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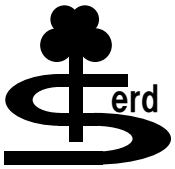

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Contents

Erosion Control by Amending Soil with Gypsum in the Dawlatzai Village of Gardez District, Afghanistan 1
Abdul Malik Dawlatzai, Machito Mihara, Takahiko Nakamura and Shafiqullah Rahmani

Microsatellite Markers and their Application on Genetic Diversity Studies of Rice Landraces (*Oryza sativa* L.) in Myanmar - A Review 8
Aye Aye Thant, Than Myint Htun, Marie Kalousová, Rakesh Kumar Singh and Bohdan Lojka

Evaluation of Seed Cane Treatments on Sugarcane Germination in Two Planting Methods 14
Khaing Tha Zin Oo, Aung Myo Thant, Kyaw Kyaw Win, Kyi Toe and Ei Ei Khaing

Equivalency and Similarity Assessment of Forest Ecosystem Services by a Multi-Point Field Survey in Nagoya City, Japan 20
Kiichiro Hayashi, Wataru Kobayashi and Makoto Ooba

Theme-Community Based Adaptation Strategies Toward Sustainable Rural Development: Case from a Local Tofu Company in Saitama Prefecture, Japan 28
Nina N. Shimoguchi, Hiroki Inaizumi and Kenji Omuro

Effects of Living Conditions on Livelihood Satisfaction in Sri Lanka: Living Sectors and Tea Industry 34
Yuko Fukuda and Eiji Yamaji

An Evaluation of Water Demand and Supply for a Small-scale Irrigation Scheme in Zimbabwe 41
Edimus Masona, Katsuyuki Shimizu and Yumi Yoshioka

Sustainable Development through Environmental Education: From the Perspectives of Past and Present Group and Individual Rainforestation Adopters 47
Guiraldo C. Fernandez, Jr. and Marlito Jose M. Bande

Determination of Lethal Concentration of Copper Compounds on Nile Tilapia (*Oreochromis niloticus* Linnaeus, 1758) Larvae 53
Natsima Tokhun, Kanittha Pamonpol, Chuleemas Boonthai Iwai and Atcharaporn Somparn

Antioxidant Activity of Crude Extract from Raw and Heat-treated *Moringa oleifera* 59
Nawaporn Lapsongphon, Monsicha Pinthong and Piyada Sukdee

Contribution of Organic Agriculture to Gross National Happiness (GNH): Bhutan 64
Serki Wangmo and Chuleemas Boonthai Iwai

Survey on the Slope Protection Method for Sloped Farmland Aimed at Conservation of Regional Unique Landscape 70
Shoko Nishiwaki, Kenji Okajima and Eiji Yamaji

Current Postharvest Management of Sesame Farmers in Selected Area of Myanmar 76
Hnin Thida Nyo, Nyein Nyein Htwe, Kyaw Kyaw Win Theingi Myint and Moe Kyaw Thu

Farmers' Perception of Fertilizer Management Practices for Cotton Production in Magway Region of Myanmar 82
Khin Khin Mu, Kyaw Ngwe, Thanda Min, Aung Naing Oo and Swe Swe Mar

Factors Affecting Farmers' Attitudes on Hybrid Rice Production in Nay Pyi Taw Area, Myanmar 88
Naing Kyi Win, Kyaw Kyaw Win, Cho Cho San and Nyein Nyein Htwe

Suitability of Groundwater Use for Drinking and Irrigation Purpose, Case Study of Kien Svay District, Kandal Province, Cambodia 95
Nareth Nut, Sony Serey, Vibol Sao and Machito Mihara

Utilization of Atis "*Annona squamosa* Linn" Desserts 102
Regucivilla A. Pobar

Evaluation of Soil Nutrient Level in Naypyitaw Agricultural Land 108
San San Myint, Kyaw Ngwe, Kyaw Kyaw Win and Swe Swe Mar

Issues of Disaster Recovery Management and Application of GIS and UAV for Resilience in Agricultural Land and Infrastructure 114
Koji Miwa, Ayako Sekiyama, Toru Nakajima, Takahiko Kubodera, Chikahiro Egami and Hiromu Okazawa

Wheat Market Instability in Afghanistan: A Case Study of Kabul, Mazar-e-Sharif, Bamyan and Ghor Provinces 122
Zaigham Kazimi, Mohammad Eshaq Rasekh, Sayed Reza Hashemi and Sayed Jalil Hashimi

The Impact of *Mimosa pigra* on Local Livelihood in the Stung Sen Core Area, Tonle Sap Biosphere Reserve 128
Somaly Chan and Machito Mihara

Research article

Erosion Control by Amending Soil with Gypsum in the Dawlatzai Village of Gardez District, Afghanistan

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Abstract Minimizing soil and water loss in agricultural land, particularly in arid and semi-arid climatic conditions, is indispensable for environmental protection and agricultural production. The purpose of this research is to evaluate the effectiveness of gypsum application in reducing sediment concentration in runoff and total soil loss. A field experiment was conducted in the village of Dawlatzai in Gardez District, Paktya, Afghanistan. Using a portable rainfall simulator, four erosion plots; gypsum-treated, clover, maize, and control were designed and applied in two replications. Surface runoff experiment using sandy loam and loamy soil textures was conducted in the Laboratory of Land and Water Use Engineering, Tokyo University of Agriculture. Gypsum mineral was applied at a rate of 5 t ha^{-1} for both experiments. The results of field experiments showed that the gypsum-treated, clover and maize fields reduced total soil loss by 67.28%, 92.04% and 54.45% compared to the control, respectively. Likewise, surface runoff was reduced by 19.62% in the gypsum-treated field compared to the control field. Similarly, the results of laboratory experiment showed that with application of gypsum, surface runoff was reduced by 38.83% and 37.07% from sandy loam and loamy soil textures with total soil loss reduced by 60.25% and 81.86% compared to control, respectively. Percolation was increased by 2.31 and 2.29 times in sandy loam and loamy soil textures, respectively. Moreover, the application of gypsum significantly reduced sodium adsorption ratio (SAR) and boosted the calcium content and flocculation phenomena. Based on these results, it can be suggested and recommended that farmers in Paktya should apply gypsum mineral to their farmlands to enhance water infiltration and minimize surface runoff and soil loss.

Keywords gypsum, infiltration, soil loss, village of Dawlatzai

INTRODUCTION

Gypsum mineral is generally used mostly because of its availability and low-cost. Gypsum has an ability to minimize clay dispersion, thereby permeability of the soil and increases the stability aggregates at the soil surface. However, the major benefits of gypsum mineral related to agriculture includes; source of calcium and sulphur for plant nutrition, improves acid soils and treats aluminum toxicity, enhances soil structure, increases water infiltration and reduce runoff and soil loss (Greenleaf Advisors, 2015; US-EPA, 2008; Hopkins, 2013).

Gypsum mineral from by-product of industrial processing called synthetic gypsum. It is composed of calcium sulphate dihydrate and similar in characteristics to natural gypsum and is

environmentally friendly. Ameliorating saline-sodic soils are indispensable for suitable agriculture and clay dispersion. Therefore, gypsum is used for sodic soil reclamation, because it is calcium-rich, dissolves at high pH and replaces of sodium from an exchange site (Horneck et al., 2007).

Gypsum mineral is able to improve soil hydraulic conductivity and significantly increases infiltration conditions (Miller, 1987). Gypsum dissolves quickly and releases electrolytes thus flocculate the soil particles and lower tendency of clay to disperse (Shainberg et al., 1989). The objective of this study is to evaluate the effectiveness of gypsum application in reducing sediment concentration in runoff and total soil loss.

