%	68.07%	2.76%	1.49%	100%

In order to identify the current agricultural status and problems faced in Paghman District of Kabul Province, Afghanistan, a questionnaire survey was conducted in Paghman District of Kabul Province, Afghanistan. Paghman District is located in the west of Kabul Province with 361 km^2 area. Qargha Reservoir is located in the Paghman District and used for irrigation and recreational purposes.

In total, 24 local farmers were interviewed. One or more local farmers (representatives) were selected from each of the 15 different villages in Qargha Reservoir watershed of Paghman District, Kabul Province, Afghanistan. The questionnaire sheets contain different type of questions; the questions were on basic information of the local farmers, cultivated crop and yield, soil erosion effects, irrigation water shortage and irrigation water sources, future farming plan, fertilizer application, agricultural extension services, assistance and technical training as shown in Table 2.

Table 2 Type of questions in the questionnaire sheet

Category	Related question	Details
Basic information	Farmer's information	Name, gender, household, address, education, age and cooperative
Future farming	Continue farming	Yes, no and not decided
Fertilizer application	Type of fertilizer	MAP/DAP, Urea, farmyard manure, green manure, Compost
Soil erosion effects	Soil erosion effect on fertility And crop field	Destroy crop, decrease productivity and not aware
Agriculture Extension service	Extension service provision	Extension worker visit to the field
Assistance and technical training	Any kind of agricultural aid to the farmers by Govt./NGO	Improved seed and nursery stock, machinery, fertilizer, and medicine
Irrigation water shortage and irrigation water source	Water shortage severity and source of irrigation	Water source and water shortage severity

RESULTS AND DISCUSSION

Pre-harvest Agricultural Problems

Afghanistan is a country in which local farmers face a number of pre-harvest problems, which causes their farmlands to yield low and direct them to agricultural insufficiency. The common problems local farmers' faces in Afghanistan are diseases and pests, low fertility, water shortage, unwanted weed. In Afghanistan, local farmers face agricultural problems during a complete growing session starting from land preparation and sowing until harvesting. According to the results diseases/pests, irrigation water shortage, soil erosion, and low fertility were the major problems in the study area with 63%, 83%, 50%, and 29%, respectively as shown in Fig. 3. Former studies have indicated that water shortage, nutrient loss, and soil erosion are the dominant problem in Afghanistan (Kawasaki et al., 2012, Sahaar, 2013 and Safi et al., 2016). Besides other factors, lack of agricultural technical knowledge is the source of low productivity.

Fig. 2 Extension workers visit

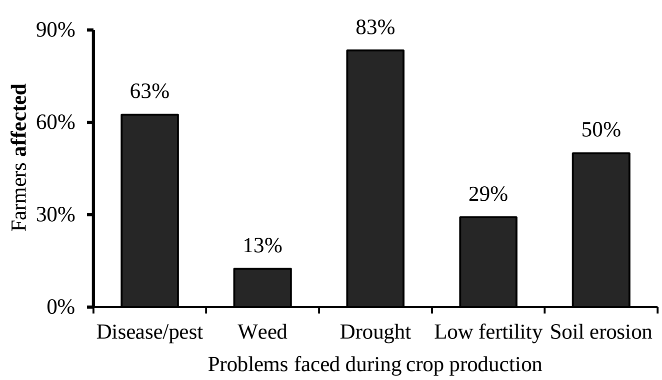
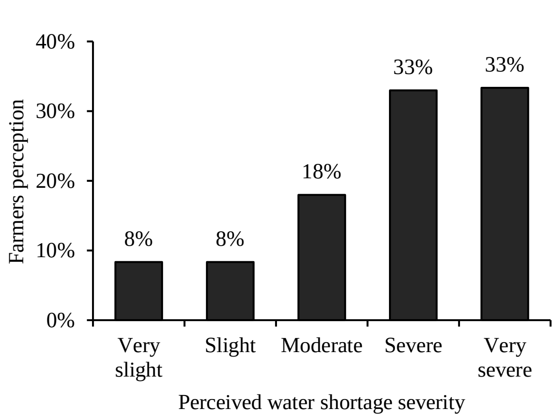


Fig. 3 Problems faced during crop production

Extension workers as shown in Fig. 2 did not visit the majority (88%) of the farmers. Thus, Agriculture in many parts of the country remains starkly underdeveloped. Hence, to solve these problems faced in the study area, proper conservation strategies as well as farmers' education on proper soil and water resource management**.**

Water Shortage

The availability of water resources is vital to the social and economic well-being and rebuilding of Afghanistan. In the Kabul Basin, 10% reduction in recharge was simulated to assess the hydrologic effect of potential climate change on groundwater resources (USAID, 2010). Size of cultivated land in Afghanistan is 3.9 million ha of which 1.3 ha is rain-fed and 2.6 million ha is irrigated land. Almost 85% of all agricultural production is produced in irrigated areas. The rainfall begins in October, reaches its peak in March and ends in May. It hardly rains during the periods from June to October, especially in summer when the temperature is high.



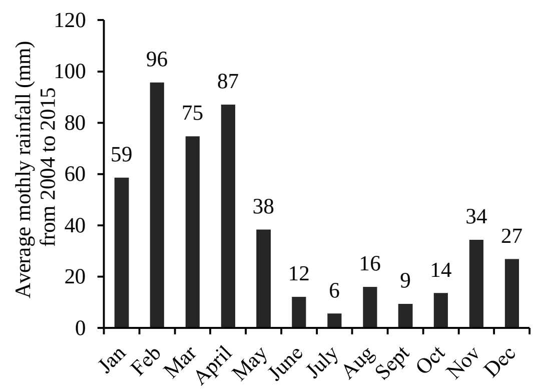


Fig. 4 Farmers perception on water shortage **Fig. 5 Average monthly rainfall (MAIL, 2016)**

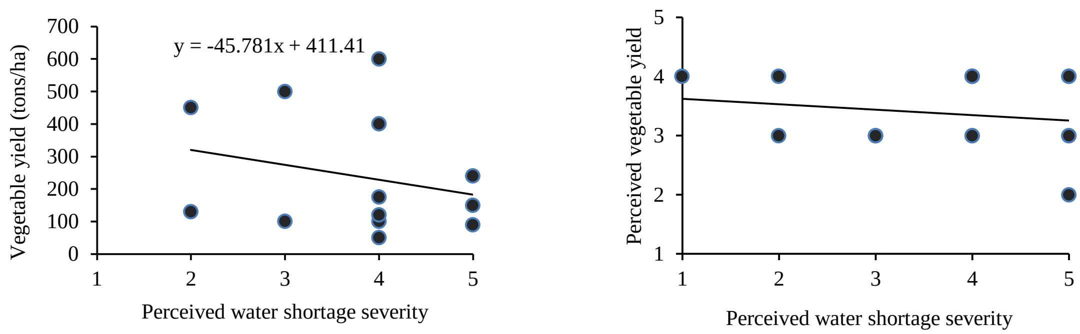


Fig. 6 Trends between vegetable yield and perceived water shortage

Majority of the farmers perceived water shortage as severe and very severe, with 33% and 33% respectively. As a result, the problem of water shortages frequently occurs in the latter part of the growing season between April and October, causing a major deficit in crop yield. Agriculture in Afghanistan faces a problem of water shortages during the latter half (summer) of planting period. The issue is the wastage of water due to the aging of irrigation facilities and unorganized irrigation practices. Therefore, the efficient use of limited water resources is an issue of paramount importance

(Kawasaki et al., 2012). Correlation analysis indicated crop yield was affected by water shortage in the study area. Hence, water shortage would cause low water inflow into Qargha reservoir. Therefore, irrigation potential of Qargha reservoir is negatively affected. Karezes (Karez is a tunnel system used to extract shallow groundwater) and tube wells were the major irrigation water sources in Paghman District.

Soil Fertility Management

Afghanistan's soils are mainly alkaline, soil pH ranges from 7 to 8.5, rich in calcium and potassium minerals. Soil organic matter content ranges from 0.2 to 2.5% (Alemi, 2010). According to the results farmyard manure, chemical fertilizers and crop rotation were the common soil fertility management practices in the study area, with 100%, 96%, and 71%, respectively. Local farmers usually used farmyard manure for soil fertility management, mainly made of cow, goat and sheep dung alongside human excreta. Chemical fertilizers were usually applied to the field by broadcasting on the soil and banding around plant roots. The liquid form of fertilizer application is not common practice in Afghanistan, only used in governmental and non-governmental owned farms. Hence, local farmers use intercropping and crop rotation in the agricultural field by growing alfalfa and clover to manage soil fertility. Urea (96%) and DAP (92%) were the major chemical fertilizers used for soil fertility enhancement in the study area as shown in Fig. 7. Potassium fertilizers are rarely used in Afghanistan. Nitrogen, phosphorous, zinc and iron, are the major elements deficient in Afghanistan soils. Organic fertilizers or Chelates (combination of an organic compound with a metallic ion) are rarely used by farmers.