MATERIALS AND METHODS

Study Site

The research was conducted in the Dawlatzai Village of Gardez District, Paktya Province, Afghanistan (Fig. 1). The village is about 5 km from south of Gardez city, which is the capital of Paktya Province. About 1,850 families live in the village and 80% of the population depends on agriculture and animal husbandry for livelihood.

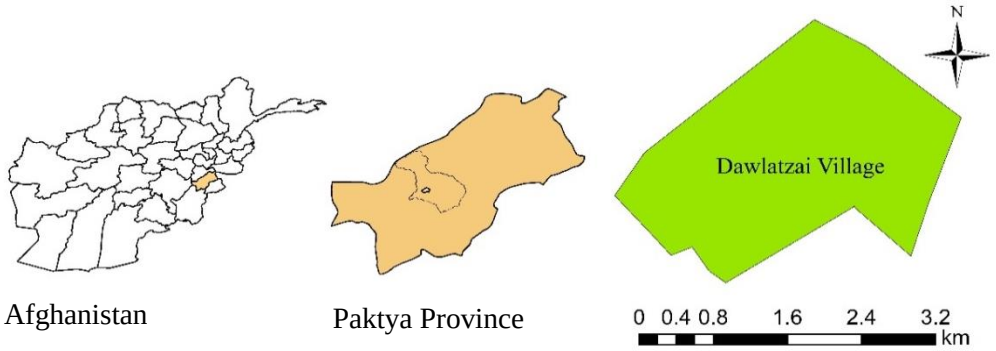

Fig. 1 Dawlatzai Village in Gardez District, Paktya Province, Afghanistan

Field Experiment

A field experiment with four erosion plots; gypsum-treated, clover, maize, and control were designed and applied in two replications. Using a portable artificial rainfall simulator; raindrop sizes approx. 3.42 mm, kinetic energy about 1.6×10^{-5} J and Marriotte bottle generated constant pressure at 981 Pa (Maore and Mihara, 2017). Gypsum mineral was applied at the rate of 5 t ha^{-1}. Runoff collector was installed on the downstream side, depending on the direction of sloppy field. The soil was pre-wetted for 24 hours before application of artificial rain (Fig. 2). Surface runoff was collected at an interval of 5 minutes for a duration of 30 minutes. It was analyzed for chemical and physical properties in laboratory of Land and Water Use Engineering, Tokyo University of Agriculture.

Laboratory Experiment

Similarly, the surface runoff experiment was conducted in the laboratory of Land and Water Use Engineering using a triangular erosion plot. The length was 91.0 cm, and width 3.0 cm and height are 2.5 cm. The slope of a plot was arranged as 8.0° (Fig. 3). Soil was used for the erosion plot compacted under a dry density of 1.61 g/cm^3 and 1.47 g/cm^3 for sandy loam and loamy soil textures, respectively. Marriotte bottle with constant pressure was used to supply water during 30 minutes. Surface runoff and percolation water were collected at 5 minutes interval. Two treatments were applied; control and gypsum-treated. Gypsum was applied at the rate of 5 t ha^{-1}. Soil was

saturated for 24 hours before the experiment. The surface runoff was analysed for calcium, magnesium, sodium, and soil loss. In addition, flocculation and dispersion experiments were conducted; using loamy soil texture and gypsum mineral was applied at rates of 2.5 t ha^{-1}, 5 t ha^{-1}, 7.5 t ha^{-1}, and 10 t ha^{-1}. Soil and gypsum were put into tubes and added 100 ml deionized water, then shaken mechanically for a minute. Samples were taken after an interval of 1 hour and experiment were run for 4 hours.

Fig. 2 Diagram of field experiment

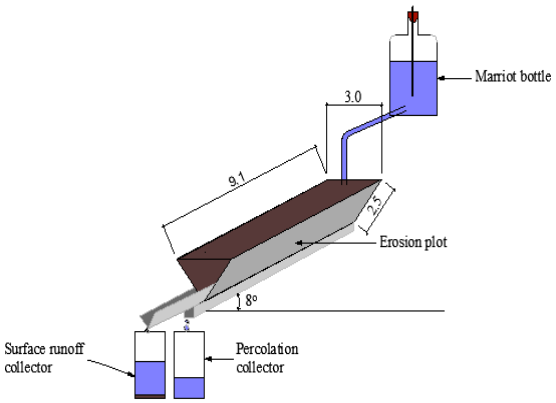

Fig. 3 Diagram of surface runoff experiment

RESULTS AND DISCUSSION

The results of field experiments showed that, the total surface runoff for all treatments' gypsum treated, clover, maize and control fields was at 3.40 L, 3.06 L 4.01 L and 4.23 L, respectively. Statistical analysis showed that there were significant differences ($P<0.05$) between gypsum-treated and clover fields, and control and maize fields (Fig. 4). Application of gypsum reduced surface runoff 19.62%. Total soil loss of gypsum-treated, clover and maize fields were reduced by 67.28%, 92.04% and 54.45% compared to control, respectively (Table 1). Gypsum has been used for reducing and controlling crust formation on the soil surface and improving water infiltration as well as stabilizing sodic soil (Agassi et al., 1981; Miller, 1987).

Table 1 Soil loss in each field

Treatment	Average soil loss (t ha^{-1})	Total soil loss, reduced from control (%)
Gypsum	4.11	67.28
Clover	1.00	92.04
Maize	5.72	54.45
Control	12.56	

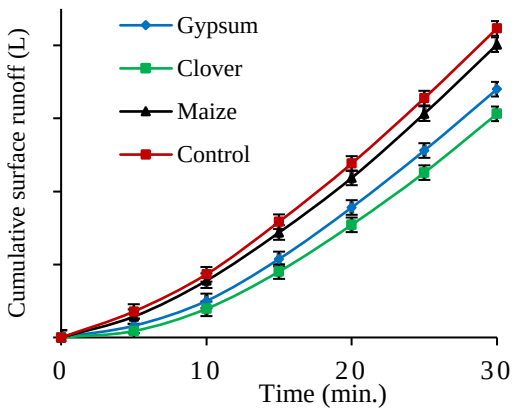

Fig. 4 Changes in surface runoff with time

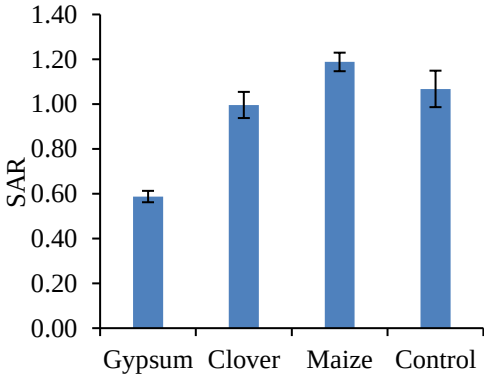

Fig. 5 SAR of surface runoff

Sodium adsorption ratio (SAR) expresses the relationships between sodium content and calcium plus magnesium contents (Eq. 1). This ratio reflects the amounts of sodium adsorbed onto clay and soil organic matter exchange surfaces, hence the potential for flocculation or dispersion processes within the soil (Keren, 1991). These processes influence the hydraulic properties of the soil, runoff and soil erosion (Lavee et al., 1991). The higher the SAR, the more likely the soil is to disperse, but low SAR soils tend to flocculate. In dispersed soils, water infiltrates and drains slowly, the water runs off the soil, increasing the potential for erosion and limiting amount of the water available for crops and soil become very poorly aerated due to inadequate of the large pores. However, the application of gypsum significantly reduced SAR value. SAR value for all treatments' gypsum-treated, clover, maize and control fields were as of 0. 59, 1.00, 1.19 and 1.07 (Fig. 5).

$$\text{SAR} = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{+2} + Mg^{+2}]}{2}}} \quad (1)$$

Table 2 shows that the application of gypsum mineral slightly increased EC of soil solution because the gypsum mineral is sparingly soluble salt. However, it did not change the pH of the soil solution. Gypsum improves chemical properties of soil such as aluminium toxicity caused by subsoil (Chen and Dick, 2011). Gypsum is a neutral salt and not a liming agent, therefore, does not neutralize the hydrogen ion in the soil solution (Fisher, 2011).