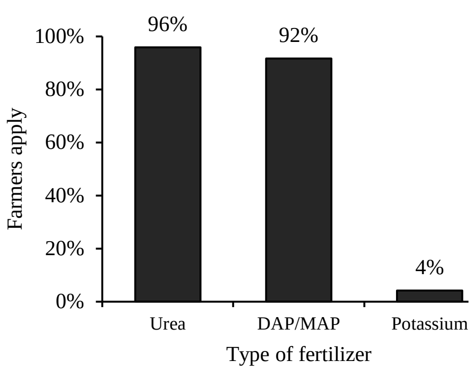


Fig. 7 Extension workers field visit

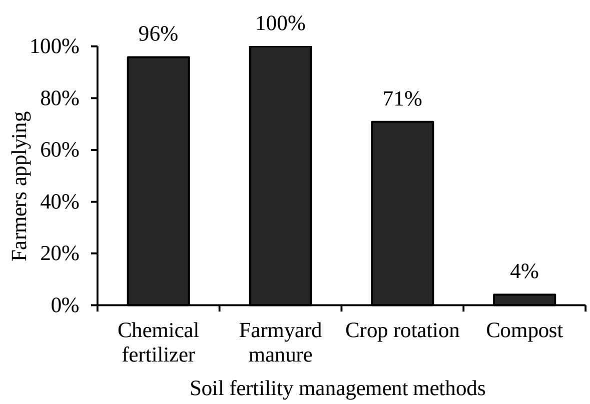


Fig. 8 Soil fertility management practice

Soil Erosion

Soil erosion is one of the issues influencing soil fertility all over the country. Due to irregular topography and low land cover, Afghanistan soils are subjected to soil erosion risk. The annual average soil loss rate of the Kabul River Basin was estimated to be 47.4 tons /ha/year and the gross mean annual soil loss rate was approximately 47.4 million tons/year. By producing 57% of the total annual average soil loss, rangelands were the primary contributor to the basin. Barren lands by producing about 38 % were the second largest contributor to the overall soil loss rate in the basin (Sahaar, 2013). Paghman District land use map shows that rangeland made 68.07% of the total land with low land cover and steep slopes, which increases the risk of soil erosion. Half of the total local farmers responded that they faced soil erosion during crop production. Thus, the majority (54%) of the responded local farmers were not aware of soil erosion effects on their cultivated lands. In case, if soil erosion occurs in the study area, Qargha reservoir would be at the receiving end by receiving a high amount of sediment yield, which could decrease water storage capacity. Safi et al., (2016) reported that surface runoff causes a significant amount of nitrogen, phosphorous, potassium and carbon losses from agricultural fields. In case, in the study area, local farmers did not realize the significance of soil erosion. It is the responsibility of governmental and non-governmental organizations to increase local farmer's awareness about soil erosion effects by offering them technical training courses and workshops in the study area.

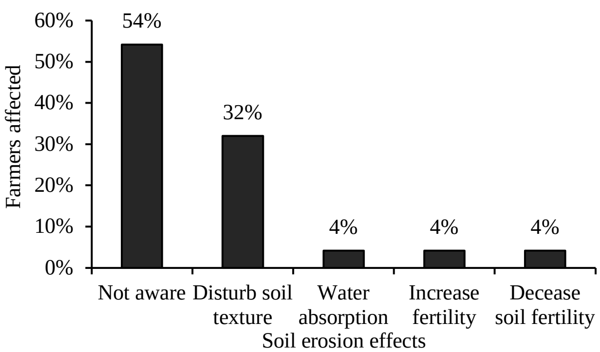


Fig. 9 Soil erosion effects

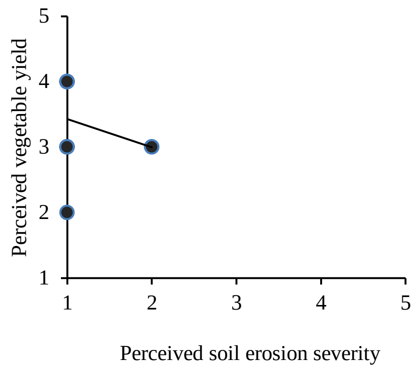


Fig. 10 Trends between perceived vegetable yield and soil erosion

CONCLUSION

This study was to identify current agricultural status and problems faced in Paghman District of Kabul Province, Afghanistan for conserving water environment of Qargha Reservoir qualitatively and quantitatively. Water shortage was one of the issues local farmers seriously faced during cropping season in the study area. About 83% of the farmers responded that they faced water shortage during crop production. Wells and karezes were the major water sources used for irrigation. Half (50%) of the local farmers faced soil erosion during crop production. However, local farmers' awareness about soil erosion effects was at very low level. The majority (54%) of the local farmers were not aware of soil erosion effects on their cultivated lands. Farmyard manure, chemical fertilizers, and crop rotation were the common soil fertility management practices in the study area with 100%, 96%, and 71%, respectively. Correlation analysis showed that soil erosion and irrigation water shortage negatively affected productivity. Soil erosion, low fertility, and irrigation water shortage were identified as major factors causing low agricultural productivity. Therefore, proper conservation strategies, as well as farmers education on proper soil and water resource management is needed to achieve sustainable agriculture in Paghman District of Kabul Province, Afghanistan.

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Research article

A Comparative Study of Housing Conditions among living sectors in Sri Lanka and among residential areas in Tea industry, Matara District, Southern part of Sri Lanka

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Abstract Sri Lanka is well-known as one of the most successful cases of human development among South Asian countries, despite widening income disparities among sectors (urban, rural, estate), especially in the estate sector. Tea industry is an important industry in the estate sector, however, working and living conditions which affect the quality of life are generally worse than other. This resulted in a decrease in well-being of the workers' capabilities. This study aims to identify the disparities in housing conditions among living four sectors in Sri Lanka and also residential areas in tea industry. Qualitative and quantitative methods are applied for analysis. To consider the well-being of people, capability approach is also applied. Data in the study relied on the secondary data conducted in 2008/2009, and 302 households' primary data obtained between 2014 and 2015. Three indexes of housing facilities used in this paper are access to drinking water, exclusive toilet facilities, and electricity lighting. Results in comparison between housing conditions and living sectors indicate that people in estates are under the low quality of housing facilities and face the risks under the unsanitary conditions. Statistically, all three indexes showed there are disparities among living sectors. Comparing indexes among sectors, accessibility to safe drinking water in estate has wider disparity than the others two index. Exploring the tea industry based on the management style (Semi-governmental estate, Private estate, Farmers) deeply found Private estates are more likely to face disadvantages than others. Accessibility to safe drinking water is lower than in others variables. Among residential areas access to safe drinking water is not statistically significant, but access to toilet facility and electricity is statistically significant at five percent level.

Keywords living conditions, capability, tea industry, rural development

INTRODUCTION

This study focuses on housing conditions of estate as whole country and inside tea industry community, and highlights differences among management styles, whiles providing suggestions to narrow the disparities. Sri Lanka has developed its status as middle income country with achievement of most of the MDG`s, even though income and social disparity among citizens and regions has being widening, especially in estate sectors where tea, coconuts and rubber has been cultivated. Tea is one of main industries and financial resources for government. Tea industry is promoted by two sectors; large-scale estate sector and smallholders. Export revenue in 2010 reached 1.37 billion US dollars, which accounted for 16 percent of the total export of the country. However, the poverty rate of estate workers was concerned for this community, accounted for 11.4 percent, compared to the urban average of 5.3 percent and to 9.4 percent of rural in 2009/10 (DCS 2011). The GINI indices increased from 0.43 in 1980 to 0.49 in 2009/10 (Central Bank of Sri Lanka 2012).

Estate sector is classified by cultivation land elevation and area. Cultivation elevation is classified into three; high-grown tea is over 1200 m, mid-gown tea is between 600 and less 1200, and low-grown tea is less than 600m. Cultivation area larger than 20 hectares is categorized as estate sector and smallholder is characterized as smaller than 20 hectares including farmers. Estate workers are protected by the estate labour laws. The quality of life as individual well-being of life is actually valuable for this person (Sen 1992). Working and living conditions in estate, however, are generally harder than other sectors, and the majority of workers have no job security (Wal, 2008). Their economic and social conditions are not enough to enhance their capabilities.

The literature reviews and interviews conducted in August 2012 at up-country found that people in tea estates have been confronted with low income, poor housing and sanitary facilities as well as other basic needs (Kumari 1984, WB 2007 and Chandrabose 2011). Recent studies reveal that number of tea cultivation managed by small holdings has increased, and living conditions in estates have been improved (DCS2005, 2012). Firstly, this study delineates disparity of housing conditions among living sector. Secondly, difference of residential areas based on the management categories will be described, and factors will be described, and factors accounting for these differences will be explored.

METHODOLOGY

Descriptive manner will be applied for this study. The results presented in this paper are based on qualitative and quantitative methods of secondary and primary data collection. Capability approach is also applied for this analysis.

Characteristics of the Secondary Data

Secondary data was from the Child Activity Survey (CAS) which was conducted by the Department of Census and Statistic with the International Labor Organization (ILO) in 2008/09. The objective of CAS was to identify the characteristics of Sri Lanka children. It, however, collected information about housing and household characteristics composed of 16,000 housing units that represent the whole country. Stratification was classified into three sectors of residence: urban, rural, and estate. Differences in housing environments among living sectors, the areas where three sectors existed were chosen from the CAS. Recent management styles of agriculture vary, and the number of small holders and farmers has been increasing. Thus, in this study, data were extracted and sorted from the rural housing variable into farmer and the rural itself. Characteristics of farmer are to own a single house and land, at least one parent is working, ownership of livestock been less than 10 cows and goats, and owns less than 100 chickens.

To deepen the multidimensional understanding of livelihood, the use of income index is not enough. One purpose of this study is to describe difference of dwelling conditions among three areas based on the management styles in tea industry. Therefore, the data on access to safe drinking water, household exclusive toilet, and electricity lighting were adapted for this analysis. Definition of safe drinking water in CAS is "Protected well within and outside premises" "Tube well" "Tap within premises and outside" and "Stream water collected & distributed by pipe lines". Definition of unsafe water is "Unprotected well" and "River/Tank/Steam/Spring and other". Stream water collected & distributed by pipe lines, however, is categorized as unsafe drinking water since this survey did not include the scientific evidence. Limitation of this analysis depends on the circumstantial, but is not to be able to show the scientific data.

Target Area and Primary Data

Sri Lanka is composed of 25 districts organized into 9 provinces. The 25 districts are divided into 331 divisions which are further divided into 14021 GN divisions. There are 36822 villages in Sri Lana (DCS 2013). Ecologically Sri Lanka is divided into two zones based on the availability of rainwater. The southern part of the country where tea cultivation has been planted receives ample rainfall while northern parts of country called the dry zone receive scarce rain.

Primary data were collected at Kotapola Division of Matara District in Southern part of Sri Lanka, famous as one of five tea cultivation areas, called Ruhuna as Low-grown tea. Kotapola division is composed of 110 villages in 37 GN divisions. Where villages and estates existed are evaluated as lower housing conditions in Martara district (DCS 2013). Tea industry in this area has a different story as oppose to upcountry where no villages were at the time of estates establishment. British government during colonial area established huge tea estates on the hillside around low-country, which were surrounded by villages even before the states were introduced (Bronkhorst 2008).