Table 2 Electrical conductivity and pH of surface runoff

No	Treatment	EC (mS/m)	pH
1	Gypsum	77.88	7.78
2	Clover	67.13	7.87
3	Maize	59.11	7.97
4	Control	55.03	7.79

Total surface runoff for gypsum-treated plots was at 0.63 L and 0.73 L and for control plots were 1.03 L and 1.16 L. The results showed the application of gypsum significantly reduced runoff by 38.83% for sandy loam soil and 37.07% for loamy soil compared to the control (Table 3). Likewise, the total percolating water for gypsum-treated plots was at 0.81 L and 0.35 L and for control plots; 0.71 L and 0.31 L. The application of gypsum increased percolation rate by 2.31 times for sandy loam soil texture and 2.29 times for loamy soil texture compared to the control (Table 4). Mahardhika et al., (2008) reported, they applied gypsum mineral at a rate of 10 t ha^{-1}, polyacrylamide (PAM) 40 kg ha^{-1} and combined application of both amendments (PAM + gypsum) at the same rates. Total soil loss was reduced by 39%, 43%, and 74%, compared to the control. The application of PAM + gypsum more significantly was reduced soil to compare with other treatments. The application of gypsum mineral was effective in considerably reducing total soil loss from agricultural land.

Table 3 Changing surface runoff from the control

Soil texture	Treatment	Total discharge (L)	Total surface decreased from control (%)
Sandy loam soil	Gypsum	0.63	38.83
	Control	1.03	
Loamy soil	Gypsum	0.73	37.07
	Control	1.16	

The results in Table 5 indicated, the application of gypsum significantly reduced the total soil loss by 60.25% and 81.86% for sandy loam and loamy soil textures, respectively compared to control. As well, significantly reduced SAR value by 59% and 52% and increased the calcium content for both soil textures (Fig. 6 and Fig. 7), although, the calcium concentration a slightly more for loamy soil texture because of Cation Exchange Capacity (CEC) of soil. Gypsum mineral boosted soil condition and improved crop yields as well as increasing the sulphur content which is

an essential nutrient for plant growth (Chen and Dick, 2011). Calcium ion is very important for cell walls, membrane and developing root growth (Fisher, 2001).

Table 4 Changing percolation from the control

Soil texture	Treatment	Total percolation (L)	Total percolation changed from control (time)
Sandy loam soil	Gypsum	0.81	2.31
	Control	0.35	
Loamy soil	Gypsum	0.71	2.29
	Control	0.31	

Table 5 Soil loss from sandy loam and loamy soil textures

Soil	Treatment	Average total soil loss (t ha^{-1})	Total soil loss decreased from control (%)
Sandy loam soil	Gypsum	16.98	60.25
	Control	42.72	
Loamy soil	Gypsum	5.34	81.86
	Control	29.50	

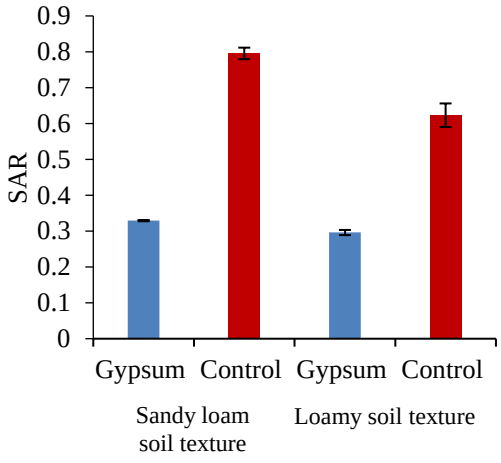

Fig. 6 SAR of surface runoff

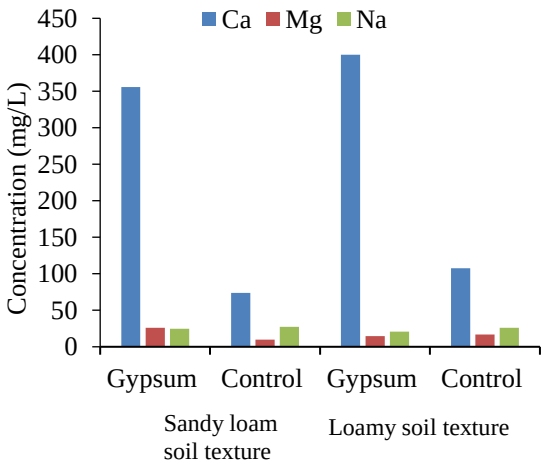

Fig. 7 Cation concentration in surface runoff

Fig. 8 Flocculation and dispersion results

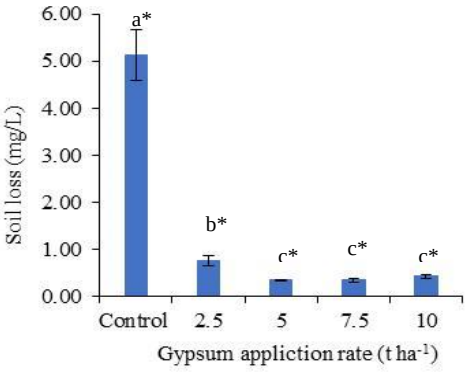

Fig. 9 Effects of gypsum on suspended soil

Flocculation is the process by which clay particles, individual coagulate or aggregate, water easy moves mostly in large pores between in aggregates. The dispersion is the reverse action of flocculation clay plug soil pores over enhances surface runoff and reduces water infiltration and drainage thereby increases soil erosion (Bratby, 1980). Gypsum is known to flocculate the soil and

pull together clay particles an aggregate. The results indicated the addition of gypsum mineral at the rates of 2.5 t ha^{-1}, 5 ha^{-1}, 7.5 ha^{-1}, and 10 ha^{-1} significantly ($P<0.05$) flocculated soil particles compared to the control. Furthermore, there is a negligible differential between high and low rates of gypsum application (Fig. 8 and Fig. 9). It means the application of high rate gypsum mineral similar affected as medium rate and the application high-rate of gypsum is uneconomical for farmers.

CONCLUSION

The results could be concluded that the total soil losses from gypsum-treated field, clover field and maize field were reduced by 67.28%, 92.04%, and 54.45% compared to the control and reduced surface runoff by 19.62% for gypsum-treated field compared to the control field. Similarly, it significantly reduced surface runoff by 38.83% for sandy loam soil and 37.07% for loamy soil compared to the control, increased the percolation rate by 2.31 times and 2.29 times and the total soil loss was reduced by 60.25% and 81.86%, from sandy loam and loam soil textures, respectively. By the application of gypsum mineral significantly reduced SAR value and boosted the calcium content. It was considered that gypsum mineral addition is effective in enhancing flocculation and aggregated of soil clay particles and reduce soil loss. The improved surface conditions in the gypsum-treated soil contributed towards reduction in sediment concentration in surface runoff and total soil loss. Accordingly, it is suggested and recommended that farmers in Paktya Province apply gypsum mineral into their farmlands for reducing surface runoff and soil loss.

ACKNOWLEDGEMENTS

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REFERENCES

Agassi, M., Shainberg, I. and Morin, J. 1981. Effect of electrolyte concentration and soil sodicity on infiltration rate and crust formation. Soil Science Society of America Journal. 45, 848-851.

Bratby, J. 1980. Coagulation and flocculation with an emphasis on water and wastewater treatment. Filtration and Separation, Uplands Pess LTD Publishers, UK.