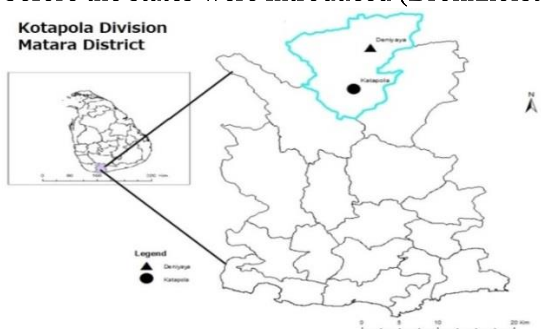


Fig.1 Location of Deniyaya GN division

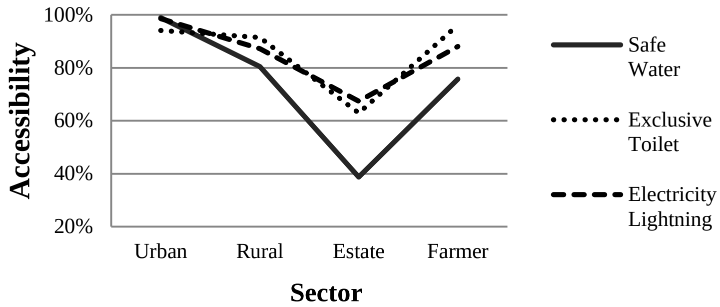
Management style of Sri Lanka tea industry are classified into three; RPC (Regional Plantation Companies=semi-governmental estate), PE Companies=semi-governmental estate), PE (private estate), and Farmer. Survey was conducted in the villages and estates around Deniyaya GN division. Kiriweldola is one of near Deniyaya is the second lowest GN division in Matara District. Primary sample size is 302 housing units which composed of 103 households at 5 Semi-Governmental Estates, 100 households at 22 Private estates, and 99 households at individual farms.

RESULTS AND DISCUSSION

Quality of housing affects quality of life. Water affects food and water contamination within the home. Toilet and sanitation conditions not only have influences on public health, but also on individual health. Inadequate lighting leads to eyesight problems, and sometimes sources of lighting causes other issues such as fire or skin problems.

Housing Conditions in Estate Sector

Estate sector is composed of mainly tea, coconuts, rubber and cinnamon in Sri Lanka. Poverty and social disparity in estate are still remained. Housing conditions among four residential sectors can be described through the CAS 2008/09.



Source: CAS 2008/09.Ministry of Finance and Planning, Sri Lanka, 2009

Fig.1 Living Conditions among Residential Sectors

Figure 1 represents the rate of access to three indexes of housing conditions among Urban, Rural, Estate and Farmer. Comparing access to safe drinking water among urban, rural and individual famer sectors, the percentage of safe drinking water was 38.7. In contrast, in urban, it accounted for 98.9 percent, among rural and farmer, it accounted for 80.4 percent and 75.8 percent, respectively. Cross-sectional analysis was statistically significant at the one percent level between residential sectors and accessibility of safe drinking water, indicating inadequate water facilities at estate sector than other sectors.

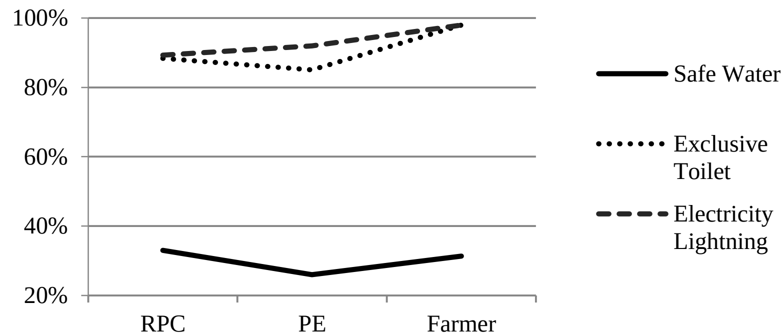
Having an exclusive toilet for households is one of important factors to avoid the spread of disease and prevent daily sicknesses. Comparing the access of the exclusive toilet facility to three sectors, the percentage of independent household's toilet was 63.0. In contrast, in urban, it counted for 94.1 percent, among rural and farmer, it accounted for 91.4 percent and 96.2 percent, respectively. Cross-sectional analysis was statistically significant at the one percent level between residential sectors and accessibility of exclusive toilet for household, indicating less possession of family independent toilet at estate sector than other sectors

Appropriate light at night or in darkness enables people to see things properly, while inappropriate degree of light causes eye problems, and sometimes affect the brain or causes mental disorder. Kerosene or candle is used for lighting in house and on the roads. On the other hand, these have been a cause of fire or burns. Couples in estates during the survey explained about the incidence of burn on their face and body by fallen Kerosene lamp. Using inappropriate resources for light are not only risky for health but also not environmentally friendly. Figure.1 shows access of electricity in estate, the percentage of electricity among other light resources was 67.34. In contrast, in urban was counted for 98.52 percent, in rural and farmer were counted for 87.16 percent and 88.01percent. Cross-sectional analysis was statistically significant at the one percent level between residential sectors and accessibility of electricity for household, indicating higher possibility to have health problems and accidents than other three sectors.

Comparative results among sectors are not different to the past literature reviews. People living in estate sector are under the low quality of housing facilities and more likely face the risks under the unsanitary conditions. Especially, accessibility to safe drinking water is lower than access to exclusive toilet and electricity. Estates owned by RPCs or companies are generally large and equipping them with adequate infrastructure costs the lot. In wet zones, however, people are more easily have access to natural water than in dry zones without huge equipment. For electricity system in estate, it is difficult for companies to maintain a proper system in such a large area even though electricity system in urban and rural is more likely equipped by government. Structure of housing in estate has an effect on housing facilities. Family living in the attached housing in a row in estate has shared kitchen and toilets rather than family in urban and rural who have lived in a single house with household kitchen and toilets.

Housing Conditions in Tea industry

Comparted to other industry sectors in estate, working at tea industry are labor intensive, involvement in working for long hours under harsh environment, and living conditions of estate workers have been pointed out as unsanitary and insufficient. Recent trend in the tea industry is the increase in the number of smallholders for promoting tea production. Conventional management system has been outdated under the current globalization of economics and society. For improving the efficiency in production and management, the government reprivatized the management of state owned estate sector in 1992 (Wenzlhuemer, 2007 and Ute 2004). Compared to the period before reprivatized management system was implemented in 1992, the tea industry management can be categorized into three styles; semi-governmental companies which were privatized called RPC, Private estates which include smallholders, and farmers.



Research Area: Kotapola Division, Matara district, Sothern part of Sri Lanka

Fig.2 Living Conditions among Management Style

To critically explore the tea industry, three indexes are examined among three management styles in low-country. Figure.2 describes the access to three indexes among residential areas based on the management styles. Except electricity light, the trend is similar, PE faces more disadvantages than RPCs or Farmers. Workers' houses are called "Line-house", where between 2 and 5 houses are attached, and were built during the colonial area to accommodate seasonal temporary workers for coffee production. Kitchen and Toilet outside premises used to be shared with neighbors. Knowledge of public health and sanitary were not enough (Oxfam 2002, Williges 2004). Tea as replacement of coffee in 1867 made the seasonal migrants become permanent residents (Kumari 1984, and Wenzlhuemer, 2007).

Compared among three indexes, accessibility of safe drinking water is lower than other two indexes. The percentage of safe drinking water in RPC was 33 percent, in PE and Famer was counted for 26 percent and for 31 percent, respectively. Cross-sectional analysis was not statistically significant at the one percent level between residential areas among three management styles, indicating accessibility to water facilities of divisions of Kotapola district are under similar circumstances.

In comparison of the access of the exclusive toilet facility among residential areas, the percentage of independent household's toilet was 88 percent in RPC, in PE, it accounted for 85 percent, in farmer, it counted for 98 percent. Almost all families in farmers own at least one household toilet within or outside premises, but 7 percent of PE must share it with others, and 8 percent of them have no toilet at home. Cross-sectional analysis was statistically significant at the one percent level between residential areas and accessibility of household's exclusive toilet, indicating there is a difference of possession of exclusive toilet.

Access of electricity light among residential areas, the percentage of electricity among other light resources was 89 percent in RPC, 92 percent was in PE, and farmer counted for 98 percent. Cross-sectional analysis was statistically significant at the five percent level. Lighting system in large estates more likely depends on the traditional way rather than other two.

Accessibility to safe drinking water is not different among people at the target area, but toilet facility and accessibility to electricity light is different among residential areas. There are many small or large river surrounding Deniyaya areas and easy access to natural water in stream or rivers. Regardless of self-employee or employed by companies, water environment around target area is under the similar conditions while it contributes to the lower late of access to safe drinking water. Introducing the individual toilet has been promoted by International or local organizations for public and individual health. One of reasons is due to the fall that there are differences in toilet facility among residential regions. Farmers live in a single house rather than sharing the house or rooms, while workers in large or medium estate are more likely to live in line-houses where small houses are attached to each other in one long line row house. As discussed above, electricity is more likely to be provided by government, small private estates are located near the roads and more easily can access electricity. Large estates are strictly regulated by laws and required to provide enough support to meet the basic needs, while small estates infrastructures are dependent on owners' decisions.

CONCLUSION

Soil contamination with pesticide or artificial fertilizer for tea cultivation has affected the quality of drinking water, unsanitary or shared toilet causes illness or disease on livings things including human, improper lighting has influences not only on health, but also on people's capability. In this paper, three indexes of housing conditions in residential sector level and industry level were examined. Differences in housing conditions among residential sectors are described through secondary data analysis, and tendency of housing condition in tea industry based on the management styles is explored through primary data analysis.

Result from secondary data analysis showed that disparities among living sectors in Sri Lanka existed in all three indexes. It indicates that people living in estates are under the low quality of housing facilities and face the risks of the unsanitary conditions. Especially, accessibility to safe drinking water is lower than in other two indexes. Result of the second data analysis is not different from the past literature reviews and researches.

To deepen our understanding of difference in living conditions of tea estates based on management style, primary data was applied. Secondary data analysis indicates that famer housing environments were better than in estates, while primary data analysis in tea industry showed different result. Among residential areas in tea industry, there is no difference in access to safe drinking water at ten percent level and to electricity lightning at one percent level. Access to electricity at five percent level, however, is changed from not significant to statistically significant. There is difference in access to toilet among residential areas. Access to toilet in estate sector (RPC and PE) is different from farmers although not statistically difference at 10 percent level between RPC and PE.