Chen, L. and Dick, W.A. 2011. Gypsum is an agricultural amendment. General Use Guidelines, Ohio State University, USA.

Fisher, M. 2011. Amending soils with gypsum. Crops and Soil Magazine, USA.

Greenleaf Advisors. 2015. Gypsum for agricultural use. The State of the Science, Bridging Enterprises for a Healthy and Sustainable World.

Hopkins, M. 2013. The role of gypsum in agriculture and five key benefits. http://www.croplife.com/crop-inputs/micronutrients/the-role-of-gypsum-in-agriculture-5-key-benefits-you-should-know.

Horneck, D.A., Ellsworth, J.W., Hopkins, B.G., Sullivan, D.M. and Slevens, R.G. 2007. Managing salt-affected soils for crop production. PNW 601, E, November 2007.

Keren, R. 1991. Specific effect of magnesium on soil erosion and water infiltration. Soil Science Society of America Journal, 55, 783-787.

Lavee, H., Imeson, A.C., Pariente, S. and Benyamini, Y. 1991. The response of soils to simulated rainfall along a climatological gradient in an arid and semi-arid region. Catena, 19, 19-37.

Mahardhika, H., Ghadiri, H. and Yu, B. 2008. Effects of polyacrylamide and gypsum on soil erosion and sediment transport. Griffith University, Nathan, Queensland, Australia.

Maore, J.M. and Mihara, M. 2017. Development of portable artificial rainfall simulator for evaluation sustainable farming in Kenya. International Journal of Environmental and Rural Development, 8 (1), 27-33.

Miller, W.P. 1987. Infiltration and soil loss of three-gypsum amended Ultisols under simulated rainfall. Soil Science Society of America Journal. 51, 1314-1320.

Shainberg, I., Sumner, M.E., Miller, W.P., Farina, M.P.W., Pavan, M.A. and Fey, M.Y. 1989. Use of gypsum on soils. Contribution from the Department of Agronomy, University of Athens Georgia, Advances in Soil Science, 9, 43-50.

UN-EPA. 2008. Agricultural uses for flue gas desulfurization (FGD) gypsum. United States - Environmental Protection Agency, National Service Centre for Environmental Publications, USA.

Review article

Microsatellite Markers and their Application on Genetic Diversity Studies of Rice Landraces (*Oryza sativa* L.) in Myanmar - A Review

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Abstract Myanmar is one of the centers of genetic diversity of rice as it has heterogeneous geographical and ecological conditions such as hills and mountains. Since 1988, owing to market oriented economic policy and international rice price, traditional varieties have been replaced by improved varieties. Landraces are known for the excellent adaptation to the local conditions; however, their productivity is very low. Increased productivity of the landraces through high input application has not been possible because they are not responsive to the inputs. However, these landraces and traditional varieties possess very useful and important traits for further breeding and genetic improvement of rice. Thus, there is an urgent need for germplasm collection, their conservation and characterization to study the diversity of traditional rice varieties in Myanmar. In recent years, DNA sequence variations have been used as markers for genome analysis since they are independent of environment and growth stages of plant and more reliable than the other phenotypic or biochemical markers. Of the different types of molecular markers, microsatellites have been utilized most extensively, because they can be readily amplified by PCR, present large amount of allelic variation at each locus, are highly informative, and require small amounts of DNA. They have become the versatile molecular markers not only for germplasm diversity studies but also for exploration of targeted gene. In Myanmar, some research on rice landrace diversity by using microsatellites has been done. Therefore, this review aims to take stock of the current status and summarize genetic diversity studies of traditional rice varieties in Myanmar, through the use of microsatellite markers.

Keywords microsatellites, genetic diversity, rice landraces, Myanmar

INTRODUCTION

Myanmar is known as a rice-based agriculture country and large fraction of national economy rely on the surplus from rice export. From historical time to now, the country has a long history of rice production. Moreover, culture, religion and belief, politics and national economy were influenced by rice and rice production. Therefore, civilization of Myanmar was established based on rice and

rice cultivation. Since 1988, owing to market oriented economic policy and international rice price, traditional varieties have been replaced by improved varieties. However, Myanmar traditional landraces are still under cultivation by resource poor farmers who practice subsistence farming (Yamanaka et al., 2011) and the outcome is low yield. Although the output is lower, these landraces have wide adaptation to local or harsh conditions and they are assumed as a harbor of great genetic potential for rice improvement.

Landraces are also an integral part of cultural heritage due to their close link with the local territory as well as the community with their associated traditional uses, knowledge and habits. Landraces are, however, threatened and suffering from genetic erosion. Major contributing factors include climate change, habitat loss, environmental degradation and changes in farming practices, leading to the introduction of new pests and diseases, a collapse of pollinators, and increased drought and salinization. These precious and irreplaceable resources urgently need to be conserved before they disappear. Therefore, in order to prevent the permanent loss of landraces, research activities on genetic diversity, conservation and utilization become critical issues for the agriculture sector in Myanmar.

Nowadays, several techniques are available for the detection of genetic diversity, i.e. for identifying DNA polymorphism, including the microsatellite ones. This marker is easily amplified by PCR, requires no large initial amounts of DNA samples and has high polymorphism due to a large variation in the number of repetitions. Furthermore, the microsatellite loci have co-dominant multi-allelic expression which permits the discrimination of homozygous and heterozygous genotypes, facilitating the characterization of different populations by allele frequency analysis (Bruford, 1996). Therefore, genetic diversity data, based on microsatellites, can be used for monitoring the genetic variability of species and support management actions to prevent the loss of genetic diversity over time. Tens of thousands of potential SSRs have been identified in rice, and over 25,000 have been developed as molecular markers (Temnykh et al., 2000; McCouch et al., 2002; IRGSP, 2005). These markers are currently being used to develop high density genetic maps, genotype rice accessions, determine the genetic structure, optimize the assembly of core collections, and for marker-assisted breeding (McCouch et al., 2002; Yu et al., 2003; Garris et al., 2005). The limiting feature of the application of these markers is the need for prior sequence information for developing primers for locus-specific PCR amplification. This limitation is alleviated for the economically important species and the ones closely related, since primer sequences of the SSR DNA markers and the amplification conditions are available in the published reports and the rice annotation project database (rap-db). Generation of complex banding patterns for SSR loci could be due to various reasons such as type of repeat, non-optimization of PCR conditions and the nature of genome (Mausa, 2014).

OBJECTIVE

This review aims to make an overall assessment of the current status and summarize genetic diversity studies of traditional rice varieties in Myanmar, through the use of microsatellite markers.

RESULTS AND DISCUSSION

In Myanmar, assessment of genetic diversity of rice germplasm have been conducted by using various characters: viz: morphological, physiological, biochemical, and molecular characters. Among them, molecular markers have been used for genome analysis since they are stable and detectable in all tissues regardless of growth, differentiation, development, or defense status of the cell. Wunna et al., (2016) studied the genetic diversity of 175 rice accessions from Myanmar, including landraces and improved types from upland and lowland ecosystems in five different areas. They evaluated on the basis of polymorphism data for 65 microsatellite markers and confirmed high genetic diversity with average polymorphism information content (PIC) value of 0.82 per locus with the range of 0.519 to 0.919. The large range of PIC values for the respective accessions provides greater confidence for the assessment of genetic diversity and relationships. Cluster

analysis based on the polymorphism data from SSR markers clearly differentiated the rice accessions into two groups. Group I, with 85 accessions, corresponded to Indica Group and was dominant in all upland regions except for the Northeastern. Group II, with 90 accessions, corresponded to the Japonica Group and was dominant in the Southern (lowland) region (Table 1).