Limitation of this analysis is not to be able to show scientific evidence on safety of drinking water and on sanitary conditions of toilet.

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Research article

Evaluation of Microfinance Institutions in Ethiopia from the Perspective of Sustainability and Outreach

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Abstract Ethiopia is a developing country, the second most populous in Africa with an estimated population of more than 94 million. The Ethiopian economy is based on agriculture, and poverty reduction has been the overriding development agenda. The coverage of formal financial services estimated to be less than 10 percent, nevertheless banks consider the poor "un-bankable". It has been assumed that Microfinance Institutions (MFIs) have reached the poor on a sustainable basis. Considering the situation, this study aims at evaluating the outreach level of Ethiopian MFIs and its sustainability. In order to achieve the planned research objectives, quantitative as well as qualitative research methods are used. The target of this research is MFIs currently operating in the country. The 14 samples of the study were selected from operating 34 MFIs by using purposive sampling technique to include all categories. Data were collected through questionnaires, whereas, secondary data from annual reports and other documents. The analysis indicated that the breadth and the depth of outreach of Ethiopian MFIs are in an increasing trend. The increase in the amount of voluntary savings was remarkable, and its ratio to the compulsory savings was 482.51 percent from 2005 to 2014. With regards to depth of outreach, 54.73 percent of women and relatively insignificant number of crop producing farmers have been covered by microfinance services. The Operational Self-sufficiency Ratio and Financial Self-sufficiency Ratio of Ethiopian Microfinance Institutions' are in increasing trends because of the enhancements in generating more revenue. Outreach trend is promising, though they have challenges to address the disadvantaged group of the society. The sustainability indicators suggested that the increase of operational sustainability and financial sustainability ratios are due to the increase in revenue and the contribution of donors and/subsidization. It is also advisable to improve its sustainability by increasing the efficiency.

Keywords outreach, sustainability, microfinance, savings, subsidization

INTRODUCTION

The emergence of Microfinance institutions (MFIs) is a late phenomenon in Ethiopia compared to other developing countries. It only counts back to the second half of the 1990s as a pilot in one region, and as a result of its success, the microfinance service was gradually replicated in other regions. The MFIs in Ethiopia focus on group-based lending and promote compulsory and voluntary savings. They use joint liability, social pressure, and compulsory savings as alternatives to conventional forms of collateral (SIDA, 2003). These institutions provide financial services, mainly credit and saving and, in some cases, loan insurance. The objectives of MFIs are quite similar across organizations. Almost all MFIs in the country have poverty alleviation as an objective. They focus on reducing poverty and vulnerability of poor households by increasing agricultural productivity and incomes, diversifying off farm sources of income, and building household assets. They seek to achieve these objectives by expanding access to financial services through sustainable microfinance institutions.

There is a big challenge in accessing financial resources from formal financial institutions/ banks by the poor in Ethiopia due to various reasons, and particularly, collateral. The experiences of some Asian countries like, Bangladesh, were considered as a success stories in tackling the problem of access to finance, and the Ethiopian government issued proclamation no. 40/1996 in 1996 that allowed the establishment of MFIs. The government takes financial inclusion as a policy objective and assumed MFIs can fill this gap. A number of studies indicated that sustainability is the basic question and challenges of MFIs in developing countries, which hinders their ability to outreach the poor. This problem has attracted the attention of many researchers and as a result many strategies have been put to ensure that MFIs are sustainable (Yaron, 1992). Therefore, one of the objectives of this study is to clearly understand the factors affecting the outreach and sustainability.

The main objective of this study is to evaluate the current performance of Ethiopian MFIs to point out the influencing factors of the sustainability and level of outreach for the better progress in performance and as well to contribute to policy formulation.

METHODOLOGY

Outreach and Sustainability: Meyer (2002) noted that the poor needed to have access to financial service on long-term basis (sustainability) rather than just a onetime financial support. This indicates that, outreach and sustainability are inseparable although there is a tradeoff between them (Izumida, 2003). Due to this fact, this study employed both outreach and sustainability to evaluate the position of Ethiopian MFIs. This study used both primary and secondary data. Primary data were taken from questionnaire followed by interviews. On the other hand, secondary data were taken from time series data (2005-2014) collected from reports, journals, and other financial statement sources. The study employs both quantitative and qualitative methods of analysis. Thus, multiple regression models have been used with IBM SPSS statistical software. The sampling was done on the basis of purposive sampling technique to incorporate from all categories (large, medium to small). Accordingly, 14 MFIs were selected as a study sample from the targeted population of about 34 MFIs operating in the country.

RESULTS AND DISCUSSION

A) Outreach Level of Ethiopian MFIs: Various studies have used the number of borrowers as a measure of microfinance breadth of outreach (Nyamsogoro, 2010; Mersland and Strom, 2009; Harmes et al., 2008). It is generally assumed that the increasing trend/ the larger the number of borrowers the better the outreach. The number of borrowers of Ethiopian MFIs were about 68, 000 in 2005 while this number increased to about 2 million in 2014. In this case we are able to say that, the Ethiopian MFIs have been expanding its outreach to the poor. The average balances of outstanding loans are proxy indicators used to indicate a client's socioeconomic level or depth of outreach. The lower the loan size is the indication of the quality of depth of outreach in which the industry average low end depth of outreach is loan size less than USD 150. The Ethiopian MFIs average loan size was about USD 121, which qualifies good quality of depth of outreach. But there was also some MFIs tending to exceed the threshold of the industry, which needs further investigation whether they are lean towards mission drift or not. Provision of different kind of product by MFIs is also noted as performance indicators.

As depicted on Table 1, the types of financial services were concentrated on saving and credit services, it has limitations on addressing the various scopes of needs of the poor. The loan programmes actually performing better thought the geographically remote area, where poor farmers have very small access to the financial services of the MFIs. Crop producing farmers have limited access to these financial services. The other indicator of outreach is the percentage of women. With regards to this indicator the Ethiopian MFIs covered only about 55%, compared to the average coverage of South Asia 86% and Africa 61%. With respect to saving characteristics, the ratio of voluntary savings to compulsory savings stretched to 482.51 percent in ten years' period of time from 2005 to 2014 which is a well-off progress.

Table 4. Types of Services, Loan Programmes, and Clients of Ethiopian MFIs

Type of Financial Services by MFIs	**Percentage**	**Percentage of MFIs who have rural farmer clients**	**Percentage**
Pension	28.6%		
Saving and Credit	100%	14.3%	< 10%
Insurance	21.4%	21.4%	< 50%
Money Transfer	21.4%	64.3%	> 50%
Type of Loan Programme		**MFIs Serving**	**Crop Producer farmers**
Loan for Geographically Remote Area	28.6%	10%	7.1%
Loan for SME	100%	40%	22.9%
Loan for Women	54.4%	50%	40%
Loan for Farmer	85.%	**Average**	**35%**

B) Sustainability: The definition of sustainability pointedly varies due to the big divides of thought (Institutionalist Vs Welfarist) in the industry. The institutionalist basically assumes MFIs as a purely business entity. They argued that, the Dollar invested as a loan in microcredit should have to work in the free market and poverty can be reduced by commercialization, democratization of capital and financializing of development (Roy, 2010). But the Walfarist argued, MFIs can achieve sustainability without achieving financial sustainability. Sustainability basically appraised by two levels of sustainability. These are Operational Self Sufficiency (OSS) and Financial Self Sufficiency (FSS). OSS requires MFIs to meet all administrative costs and loan losses from operating income of any kind; while FSS measures the extent to which an MFI's business revenue; mainly interest received covers the MFIs adjusted costs. Both OSS and FSS ratios are expected to be equal and/or more than 100% to prove sustainability of a particular MFI. Based on this assumption the analysis of the trends of OSS and FSS ratios are indicated in Figure 1 below. Ethiopian MFIs were in increasing trend both in OSS and FSS during the study period of time, except it tends to decrease of FSS ratio from 2013. The basic question here is, what are the influencing factors behind this trend.

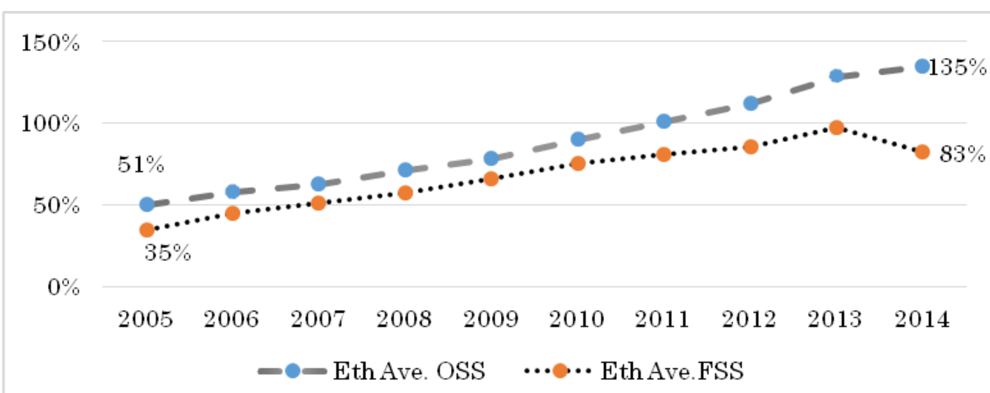

Fig. 2 Trends of OSS and FSS Ratios of Ethiopian MFIs

Multiple regression models have been used to assess the significant determinants of sustainability. OSS and FSS are the dependent variables, where about eight independent variables have been identified based on the Microfinance Information Exchange platform (MIX market), and from the detailed reviews of the related literatures. These variables are YIELD, Cost Per Borrower (CPB), Operating Expense Ratio (OER), Active Loan Balance Per Borrower (ALBPB), SIZE, Debt to Equity Ratio (DER), Number of Active Borrowers (NAB) and Age of MFIs. The IBM SPSS statistical software have been used for empirical analysis. To apply this model most of the assumption of the regression model has been implemented; and the validation of the data used have been done. Accordingly, the regression diagnostic test of the null hypothesis *"normally distributed errors"* has been done and the Shapiro-Wilk's tests for normality showed, there is insufficient evidence to suggest that the data set is not normally distributed. Test of skewness and kurtosis also indicated the value of 'zero' is within the 95% confidence interval. So in both tests we fail to reject the null hypothesis. An admittedly arbitrary rule of thumb is established to constrain simple correlations between explanatory variables to be smaller than 0.8 to 0.9. The null hypothesis to check for *"No Multicollinearity"* has been tested using person correlation and reject the null hypothesis. To solve this problem, number of active borrower is removed according to its relative importance to size and the second test proves no multicollinearity problem. The Durbin-Watson (DW) test for autocorrelation has been done and failed to reject the null hypothesis, *"no autocorrelation"*. The disturbance of the error was also checked by scatterplot and proves no autocorrelation. After the consecutive test of validity and reliability of the dataset, the OSS and FSS determinants are identified along their significance level.