Table 1 Relationships among groups, areas, and rice cultivation ecosystems

Ecosystem	Landrace or improved	Area	No. of accessions (%)		
			Group I	Group II	Total
Upland	Landrace	Northern	16 (9.1)	2 (1.1)	18 (10.3)
		Western	11 (6.3)	1 (0.6)	12 (6.9)
		Southeastern	29 (16.6)	4 (2.3)	33 (18.9)
		Northeastern	12 (6.9)	18 (10.3)	30 (17.1)
		Sum	68 (38.9)	25 (14.3)	93 (53.1)
	Improved	Northeastern	0 (0.0)	7 (4.0)	7 (4.0)
	Subtotal		68 (39.4)	32 (18.3)	100 (57.7)
Lowland	Landrace	Southern	3 (1.7)	50 (28.6)	53 (30.3)
	Improved	Southern	12 (6.6)	2 (1.1)	14 (8.0)
	Subtotal		15 (8.6)	52 (29.7)	67 (38.3)
Others					
Upland	Improved	Unknown	1 (0.6)	0 (0.0)	1 (0.6)
Lowland	Landrace	Unknown	1 (0.6)	6 (3.4)	7 (4.0)
	Subtotal		2 (0.11)	6 (3.4)	8 (4.6)
Total			85 (48.6)	90 (51.4)	175 (100.0)

Pawsan rice cultivars, quality rice, seems to be originated in Myanmar and due to their delightful aroma and good eating quality, they are recognized as premium rice cultivars in Myanmar. Min Soe Thein et al., (2014) collected 38 Pawsan cultivars mainly from Ayeyarwaddy region and documented the variation of genetic structure of these collected Pawsan cultivars in order to fingerprint, conserve and exploit potential cultivars for breeding program. Twenty two SSR loci of Pawsan cultivars with two controls generated 112 alleles with an average of 5.09, and PIC ranged from 0.22 to 0.80 with an average of 0.54. SSR genotyping revealed that pair-wise genetic similarity of Pawsan cultivars ranged from 14% to 84% and averaged of 49%, and Pawsan group was separated from two controls (IR36 and Koshihikari). However, genetic similarity of Pawsan group was closer to Koshihikari (japonica). Among the local varieties in Myanmar, Meedon rice, which is one of the five rice varietal groups in Myanmar, is important for local adaptability, grain quality, premium price and market availability. Minn San Thein et al., (2012) carried out a study to assess genetic diversity and to analyze population structure of Meedon rice germplasm conserved in Myanmar Seed Bank using SSR markers. 154 accessions of Meedon rice germplasm were analyzed with nine SSR markers. A total of 86 alleles were detected with an average of 9.6 alleles per locus. All the loci were found to be polymorphic, and there were considerable genetic variation among accessions with mean values of expected heterozygosity (HE) = 0.5774 and polymorphic information content (PIC) = 0.5496. High frequency of rare alleles was identified, among which 35 unique (accession-specific) alleles were observed. Based on cluster analysis, the three population groups consist of 105 accessions, 43 accessions and 6 accessions indicating the inclusion of non-Meedon rice accessions, which was about one-third of the germplasm, and it was a large proportion. This study revealed that the small number of SSR markers is possible for discriminating Meedon and non-Meedon rice. Yamanaka et al., (2011) conducted a study on genetic variation in Myanmar by using 12 SSR markers. 41 out of 83 strains were obtained from the Myanmar seedbank. The other 42 strains were directly sampled from agricultural fields in the areas where the seed-bank materials were originally derived. The gene

diversity were 0.809 in seed-bank and 0.826 in on-farm. This suggested that on-farm material was comparatively more diverse than the seed-bank samples.

Isozyme analyses classified majority of the rice cultivars into six groups; group-I corresponds to the indica and group-VI refers to both temperate and tropical japonica. Groups II, III, IV and V were classified as indicas conventionally (Glaszmann, 1987). Recently, a diversity analysis was conducted using DNA markers on Myanmar rice varieties and found that some varieties from isozyme group-V appeared to be japonica types. Thawda et al., (2005) analyzed 31 rice varieties from Myanmar and they reported that the rice varieties, in isozyme group-V (Singh, 2000; Khush et al., 2003) could also be considered as japonica. Therefore, Moe Moe Oo et al., (2009) conducted a research to obtain more information on Myanmar rice varieties from isozyme group-V for proper genetic resource conservation and management. A total of 43 microsatellite primers were utilized and 41 primers showed polymorphism among the 52 accessions. The number of alleles per locus detected by microsatellite primers varied from 2 to 15 with an average of 5.63 alleles per primer. The highest polymorphism was observed at RM334 on chromosome no.5 which showed 15 alleles. According to the cluster analyses, most of the Myanmar rice varieties from the isozyme group-V are genetically closer to japonica and a few of them are found closer to indica. The dendrogram reveals two main groups with the genetic similarity of 0.476. The group-I consisted 5 rice varieties including indica control and 4 Myanmar rice varieties with maximum genetic similarity of 0.520. The group-II was formed cluster by 48 Myanmar rice varieties together with temperate japonica control and tropical japonica control. All the rice varieties in group-II possess japonica type DNA in both nuclear and chloroplast genomes. Therefore, it is assumed that the rice varieties from the group-I are genetically closer to indica and the group-II closer japonica.

Table 2 Number of alleles and gene diversity of rice landraces from Myanmar and standard strains observed for 10 SSR loci

Locus	Alleles/locus		Gene diversity	
	Myanmar	Standard	Myanmar	Standard
RM1	9	4	0.876	0.718
RM7	18	9	0.939	0.839
RM19	10	11	0.930	0.919
RM20A	15	10	0.877	0.911
RM20B	18	8	0.918	0.888
RM120	11	5	0.885	0.851
RM164	17	12	0.919	0.904
RM167	17	10	0.908	0.888
RM241	15	10	0.879	0.888
OSR21	20	14	0.922	0.900
Average	15	9.3	0.905	0.871

According to Htay Htay Aung (2007), SSR analysis revealed high variation among the Myanmar rice varieties. There are 202 alleles in 132 accessions using 34 SSR loci, the Myanmar rice varieties showed 197 alleles. The average alleles per locus for all accessions and Myanmar rice varieties are 5.94, and 5.79, respectively. The average gene diversity for all accessions is 0.71 while for the Myanmar rice varieties, it is 0.70. This indicates that high gene diversity exists among Myanmar rice varieties. The dendrogram based on cluster analysis of SSR markers generated two major clusters. Cluster I consisted of mostly japonica, javanica and high quality aromatic rice types. Cluster II corresponded to the indica group. Glutinous rice varieties are mostly scattered in cluster II with a few included in cluster I. It has been indicated that most glutinous cultivars arose independently from indica types. Myanmar rice varieties represented a genetically diverse and heterogeneous group with multiple alleles at many of the SSR loci. Genetic polymorphism of ten microsatellites loci were examined in 100accessions of rice including 77 landraces from Myanmar, 3 cultivated varieties from Japan, 4 from China, 1 from Vietnam, 4 from Philippines, 5 from Taiwan area, 6 from India and 2 from Indonesia (San San Yi et al., (2005). Those other varieties were representative strains for each country (Oka, 1958). In this study, RM 1 produced the smallest

number of alleles per locus and OSR 21 generated the largest number in both samples. Range of alleles per locus is 9-20 and totally 150 alleles in Myanmar strains and 4-14 and totally 93 alleles for standard strains. Therefore, in Myanmar samples, total and average numbers of alleles are higher than those in standard strains. Gene diversity of Myanmar strain is also greater than standard strains from different Asia countries (Table 2). Oka (1988) also stated that the diversity of Oryza sativa is the highest in Myanmar compared with other Southeast Asia countries because these standard strains are core collection of landraces of Asian rice that seeds were donated from National Institute of Genetics (Japan). In cluster analysis, it produced 5 main clusters. 4 main groups are indica and the other one is japonica rice group.

Table 3 Informative primers

SSR locus	Chromosome	No. of alleles	Gene diversity
RM1	1	12	0.90
RM263	2	17	0.62
RM7	3	18	0.94
RM241	4	15	0.88
RM164	5	17	0.92
OSR21	6	20	0.92
RM11	7	9	0.80
RM72	8	11	0.81
RM3164	9	8	0.80
RM271	10	8	0.84
RM167	11	17	0.91
RM247	12	9	0.77

CONCLUSION

Overall we can conclude that microsatellites are useful markers and they detect a high level of allelic variation and give an understanding of the genetic relationships and diversity among the Myanmar rice varieties. SSRs can also be used not only in rice germplasm evaluation but also effectively in indica-japonica differentiation. According to the survey articles, the genetic diversity of over 600 Myanmar landraces have been evaluated by using 148 SSR loci, which are distributed all over the 12 chromosomes. Despite this, the publications involving genetic diversity measurement using microsatellites are still rare in Myanmar rice varieties because around 7,000 accessions are kept in the Seed Bank at the Department of Agricultural Research, Myanmar. Based on the level of polymorphism detected by individual primers, the most informative primers were identified with different polymorphic bands (Table 3). Therefore, future research studies of genetic variation should be performed on Myanmar rice landraces through the use of those high polymorphic SSR loci.

REFERENCES

Bruford, M.W., Cheesman, D.J., Coote, T., Green, H.A.A., Haines, S.A., O'Ryan, C. and Williams, T.R. 1996. Microsatellite and their application to conservation genetics. In Smith, T.B. and Wayne, R.K. (Eds.), Molecular Genetic Approaches in Conservation, Oxford University Press, 278-297, New York.

Garris, A.J., Thomas, H.T., Coburn, J., Kresovich, S. and McCouch, S.R. 2005. Genetic structure and diversity in *Oryza sativa* L. Genetics, 169 (3), 1631-1638.

Glaszmann, J.C. 1987. Isozymes and classification of Asian native rice varieties. Theoretical and Applied Genetics, 74, 21-30.

Htay Htay Aung. 2007. Genetic diversity assessment of Myanmar rice (*Oryza sativa* L.) varieties using morphological characters and SSR markers. MS Thesis, University of Philippines, Los Baños (UPLB), 197, Philippines.

IRGSP. 2005. The map based sequence of the rice genome. The International Brachypodium Initiative, International Rice Genome Sequencing Project, Nature, 436 (7282), 793-800.

Khush, G.S., Brar, D.S., Virk, P.S., Tang, S.X., Malik, S.S., Busto, G.A., Lee, Y.T., McMally, R., Trinh,

L.N., Jiang, Y. and Shata, M.A.M. 2003. Classifying rice germplasm by Isozyme polymorphism and origin of cultivated rice. International Rice Research Institute, Discussion Paper, 46, Philippines.

Mausa, E.A. 2014. Genetic diversity of rice (*Oryza sativa* L.) landraces conserved at the national genebank as revealed by simple sequence repeat (SSR) DNA markers. MS Thesis, University of Agriculture. Morogoro, 67, Tanzania.

McCouch, S.R., Leonid, T., Xu, Y., Katarayna, L.B., Karen, C., Walton, M., Fu, B., Reycel, M., Li, Z., Xing, Y., Zhang, Q., Kono, I., Yano, M., Fjellstrom, R., DeCLERCK, G., Schneider, D., Cartinhour, S., Ware, D. and Lincoln, S. 2002. Development of 2240 new SSR markers for rice (*Oryza sativa* L.). DNA Research, 9 (6), 199-207.

Minn San Thein, Lee, G.A., Cho, K.T., Sung, J.S., Jeong, J.W., Park, J.H. and Baek, H.J. 2012. Assessment of genetic diversity in Meedon Rice (*Oryza sativa* L.) germplasm. Journal of the Korean Society of International Agriculture, 24 (2), 232-240.

Min Soe Thein, Htay Htay Aung, Ye Win Aung, Nan Su San, Thanda Tin, Wah Wah Lwin, Ko Ko Maung, Pa Pa Aung and Khin Maung Thet. 2014. Variation of some pawsan rice (*Oryza. sativa* L.) cultivars of Myanmar using morphological, physiochemical and molecular characters. Proceedings of the Eighth Agricultural Reserach Conference in Commemoration of the 90th Anniversary of Yezin Agricultural University, Myanmar, 60-71, Myanmar.

Moe Moe Oo, Thawda Myint, Wunna, Khin Maung Thet, Yamanaka, S. and Watanabe, K.N. 2009. A study on Myanmar rice varieties from isozyme classification group. V. Myanmar Academy of Agricultural, Forestry, Livestock and Fishery Sciences, Proceeding of Sub-Agricultural Reserach Conference, 45-73, Myanmar.

Oka, H.I. 1958. Intervital variation and classification of cultivated rice. Indian Journal of Genetics and Plant Breeding, 18, 79-89.

Oka, H.I. 1988. Origin of cultivated rice. Japan Scientific Societies Press, Elsevier, 121.

San San Yi, Kyaw Win, Hu, J. and Fujimura, T. 2005. Polymorphism of microsatellities in some Myanmar rice varieties. Myanmar Academy of Agricultural, Forestry, Livestock and Fishery Sciences, Proceeding of the Annual Research Conference, 1, 63-89, Myanmar.

Singh, V.P. 2000. The basmati rice of India. Oxford and IBH Publishing Co. Pvt. Ltd., 137-153, New Dehli.

Svetlana, T., William, P.D., Nicola, A., Sam, C., Hauck, N., Leonard, L., Gu, C.Y., Ishii, T. and McCouch S.R. 2000. Mapping and genome organization of microsatellite sequences in rice (*Oryza sativa* L.). Theoretical and Applied Genetics, 100 (5), 697-712.

Thawda Myint, Aung, P.P., Khin Maung Thet, Yamanaka, S. and Watanabe, K.N. 2005. Genetic identification of some rice varieties using PBA markers. Proceeding of Myanmar Academy of Agricultural, Forestry, Livestock and Fishery Sciences, 7 (9), 518-532.

Wunna, Watanabe, K.N., Ohsawa, R., Obara, M., Yanagihara, S., Aung, P.P. and Fukuta, Y. 2016. Genetic variation of rice (*Oryza sativa* L.) germplasm in Myanmar based on genomic compositions of DNA markers. Breeding Science, 66, 762-767.

Yamanaka, S., Jatoi, S.A., San San Yi, Kothari, S.L., Tin Htut and Watanabe, K.N. 2011. Genetic diversity of Myanmar rice and their implementation on management methods. African Journal of Biotechnology, 10 (8), 1290-1298.

Yu, S.B., Xu, W.J., Vijayakumar, C.H., Ali, J., Fu, B.Y., Xu, J.L., Jiang, Y.Z., Marghirang, R., Domingo, J., Aquino, C., Virmani, S.S. and Li, Z.K. 2003. Molecular diversity and multilocus organization of the parental lines used in the International Rice Molecular Breeding Program. Theoretical and Applied Genetics, 108 (1), 131-140.