Determinants of Operating Self Sufficiency

Table 2 Econometric Results of OSS's Determinants

Variables	Std. Error	Standardized Coefficients Beta	t	Sig.
(Constant)	1.099		0.170	0.245
SIZE	0.046	0.249	0.768	0.228
YIELD	0.022	0.738	0.636	0.267
CPB	0.003	-0.951	-4.129	0.000***
OER	0.129	-0.698	-0.456	0.327
ALBPB	0.127	0.052	3.486	0.002**
DER	0.101	0.775	0.786	0.222
Age	0.114	0.221	0.184	0.428

Dependent Variable: OSS, ***** Significant at 1%; ** Significant at 5%; * Significant at 10%**
Source: Author's Computation using IBM SPSS (2016)

As it can be seen from Table 2 above, from the estimated seven variables only about two variables have a significant impact on OSS. The null hypothesis for these factors were: -

Ho: There is a negative significant relationship between cost per borrower of microfinance institutions and operational self-sustainability.

H0: There is no significant positive relationship between average loan balance per borrower and operational self-sustainability.

The result revealed that CPB have a negative significant impact on OSS at 1% significant level. Therefore, we failed to reject the null hypothesis. The findings by (Woller and Schreiner, 2002; Christen et al, 1995) also indicated the CPB negatively and significantly affect operational sustainability. With regards to ALBPB, the statistics result indicated that it has positive impact on OSS at a significance level of 5%. The ALBPB for Ethiopian MFIs is about USD 121. Thus, the Ethiopian

MFIs average loan size evidences high cost from this analysis. The smaller the loan size, the better in outreach, but the higher the cost; here is where the tradeoff between the two triggered. The average loan size for African countries was 307 USD during the study period of time. Other studies, for instance (Adongo and Stork, 2006) similarly found that profitability is related to selling bigger loans.

Determinants of Financial Self Sufficiency (FSS)

The result of the econometric analysis indicated that, about three factors, namely, CPB, YIEDER, and DER have significant effect on financial sustainability.

The proposed hypothesis for the above mentioned influencing factors were as follows.

Ho: There is negative significant relationship between cost per borrower of microfinance institutions and financial self-sustainability

H0: There is a significant positive relationship on the yield on gross loan portfolio of microfinance institutions with financial self- sustainability.

H0: There is no positive significant relationship between debt to equity ratio of microfinance institutions and financial self-sustainability.

Table 3 Econometric Results of FSS's Determinants

Variables	Std. Error	Standardized Coefficients Beta	t	Sig.
(Constant)	0.706		0.652	0.262
SIZE	0.030	0.371	0.163	0.436
YIELD	0.144	0.879	3.532	0.001**
CPB	0.085	-0.951	-3.976	0.000***
OER	0.083	-0.048	-0.376	0.356
ALBPB	0.082	0.118	0.320	0.104
DER	0.065	0.792	3.141	0.003*
Age	0.073	0.235	0.780	0.224

Dependent Variable: FSS, ***** Significant at 1%; ** Significant at 5%; * Significant at 10%**
Source: Author's Computation using IBM SPSS (2016)

As one can depict from Table 3 above, CPB have a negative significant effect on FSS at 99% confidence interval, we failed to reject the null hypothesis. To the contrary, the study made by (Nyamsogoro, 2010), indicates that CPB has no significant impact on FSS of Tanzanian MFIs. The YIELD from gross loan portfolio influenced FSS positively at 95% confidence interval, fail to reject the null hypothesis. Correspondingly, the research finding by (Cull and Morduch, 2007) indicates that the coefficient for gross portfolio yield is positive and significant on financial self-sufficiency. The result also exhibited DER have positive effect on FSS, rejects the null hypothesis. In the same way, (Coleman, 2007) for example, found that highly leveraged microfinance institutions have higher ability to deal with moral hazards and adverse selection than their counterparts with lower leveraged ratio. This states that high leverage and profitability are positively correlated

CONCLUSIONS AND RECOMMENDATIONS

Access to financial resources in Ethiopia, particularly by poor is very limited, and the poor are regarded as unbearable by formal banks. MFIs are playing vital roles to fill these gaps. In this study the MFIs are evaluated on two main indicators, *outreach* and *sustainability*. Concerning the outreach, it is found that the outreach level of Ethiopian MFIs has been improving in width and depth, although there is still a need to diversify the services and programs to address the uncovered need of the disadvantage groups of the society, such as people in the geographically remote location, gender, crop farmers. We recommend the MFIs have to work against achieving this goal to fight poverty as per their major goals. The government is also expected to set appropriate regulations, and policy framework which motivate and enable the MFIs to address these unmet needs, for instance supporting the MFIs to access cheap loans. The intervention of the government in the operations of MFIs, particularly in a loan recruitment is vital because the MFIs cannot fully operate in self-sustainable manner.

Sustainability was measured on two levels, operationally, and financially. The study revealed that Ethiopian MFIs are operationally self-sufficient while financially subsidy dependent. The increasing trend of both financial and operational self-sufficiency is mainly due to the increase in revenue, and the existence of subsidy; we recommend to keep the trend. The determinant factors on operational sustainability were the cost per borrower, and loan size. Therefore, the MFIs are expected to reduce cost per borrower by innovation, for instance, by introducing village banking systems, and mobile phone in microfinance services. In case of loan size, the current loan size of the MFIs is desirable, qualifying depth of outreach but risks sustainability. Hence, we recommend the donors and government should give priorities for those MFIs addressing the need of the very poor providing small loans. The influencing factors for financial sustainability were the cost per borrower, and yield from gross loan portfolio and debt equity ratio. The MFIs have to work against these negative factors by increasing their yield innovatively, increasing the volume of revenue, and/or the profit margin and by reducing the cost to the optimal level. The debt equity ratio basically refers to cheap fund. It may be desirable to increase this ratio by attracting the interest of donors/lenders using inclusive plan to address the need of the poor, particularly to reach the female beneficiaries. The study also recommend that the government of Ethiopia should encourage involvement of private sector and donors in building capacity of MFIs.

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Research article

Supply Chain Analysis for Determining the Requirements for Continuous Woody Biomass Energy Utilization Systems: Comparison of the Actual Management Conditions in Japan

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Abstract In Japan, the number of newly constructed woody biomass power plants are expected to increase with the introduction of the Feed in Tariff mechanism. However, many woody biomass energy plants, including heat supply systems, face difficulties because of issues such as high fuel costs and find it difficult to maintaining a stable supply. This study aims to reveal the requirements for continuous business regarding woody biomass energy, focusing on four factors: wood supply, fuel manufacturing, energy supply, and energy demand. Specifically, we selected multiple Japanese cases that focus on the types of woody fuels such as cordwood, wood chips, and wood pellets, conducted semi-structured interviews, and compared and examined how their supply chains successfully developed. We found that integral cooperation among the four factors was essential, and support regarding each factor, economic viability, as well as balanced supply and demand for wood were necessary for ensuring continuous woody biomass energy utilization systems.

Keywords renewable energy, forest industry, regional revitalization, wood fuels

INTRODUCTION

In regions with abundant forests, woody biomass is a potentially promising renewable energy resource and is expected to develop into a regional industry. In Japan, the utilization of woody biomass to generate electric power expanded with the introduction of the Feed in Tariff (FIT) in 2012, which resulted in the construction of woody biomass power plants in various parts of the country. In addition, energy supply systems using woody biomass heat were being introduced as government subsidized projects. After a biomass energy system has been created, trees must be cut down and transported from the forests to produce fuel. Fuel has to be fed to heat boilers; its combustion must also be controlled. Therefore, to ensure the continuity of a biomass energy system, it is vital to establish a stable system to supply woody fuel from the upstream to the downstream end of the system.

This study was based on the idea that it was important to build a supply chain that ensures business feasibility for organizations that stabilize supply, and maintain cooperative relationships between these organizations. For a biomass supply chain, of course it was important to balance expenditures and income to ensure continuous operation. Further, because of the large number of organizations characteristically involved, business feasibility and inter-organizational relationships were selected as the themes of this study. Regarding woody biomass energy utilization systems, Raychaudhuri (2015) surveyed the literature on biomass supply chains in some countries in Asia and Europe, but Japan was not included. Becker (2011) suggested supply chain analysis framework for assessing policies in the United States. Tahvanainen (2011) and Yoshida (2016) analyzed costs of wood chip supply chains in Europe and the US respectively. In Japan Sato (2015) designed a model for wood biomass supply chains in Tohoku area. However, there was no research related to biomass energy utilization systems in Japan that evaluated actual supply chains from the perspective of business feasibility. Further, there was very little research on the supply chains of the systems in Japan from the perspective of inter-organizational relationships and the balance between biomass supply and demand among the players. Therefore, this study analyzed supply chains from three perspectives: business feasibility, the related inter-organizational relationships and the balance between biomass supply and demand.

OBJECTIVE

This study examined Japan's woody biomass energy utilization systems that utilize forest resources in order to identify the entire supply chain formed by a series of linked business organizations, and the state of operation of each constituent player in this supply chain based on actual cases. Next, based on the information obtained, the supply chain and its constituent players were analyzed from the perspectives of their business feasibility and inter-organizational relationships and the balance between biomass supply and demand among the players in order to state the conditions required to ensure the continuity of the system.

METHODOLOGY

This study proposed the framework shown in Fig. 1, which divided the supply chain for a woody biomass energy utilization system into four constituents: raw material supply, fuel production, energy supply, and energy demand. For a system to be sustainable each player in the system should have business feasibility and all players should be interconnected. Raw material supply referred to the cutting of trees in the forest, the transportation, and sale of timber. Fuel production referred to the production and/or sale of woody fuel (including firewood chips or pellets). Energy supply included burning woody fuel in the equipment and supplying the energy to users as heat or electric power. Energy demand referred to consumption of electric power or heat for air conditioning, hot water in households, businesses, public baths, and similar facilities.

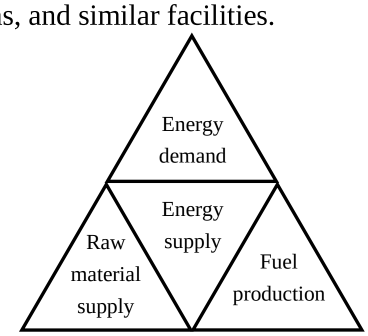

Fig 1. Analysis Framework of the Woody Biomass Energy System

This study evaluated the four constituents of the supply chain of a woody biomass energy system from the following three perspectives. The first was the business feasibility of each constituent player, whether each could be established alone without the support of external financial subsidy. The second perspective was the relationship between the constituent players. The third was the balance between biomass supply and demand among the players. To build a supply chain, the links between its players were indispensable. It was also important for them to establish business relationships to ensure smooth business. Moreover, it was equally important that they balance biomass supply and demand through the links between them.

This study conducted a survey to analyze a supply chain consisting of the four constituents explained above by selecting six cases as typical energy utilization systems from among energy systems such as electric power systems, heat systems. The six cases selected were shown in Table 1. The supply chain and constituent players of the energy systems in each of these cases were shown in Table 2. In Cases D, E, and F, local governments played major roles in building the overall supply chains; therefore, these local governments as supporter were also included in our study.

Semi-structured interviews were conducted. The questions dealt with the business which the player conducts, stakeholders such as its suppliers and customers, quantities of biomass-related products it acquired and sold, business costs such as the cost of production equipment, total sales, business prospects, and business challenges. The interviews were conducted from August 2014 to September 2016.

Table 1 Cases Analyzed

Case	Form of fuel	Energy equipment	Energy demand	Amount of biomass fuel (wet-t/y)
A	Firewood	Stoves	Heating	1,900
B	Firewood	Boilers	Hot water	300
C	Chips	Generator	Electric power generation	20,000
D	Chips	Boilers	Cooling/heating/hot water	1,600
E	Pellets	Stoves/boilers	Heating/hot water	500
F	Pellets	Stoves/boilers	Heating/hot water	1,300

Table 2 The Supply Chain and Constituent Players in Each Case

Case	Raw material supply	Fuel production	Energy supply	Energy demand	Supporter
A	Forestry association, Citizens association, independent forester	Company selling wood stoves	Households	Households	—
B	Independent forester	Community group	Public baths	Public baths	City government
C	Lumber company, orchard operator	Private enterprises	Electric power utility	Households	—
D	Lumber company	Sawmill operator	Third-sector	Public facility	Town government
E	Sawmill operator	Third-sector	Public facility Households	Public facility households	City government
F	Forestry association	Cooperative association	Public facility, business office	Public facility, business office	City government

RESULTS AND DISCUSSION

1) Case A (wood stoves)

The system was principally supplying firewood for use in wood stoves used to heat households. With regards to raw material supply, suppliers sorted out raw timber from managed forests for lumber and firewood. With regard to fuel production, a wood stove company purchased the raw material and part-time workers used wood-splitting machines to process and naturally dried the material for producing firewood. The processing was partly contracted to the raw material suppliers. Households equipped with wood stoves purchased the firewood and used the energy to heat up their households.

The wood stove company established the supply chain. It had developed its firewood supply system and home-delivery service, which helped to expand its wood stove market. Concurrently, the demand for firewood rapidly surpassed forecasts, and with the production unable to keep up, stocks became inadequate. This in turn led to deliveries being made after artificially drying the firewood for a temporary duration. While the firewood fuel production system had balanced incomes and expenditures, profits from new wood stove sales were higher; therefore, firewood fuel production was not the principal business of the organization.

2) Case B (firewood boiler)

The system comprised a community group processing raw timber, which was supplied by independent foresters, into firewood, which was subsequently supplied for use in a firewood boiler used to meet the demand for hot water in public baths. In this case, the community group led the establishment of the supply chain by forming an organization that purchased raw timber and made firewood. It purchased the timber, with half of the necessary funds contributed by a local government. It built three yards (places to collect thinned wood), and in addition to firewood, handled the timber to sell to paper makers. It also encouraged independent foresters to receive forestry training. A firewood boiler was installed with the support of subsidies that covered two-thirds of the cost.

3) Case C (generating electricity with chips)

The system was the supply of woody chips for fuel to a woody biomass power plant. In this case, an electric power utility built the supply chain. Fuel production was performed by a company affiliated with the power utility. The fuel production company signed raw material contracts with a group of lumber companies in order to stabilize supplies of raw material. The raw material consisted of about 80% thinned wood, and woody waste was 20%. Energy supply was achieved by burning wood chips to generate electric power for households. The purchase price of the electric power was supported by FIT system, such that the power could be bought for a good price in relation to the overall production costs set according to the type of raw material used as the woody fuel.

4) Case D (chip-powered boilers)

In this system, wood chips were supplied to a biomass boiler that supplied heat to a group of public facilities. The town built the supply chain. At the suggestion of the town, a wood chip company financed by a lumber company and a sawmill operator was established. Energy supply was the role of the third-sector public company that operated and maintained chip boilers owned by the town. The cost of installing the three boilers was incurred by the town, prefecture and national government subsidy. It cut the total value of fossil fuel costs in 2013 by 38.6 million yen per year. On the other hand, the town paid 38 million yen for chip supply and equipment management. The town not only bore the cost of the chip production facility, it also signed supply contracts to help stabilize the income earned by the system for stable supply of the fuel.

5) Case E (pellet stoves and pellet boilers)

In this system, a city built a supply chain as a pellet production system to utilize forest resources. The raw material (chip dust) for pellets was provided by chipmakers. In fuel production, a third-sector company was formed with funds invested by the city, a forestry association, and small-scale shareholders. Total funding for the fuel production equipment was provided by the city and national government subsidy. Initially, it was predicted that it would supply pellets for stoves in households. However, because stoves had not gained as much ground as was expected, most of the pellet was consumed by the city hall, schools, and welfare facilities.

6) Case F (pellet stoves and pellet boilers)

In this system, pellets were supplied to stoves in business offices and to pellet boilers installed in public baths in a city. Regarding raw material supply, raw timber was supplied through a market. In fuel production, a cooperative association produced chips for paper makers in addition to those used to produce pellets. Energy supply and demand were primarily regarding pellet boilers and pellet stoves owned by the city along with demand for hot water supply and heating. The city led the development of the supply chain. It supported the formation of a cooperative association to manufacture pellets and worked to create demand for these pellets in order to revitalize the forestry industry. The city installed pellet boilers in public facilities, and pellet stoves in schools.

Analysis of the supply chain from three perspectives

1) Business feasibility of constituent players

As seen from the six cases, in all systems, each constituent system could be operated stably. However, it could not be concluded that their systems were established economically, as many of these constituent players covered costs of equipment for fuel production and energy supply with subsidies. In Case C, it was clear that the system could continue as long as the FIT system was maintained. Regarding Case A which acquired no subsidy, the system was established in combination with other business. The system was achieved by combining the production of firewood with the sale of stoves. In addition, there were also cases where a player established its own systems in combination with other business. Regarding fuel production in Case B and F, biomass was a source of secondary income for the players. They manufactured and sold materials to paper makers separately from biomass energy utilization systems. Previous studies state that business feasibility requires an increase in efficiency through measures such as increasing the scale of fuel production or changing the location of the chipper, or financial assistance to initial investments in each system. However, these studies do not discuss combining different businesses together.

2) Interrelationships between constituent players

An analysis of the six cases confirmed that private companies, administrative bodies, or community groups acted as the builders of supply chains by creating business relationships between the various players. Moreover, even after a supply chain had been constructed, the local government was seen to play the role of overall manager of the chain in Case D, E and F. There were also cases where the builders also took part in the formation of constituent players or fuel production system of the supply chain in Case A, B and C. For example, in Case B, a community group created a purchasing system and provided independent foresters with practical forestry training. It also assisted with preparations of subsidy requests to introduce firewood boilers that would be later supplied with firewood through the system. Previous studies point to the need of coordinating with the stake holders and present case studies where timber owners manage their businesses by outsourcing of fuel production. The role of the supply chain builders in our study incorporates all these activities.

3) Balanced biomass supply and demand between organizations

In many cases each constituent ensured multiple suppliers and purchasers in order to prepare for fluctuations in demand for their energy systems. For example, in Case A, the firewood producer associated with multiple suppliers, and also entrusted to the suppliers some part of processes in firewood production. While in Cases D, E and F, the local governments created a large demand by increasing the number of boilers in public facilities. Even after their supply chains were completed and the systems were in operation, there were cases where it was important to watch the flow of biomass throughout the supply chain and overcome problems of quality control in the fuel and the supply system. In both ways, the builders of the supply chains played important roles. Previous studies mention the need for securing storage space, temporary workers for fuel production or the importance of communication between upstream and downstream stakeholders. The multiple suppliers and purchasers in our research extend these aspects and add management of energy demand.

DISCUSSION

Conditions of economic support for the supply chains were different between the electric power generation system and the heat system in which stoves or boilers operated. The FIT system was available for electric power generation systems, and the system economically ensured the continuity of sales. In the case of heat system, although subsidies were available to cover cost such as introducing boiler for the heat supply systems, there were no systems designed to ensure continuous operation of the heat supply system along the overall supply chain. The economic difficulty in establishing a heat system could be analyzed through the following two aspects. Firstly, the heat system competed with low-priced energy systems, such as fossil fuel. Secondly, some regions would have small or no markets for the heat system. These regions faced challenges such as few sellers of woody fuel or materials and fluctuations in supply and demand.