Research article

Evaluation of Seed Cane Treatments on Sugarcane Germination in Two Planting Methods

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Abstract The experiments were conducted in the glasshouse of Sugarcane Research and Development Farm, Pyinmana to evaluate the effect of seed cane treatments on sugarcane germination of K-95/84 variety in two planting methods from August-October 2015 and June-August 2016. The glasshouse experiments were conducted in 2×4 factorial arrangement in Randomized Complete Block Design (RCB) with three replications. It evaluated two different planting methods (single budded setts and three budded setts) with pre-planting treatments by using different levels of lime (0, 7.5, 15, 22.5 g l^{-1}), different levels of topsin fungicide (0, 0.5, 1, 1.5 g l^{-1}) and different degree of hot water (0, 50, 52, 54˚C). Single budded setts gave the earliest and higher percentage of germination than three budded setts. Among the pre-planting treatments, the earliest and higher percentage of germination was obtained from the lowest level of lime 7.5 g l^{-1} (L_1), topsin fungicide 0.5 g l^{-1} (F_1) and hot water 50˚C (H_1) treatments. As a combined effect of two factors, single budded setts with lime 7.5 g l^{-1} (SL_1), topsin fungicide 0.5 g l^{-1} (SF_1) and single budded setts with hot water 50˚C (SH_1) gave maximum germination. Thus, this study highlighted that the single budded setts with lime 7.5 g l^{-1}, topsin fungicide 0.5 g l^{-1} and hot water 50˚C treatment should be used for the uniformity of germination.

Keywords sugarcane, planting method, pre-planting treatment, germination

INTRODUCTION

Sugarcane (*Saccharum* spp.) is one of the priority crops for many regions of the world including Myanmar. Its domestic production, local consumption and international trade were gradually progressed in Myanmar (MOAI, 2005).

Seed material is one of the costlier inputs in sugarcane and accounts for nearly 25% of the total production. The conventional use of three-eye setts imposes high cost to the estate and growers resulting in the shortage of planting materials. The use of high planting rates also forces an increase in the acreage of seed cane which competes for fertile land (Netsanet et al., 2014). The size of the cutting has a significant effect on both the percentage of germinated buds and the vigour of the cane plants (Croft, 2000).

The planting materials which have suitable sett size and seed rate, without any harmful effect on plant stand, may help in receiving higher cane yield with lower cost of production (Patel and Rinku, 2014). Moreover, pre-planting treatments should be used to protect the crop from soil borne diseases, sett rotting and damage to buds which affected the germination. It may be achieved about 60% by sett treatment which is quite simple and cheap (Sundara, 1998).

In Myanmar, most of the sugarcane farmers used to grow three-budded setts as planting materials without pre-planting treatments. It seems that three-budded setts generally cannot give the uniform germination as of an individual bud and damage to the setts can cause large gaps along the cane rows. To overcome the poor germination and poor crop stand, the suitable cane treatments, cane sett size and planting methods are essential for commercial sugarcane planting. Based on the above information, it seems that the evaluation of germination is still the critical component in sugarcane cultivation as well as varietal assessment before releasing a new variety (Sanda Kyaw Win and San Thein, 2006).

OBJECTIVES

This study aimed to find out the suitable seed cane treatment for uniform germination and crop stand, and to compare germination percentage and vigorous of sugarcane affected by seed cane treatments and planting methods.

METHODOLOGY

These glasshouse experiments were conducted in 2×4 factorial arrangement in Randomized Complete Block (RCB) design with three replications in Sugarcane Research and Development Farm, Pyinmana. It evaluated on two different planting methods (single budded setts and three budded setts) with three pre-planting treatments which include different levels of lime (0, 7.5, 15, 22.5 g l^{-1}), different levels of topsin fungicide (0, 0.5, 1, 1.5 g l^{-1}) and different degree of hot water (0, 50, 52, 54˚C). Zero (0) levels in each experiment referred to as control treatments. The cane setts used in all treatments were cut into single budded setts and three budded setts before planting. These two sets of cane setts cuttings were soaked in each solution of different pre-planting treatments for 30 minutes.

The numbers of shoots germinated were counted at 3 days interval from 4 to 45 days after planting (DAP). The WGP and FGP were calculated by the equation (1) and (2) (Al-Mudaris, 1998).

$$\text{Weighted Germination Percentage (WGP)} = \frac{[r^{th} \times n_1 + (r-1)^{th} \times n_2 + \cdots + 1^{th} \times n_{15}]100}{15 \times N} \quad (1)$$

Where n_1, n_2,…, n_{15} are the number of cane setts germinated on the 1st, 2nd and consequent days until 45 DAP in each which is multiplied by the counting times, r^{th} (up to 15th count in this experiment). The weighted germination percentage (WGP) was calculated by giving maximum weight to the seeds that germinated first and progressively less weight to that germinated setts subsequently. N is the total number of eye buds placed for germination.

Final germination percentage - Germination count is only based on the number of eye-buds per row, regardless of the cane sett length.

$$\text{Final Germination Percentage (FGP)} = \frac{\text{final number of shoots germinated}}{\text{total number of eye buds seeded}} \times 100 \quad (2)$$

The data were subjected to analysis of variance by using Statistix (version-8) software and mean comparisons were done by Least Significant Different (LSD) at 5% level.

RESULTS AND DISCUSSION

Weighted Germination Percentage (WGP) and Final Germination Percentage of Lime Experiment

There was highly significant different in weighted germination percentage (WGP) in lime experiment. In lime experiment, single budded setts gave faster germination speed, also called WGP than three budded setts overall in Table 1, although they were the same germination percentage at last. There was 482.02% in WGP in single budded sett planting whereas 360.25% WGP in three budded sett planting method. However, there was no difference in the germinated buds at the end, which both accounted for nearly 87% of final germination percentage (FGP). According to Singh and Gurpreet (2015), a small volume of tissue and a single root primordial adhering to the bud are adequate to ensure germination of the bud. This finding was also observed by Chen et al.1981 that pretreatments such as soaking the seed cuttings in solutions of $CaCO_3$, $MgSO_4$, and KOH could enhance the germination of sugarcane cuttings under laboratory conditions.

Fig. 1 shows that different levels of lime treatment were statistically significant in WGP in two planting methods but not in FGP. There was no noticeably different in WGP in each planting methods but single budded sett planting method is superior to three budded sett planting. The lime level (7.5 g l^{-1}) should be selected because of low amount of dosage which would be economical for the farmers.

Table 1 Comparison of WGP and FGP in different levels of treatments in two planting methods

Planting Methods	Lime Experiment		Fungicide Experiment		Hot Water Experiment	
	WGP (%)	FGP (%)	WGP (%)	FGP (%)	WGP (%)	FGP (%)
Single budded setts	482.02 a	87.77 a	493.79 a	92.22 a	367.22 a	75.55 a
Three budded setts	360.25 b	87.22 a	355.05 b	83.88 b	321.82 a	81.66 a
$LSD_{0.05}$	42.87	10.49	33.23	7.86	51.37	9.47
Pr>F	<0.01	0.91	<0.01	0.04	0.08	0.19
CV%	11.63	13.70	8.94	10.20	17.03	13.77

Mean values followed by the same letter in each column are not significantly different at 5% LSD level.

Weighted Germination Percentage (WGP) and Final Germination Percentage (FGP) of Topsin Fungicide Experiment

As in lime experiment, the two planting methods were highly significantly different in WGP in topsin fungicide experiment (Table 1). Single budded sett planting method gave the higher speed of germination than three-eye setts. The WGP in single budded sett was 493.79% which was almost one-third higher than that of three budded sett planting (355.05%).

There was also significant different in final germination percentage in fungicide experiment at LSD 5% level. Single budded sett planting showed the higher germination which accounted for 92.22% compared to the 83.88% in FGP of three budded sett planting (Table 1). Talukder et al. (2007) reported that systemic fungicides helped in improving sugarcane sett germination by the protection from the fungus disease and similarly significantly increased the cane yield.

In Fig. 2, it can be concluded that single budded sett planting was higher in WGP and FGP in each different levels of topsin fungicide treatments. None of topsin fungicide treatments were significantly different with each other in both WGP and FGP except the control treatments (zero level of fungicide which means spraying water only to the plants). Therefore, the lowest level of topsin fungicide (0.5 g l^{-1}) can be recommended to treat the cane setts before planting if the growers wished to use fungicide treatments.