In the light of the above underlying circumstances, followings steps were being taken. With regards to the first point, players were believed to have established systems by combining the biomass energy business with other businesses. But, it relied on capabilities and size of the business management of the players. With regards to the second point, it was necessary for a local government or community group to build the supply chain. They should encourage the players to cooperate, help the players to obtain public fund for fuel production equipment and create heat demands in regional and public facilities. In addition to a balanced wood fuel supply and demand, the builders of the supply chain needed to encourage players to have multiple suppliers and purchasers in regions where there were no markets to trade inventory shortfalls or surpluses. Besides this, supply chain builders could not exist in all regions because it depended on the capability of the builders and their financial conditions. Therefore, just like an electric power generating system, a heat supply system also would require a system to support the overall supply chain. It was thought to be important to create, for example, a system to correct the price gap between fossil and woody fuel, or a system to subsidize the purchase price of the biomass fuel or the heat supplied.

In terms of future challenge, this study couldn't include wood biomass combined heat and power systems because of no such systems operating stably in Japan at the time of the survey. It was predicted that the future construction of many biomass power plants would rapidly increase the demand for wood and raise its price. Therefore, even in the cases surveyed for this study, changing the supply constituents would be unavoidable. These issues will have to be taken up in a future survey.

CONCLUSION

This study was undertaken by conducting interviews concerning six cases in order to clarify the requirements for continuous stable operation of biomass energy utilization systems using forest resources in Japan. The supply chains in each case were divided into four constituents and analyzed from three perspectives, that is business feasibility, relationship among constituents, and balance of the biomass supply and demand. The results showed that the following conditions were required to continuously operate a woody biomass energy utilization system.

1) For the constituent players, combining the biomass energy utilization system with another business was necessary in order to ensure business feasibility.
2) In order to link the four constituents, it was important that there was a supply chain builder to establish the necessary constituent players where none existed and to interconnect these players.

3) It was necessary to ensure multiple suppliers and purchasers for balancing the flow of materials in demand and supply between the constituents.
4) A system such as FIT for electric power systems was also necessary for heat supply systems in order to ensure the business continuity of the entire supply chain.

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Research article

Assessing Factors Influencing Farmers' Perceptions on Adaptation to Climate Change: A Case of Apple Farmers in Cheongsong, Korea

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Abstract One of the most important consequences of climate change in Korea is the moving of the adequate cultivation area for apple. To respond adequately to such consequences, the farmers require performing on the adaptation measures. Although Korean government puts great efforts to develop adaptation measures, the livelihoods of agriculture and rural communities are still posing great threats from climate variability and change. It is because the most of adaptation studies and policies fail to address the perception of farmers who decide and perform the adaptation measures. Without an understanding of farmers' perceptions, private adaptation strategies are unlikely to be effective. This paper, therefore, aims to investigate and analyze factors influencing farmers' perception on adaptation behaviors. To meet such objectives, this study based on theory, a Model of Private Proactive Adaptation to Climate Change (MPPACC), explaining individual's intention of adaptive behavior is based on socio-cognitive aspects including perceived adaptation measure efficacy, self-efficacy and adaptation costs. To analyze the factors influencing farmers' perception and behavior of climate change adaptation, 170 apple farmers in Cheongsong County is selected for farm household survey. By analyzing through multiple linear regressions, the results were found that the farmers' perceptions of adaptive efficacy are significantly associated with farm household demographic and socioeconomic factors including investment in crop insurance, and contents and sources of information. This implies that to enhance the farmers' motivation to adaptation, the local government should pay further attention to improve credibility of crop insurance efficacy and the quality and source information to increase farmers' adaptive capacity through increased farmers' perception on adaptation efficacy.

Keywords Climate Change, Adaptation Behaviors, Perceived Adaptation Efficacy, Apple Farming

INTRODUCTION

Agricultural communities in Korea have already experienced the impact of climate change, including crop and livestock losses from severe drought and flooding, large-scale losses from weather-related disasters, shifts in planning and harvesting times and cultivation lands (MoE, 2015). According to Ministry of Environment (2015), the assessment of the climate change vulnerability and its impact on apple cultivation in Korea indicated that adequate apple cultivation area, which has been in the southern, eastern parts of Korea, is moving to the northern parts of the Korean peninsula. Moreover, in the Northern Provinces in Korea, it is already increasing apple production in the area. Although Cheongsong County, one of the top apple-producing counties in southern parts, is increasing its apple production until recent years, the County is also projected to become inadequate to produce the apple crops from the 2030s (RDA, 2015). Not only the projected climate is shown to change apple cultivation in the County, the current climate variability already has been increasing farmers' awareness on the climate variability and adaptation behaviors. To increase farmers' resilience to climate change, enhancing the adaptation capacity is vital. The farmers have been conducting adaptation behaviors to prevent and lessen the damage of climate variability and change. The private adaptation behaviors can be influenced by farmers' perceptions and assessments on the specific adaptation measures. However, only limited studies examined the factors influencing farmers' perceptions on the adaptation behaviors.

The Model of Private Proactive Adaptation to Climate Change (MPPACC) is one of the limited research to examine the socio-cognitive perspective of adaptation behaviors derived from discourses in psychology and behavioral economics (Grothmann and Patt, 2005). According to this model, individuals' adaptation behavior to climate change can be influenced by some socio-cognitive factors including perceived adaptation efficacy which is measured by individuals' perceptions of 1) adaptation measure efficacy (PME), 2) self-capacity to perform the adaptation measures (PSE), and 3) the cost associated with such performance (PAC). In this study, the factors hypothesized to influence such perceptions are farm households' characteristics (socioeconomic factors), previous experience with climate change, and information (climate change, adaptation) from various sources. To enhance the apple farmers' resilience to increasing climate risks, it is important to not only to develop adequate adaptation measures but also to understand what factors may motivate the farmers to perform the adaptation measures.

OBJECTIVE

The main objective of this paper is to suggest some policy implications for enhancing farmers' adaptation capacity by investigating and analyzing farmers' perceptions on the effectiveness of private climate change adaptation behaviors and the factors influencing such perceptions.

METHODOLOGY

As shown in Fig. (1), North Gyeongsang Province is located in the southeastern part of Korea and Cheongsong County is located in the eastern part of the Province. The Province produced 372,627 ton in 2015 which is about 64 percent of total apple produced in Korea (RDA, 2015). Cheongsong County is evaluated as one of the top County to produce the highest quality apples in Korea (Cheongsong County, 2016). Because of its location, altitude and temerature, the County has been well-suited for producing high-quality apples. The County is surrounded by mountains that provide a high diurnal range which is an advantage climate for apple cultivation. Moreover, the County usually has less rainfall compared to neighbor Counties which are also an advantage climate factor for apple cultivation. The County's annual average temperature, although increased from 12.5℃ in 2014, is recorded as 12.9 ℃ in 2015 (KMA, 2016). Since the County has been known to have the suitable environment and climatic for apple cultivation, about 80% of farmers are engaged in apple cultivation in the County (Cheongsong County, 2016). The County not only produces the high-quality apples, but it also organizes several major events including the biggest apple festival in Korea. Apple cultivation is not only an extremely important economic source, but it also has become a part of the lives of the people living in the County.

The farmers' adaptation behaviors to climate change are collected through intensive review of previous studies and government reports. After listing all the adaptation measures that are applicable to the apple farmers, the authors conducted interviews with the farmers and the local agricultural officials for final selection. Finally, 9 adaptation measures were selected and analyzed in this study includes: adjusting farming dates, adjusting use of pesticides, switching to different crop, paying attention to climate information, diversifying crops, buying crop insurance, improving soil condition, changing to other apple variety and searching for non-farming job.

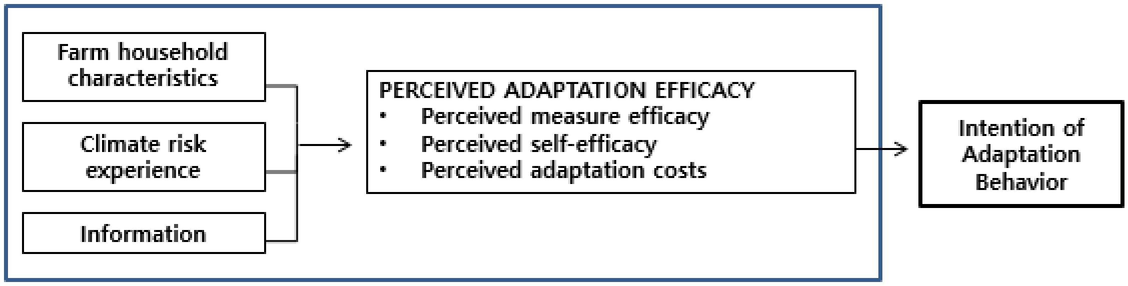

Fig. 1 Conceptual Framework

From April to June 2016, a farm household survey with 170 apple farmers in Cheongsong County was conducted with structured questionnaires and in-depth interviews and focus group discussions were conducted to collect the data on farmers' characteristics, experiences with climate change and climate change and adaptation information from various sources including neighbors, community leaders, local agricultural extension services, public media and cooperatives. Farmers were also asked about their perceptions of the adaptation effectiveness including their perception of adaptation measure effectiveness, self-ability to perform measures, and the costs performing the 9 specific adaptation measures. For perceptions of measure effectiveness and self-capacity, farmers were asked to scale 1 (not effective at all) to 4 (extremely effective) while on the costs were scaled as 1(extremely expensive) to 4 (not expensive at all). Four linear regressions were conducted for analyzing the factors affecting farmers' perceptions on adaptation efficacies. For the regression, farmers' adaptation assessments were represented by four dependent variables: perceived measure efficacy (PME), perceived self-efficacy (PSE), perceived adaptation cost (PAC) and overall perception of adaptation efficacy. The overall perception of adaptation efficacy is calculated by adding three adaptation perceptions and divided by three to weigh all three perceptions equally.

$$\text{Overall Perceived Adaptation Efficacy} = (\text{PAE} + \text{PSE} + \text{PAC}) / 3$$

The explanatory variables considered in the regression are farm household characteristics, socioeconomic factors such as income, sales mechanisms, crop insurance status, previous experience in climate risk and information from various sources. Previous studies on individuals' adaptation behavior found that some demographic and socioeconomic factors such as age, experience, gender, income, education and sales mechanisms influence farmers' adaptation behaviors (Bryan et al., 2013; Deressa et al., 2011; Fujisawa and Kobayashi, 2011; Grothmann and Patt, 2005). Personal experience with climate risk can also motivate private adaptation by influencing one's cognitive factors (Grothmann and Patt, 2005). Moreover, information can play a vital role in the farmers' perception on the adaptation efficacies (Grothmann and Patt, 2005). Not only the contents itself but how farmers receive such information can have a diverse effect on them. Therefore, in this study, both climate and adaptation information are considered to be disseminated by public media, neighbor farmers, village leaders, agriculture extension service centers, and agricultural cooperation. This study assumes that climate change and adaptation information from different sources can have a different influence on the farmers' perception of three adaptation efficacies. The models were tested for the R-squares, multicollinearity, normality, linearity and homoscedasticity of the residuals

Perceived Adaptation Efficacy = *f* (Farm household characteristics, climate risk experiences, climate change information, adaptation information)

RESULTS AND DISCUSSION

To analyze the factors influencing farmers' cognitive adaptation capacity, particularly on the cognitive evaluation of adaptation behaviors are found from the four regression models. Table 1 shows the results of the regressions, and it was found that farmers' perceptions of adaptation measure efficacy, self-efficacy, adaptation costs and overall adaptation behaviors are influenced by some farm household characteristics, socioeconomic factors, and climate and adaptation information from various sources. Moreover to all the regression coefficients presented in Table 1, Table 2 demonstrates the R^2, adjusted R^2, F-test (p-value) and VIF. The R^2 for all models indicated that the statistically significant explanatory variables could explain 46 to 57% of the variation of farmers' adaptation perceptions. The variance inflation factor (VIF) for all explanatory variables was less than 3and this indicates that there is no multicollinearity problem found for the variables.

Farm household characteristics

Farm household characteristics found to have the significant influence on farmers' assessment of adaptation behaviors. According to the regression results, farmers' age is statistically significant in relation to farmers' perception on the measure efficacy. The coefficient indicates that as the farmer is younger, they perceive adaptation measures as more effective. Gender is also found to be a significant factor. The female farmers than male farmers perceive overall adaptation behavior as effective. In addition, years of education seems to be negatively related to the farmers' perceptions, particularly significant with the overall adaptation behaviors. Farm area is positively related to how farmers perceive adaptation measure effectiveness while negatively correlated with adaptation cost. With increasing farming area, farmers perceive adaptation measures as effective while the costs associated with the adaptation measures expensive. Income can play an important role in farmers' assessment of the cost of the measures. According to the results, a farmer with higher income can perceive the adaptation cost as more expensive. In general, farming is a family business that sons usually take over the farm from their parents. Having successor can influence farmers' perception on adaptation, especially related to the perception on self-capacity to carrying on the measures on their farms. Moreover, the number of participation in the agricultural training programs does show the significant relation with how farmers assess their own adaptation capacity.

The apple farmers sell their apple through direct or indirect markets. Direct sellers can receive feedbacks and new information. According to the regression model, the farmers with such market channels can have a higher perception of the adaptation measure and overall adaptation behavior as effective. Crop insurance plays an important role not only to recover the damages from the natural disasters but to prevent and remedy farmers from future disasters. Farmers who bought the crop insurance are more likely to perceive adaptation cost as less expensive and have a higher perception of the overall adaptation behaviors. However, simply buying crop insurance and how many years the farmers with crop insurance can have a different influence on their perceptions. Interestingly, as the cumulative years of buying crop insurance increases, farmers' perception on the adaptation measure, self –capacity and overall adaptation behaviors can diminish. This indicates that as farmers' buying crop insurance increases, they find the fraud in the system and feel that they do not get any benefit of buying the insurance. This induces the necessity of improving the current insurance system.

Climate risk experiences

Climate risk experiences with increasing temperature, changing patterns and intensity of precipitation and extreme weather events including typhoon can influence farmers' motivation to perform adaptation measures; however, according to the regression results in this study, climate risk experiences did not show any statistically significant influence on the farmers' perceptions, particularly related to the adaptation efficacies. However, it could be worth of mentioning that according to previous studies, it was found that previous climate-related risk experiences can have an influence on farmers' motivation or intention to adaptation. Therefore, although not directly influencing the farmers' perceptions related to adaptation measures, it could have an influence on other cognitive factors that influence farmers' motivation to climate change adaptation behaviors.

Table 1 Multiple linear regression models on farmers' perceptions of adaptation behaviors

Explanatory variables	Perceived Measure Efficacy	Perceived Self-efficacy	Perceived Adaptation Costs	Overall Perception
Farm household characteristics				
Age (continuous)	-0.0085*	-0.0018	-0.0021	-0.0124
Gender (1=male, 0= female)	-0.1663	-0.1197	-0.0866	-0.3725*
Education level (continuous)	-0.0224	-0.0113	-0.0259	-0.0597**
Farming area (continuous)	0.0966**	0.0664	-0.0960*	0.0671
Farming Experience (continuous)	0.0032	-0.0001	-0.0017	0.0013
Income (continuous)	-0.0047	0.0398	-0.0822***	-0.0471
%of income from apple (continuous)	-0.0001	0.0026	0.0004	0.0029
Successor (1=yes, 0=no)	0.1136	0.2233**	0.1030	0.4399**
Agricultural training (continuous)	0.0040	0.0230***	-0.0119	0.0151
Smart-phone use (1=yes, 0=no)	-0.1632	-0.0712	-0.2509**	-0.4854
Sales channels (1=indirect, 0=direct)	-0.1084**	-0.0658	0.0181	-0.1562**
Land ownership (1=yes, 0=no)	-0.0121	-0.0183	0.0337	0.0033
Buying crop insurance (1=yes, 0=no)	0.1830	0.0781	0.4582***	0.7193***
Yrs. crop insurance (continuous)	-0.0472***	-0.0250*	0.0087	-0.0636**
Other crops (1=yes, 0=no)	0.0559	0.0195	0.0216	0.0972
Climate Risk Experiences (1=not at all, 2=barely, 3=have experience, 4=extremely)				
Risk Experience (Temperature)	0.0207	-0.0085	0.1027	0.1149
Risk Experience (Precipitation)	-0.0605	-0.0998	-0.0224	-0.1827
Risk Experience (Extreme weather)	0.0329	0.0319	-0.0395	0.0253
Information (1=not at all, 2=sometimes, 3=often, 4=always)				
Climate change info. (Public media)	0.1195*	0.1043*	0.0015	0.2253*
Climate change info. (Neighbor farmers	0.0405	-0.0032***	0.0270	-0.0618
Climate change info. (Village leader)	-0.0837	0.0220	-0.1639**	-0.2256*
Climate change info. (Agri. Ext. center)	0.1138*	0.0943	0.1130	0.3210***
Climate change info. (Agri. Cooperative)	0.1414**	0.1479**	-0.0208	0.2686**
Adaptation Info. (Public media)	0.0428	0.0403	-0.0387	0.0444
Adaptation Info. (Neighbor farmers)	0.0792	0.2847***	-0.0224	0.3414***
Adaptation Info. (Village leaders)	0.2003***	-0.1358**	0.0635	0.1281
Adaptation Info. (Agri. Ext. center)	0.1734***	0.0134	-0.0952	0.0916
Adaptation Info. (Agri. Cooperative)	-0.1095*	0.0173	0.0786	-0.0136

Significant at 10% level (p<0.1), ** significant at 5% level (p<0.05), * significant at 1% level (p<0.001)*

Information

As explained in the previous section, the contents and the sources of information can influence farmers' perceptions. According to the regression results, information on climate change received from public media, agricultural extension center and cooperatives can positively influence farmers' perceptions on measure efficacy, self-efficacy, and overall adaptation efficacy. However, the information from neighbor farmers and village leaders can negatively influence farmers' perceptions, particularly on self-efficacy, costs and overall adaptation efficacy. From these results, it can be analyzed that the farmers perceive adaptation efficacies positively associated with climate change information from objective sources. Interestingly, unlike the climates change information, the farmers' perception of adaptation efficacies is positively and significantly related with adaptation information from neighbors and village leaders. It can be analyzed that the farmers' perception on adaptation efficacies, which would eventually increase farmers' motivation to perform on the adaptation can be enhanced if adaptation information could be disseminated by neighbors and village leaders, who the farmers are personally connected with. The inclusion of subjective opinion or the personal experience in disseminating the information related to adaptation measures could bring greater success in delivering adaptation information to farmers.

Table 2. Assessing the fit of regression models and multicollinearity

Dependent variables in the models	R^2	Adjusted R^2	F test, *p*-value	VIF
Perceived measure efficacy	0.53	0.38	0.00	
Perceived self-efficacy	0.49	0.33	0.00	Max: 2.92
Perceived adaptation costs	0.46	0.28	0.00	Min: 1.14
Overall perception	0.57	0.43	0.00	

CONCLUSION

To enhance the adaptive capacity of farmers, this study aims to investigate and analyze the factors affecting the cognitive, adaptive capacity of the apple farmers, in Cheongsong, Korea. According to the MPPACC, the cognitive capacity to motivate adaptive behavior includes individuals' perception of adaptation behaviors and adaptation perception can be measured through perceived measure efficacy, perceived self-efficacy, and perceived adaptation costs. This study conducted multiple regressions, and as a result, demographic and socioeconomic factors and information from different sources can have an influence on the farmers' perceptions differently. In sum, among the demographic and socioeconomic factors, crop insurance and years of buying the insurance seem to influence farmers' perceptions on adaptation assessment. Moreover, climate information from objective sources, such as public media and public centers can have higher influence than neighbors and village leaders, however, with regard to adaptation information, the farmers' perception of adaptation behaviors can be influenced more by information from neighbors and village leaders. There was no significant correlation was found with previous climate risk.

The results of this study suggest some directions for how to achieve successful dissemination of adaptation policies in the agricultural sector. Not only the contents but sources and quality of information should be considered as important due to the potential influences on farmers' perceptions and their adaptation evaluations. Moreover, an improvement on the system of crop insurance in addition to increasing credibility is deemed a necessity for successful adaptation strategies in Cheongsong County. By understanding different elements that induce farmers' perception on adaptation appraisal, apple farming communities can increase its adaptive capacity and lessen the damage from the impacts. However, there is the tendency of ignoring the importance of cognitive factors. Enhancing broader application of measuring cognitive capacity should have a clearer understanding of climate change adaptation capacity in apple farming communities. Moreover, this study can be more developed to be applied to other regions and other sectors to be referred in integrated climate change vulnerability assessment of rural agricultural communities.

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