Weighted Germination Percentage (WGP) and Final Germination Percentage (FGP) of Hot Water Experiment

In hot water experiment, there were not statistically different in weighted germination and final

germination in both planting methods (Table 1).

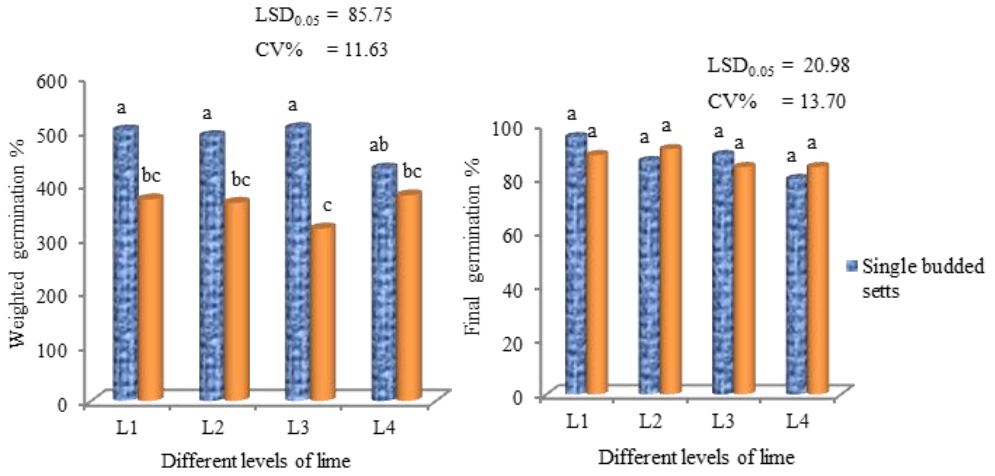

Fig. 1 Weighted germination percentage (WGP) and final germination percentage (FGP) as affected by different levels of lime treatment in two plating methods

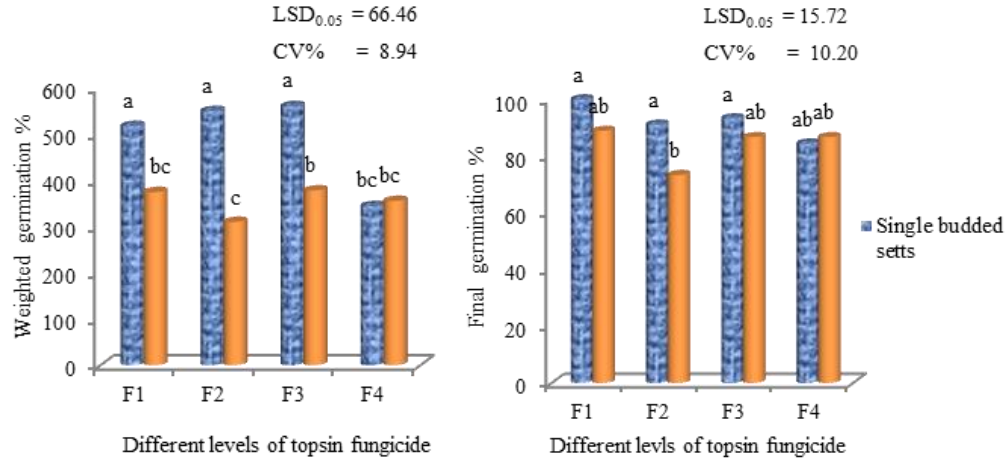

Fig. 2 Weighted germination percentage (WGP) and final germination percentage (FGP) as affected by different levels of topsin fungicide treatment in two planting methods

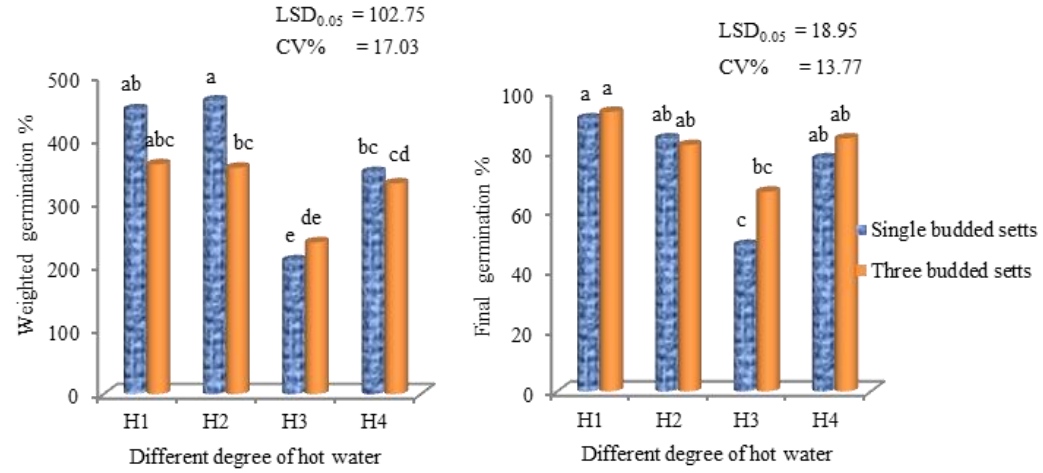

Fig. 3 Weighted germination percentage (WGP) and final germination percentage (FGP) as affected by different degree of hot water treatment in two planting methods

However, the combined effect of planting methods and different levels of hot water treatments were significantly different in both WGP and FGP (Fig. 1). The hot water level (52˚C) showed the highest percentage in WGP in both planting methods which was not statistically differ from 50˚C of hot water. The slowest speed of germination was observed at the hot water level (54˚C). Trippi (1961) stated that the germination of the buds in sugarcane cuttings was stimulated by hot water treatment at 50˚C. Similarly, Goodall (1998) reported that ratoon stunting disease is eliminated and germination is not unduly adversely affected by using the shortening heat treatment.

CONCLUSION

In conclusion, these experiments were conducted to determine the suitable seed cane treatment for sugarcane germination which will support for the farmers in choosing the seed cane treatment before planting. In addition, the experiment can reveal the suitable planting method for the farmers who normally familiar with the three budded sett planting techniques in Myanmar.

The results showed that single budded sett planting gave the higher germination percentage in terms of speed and the final germinated buds. Single budded sett planting were higher in WGP than those of three budded sett planting method in both lime and topsin fungicide treatments.

Among the different levels of treatments, the lowest levels of lime, topsin fungicide and hot water degree showed the higher percentage and speed of germination in both planting methods. As a recommendation, this research should be undertaken for further study in different regions and different seasons of the country to verify the strong result in sugarcane cultivation.

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REFERENCES

Al-Mudaris, A.M. 1998. Notes on various parameters recording the speed of seed germination. Der. Tropenlandalrt, 2, 147-154.

Chen, J.B., Lo, C.C., Yang, C.P. and Ho, W.F. 1981. Effect of freshness and pretreatment on the germination of seed cuttings of sugar cane variety ROC 1. Rept., Taiwan, Sug. Res. Inst., 93, 1-10.

Croft, J.B. 2000. Literature review of improving the germination of sugarcane. Sugar Research Australia Ltd. Bureau of Sugarcane Experiment Stations Queensland, Australia. 15.

Dillewijn, V.C. 1952. Botany of Sugarcane. The Chronica Botanica Co., Waltham, Mass. 371.

Goodall, L.J. 1998. Factors affecting germnation and growth of sugarcane tranplants. Master of Science. Department of Microbiology and Plant Pathology, University of Natal, 170, Pietermaritzburg.

MOAI. 2005. Myanmar agriculture planning. Master Plan from 1999-2000 to 2029-2030, Ministry of Agriculture and Irrigation, Myanmar.

Netsanet, A., Abiy, G., Tadesse, N. and Zinaw, D. 2014. Effect of planting density on yield and yield effect of planting density on yield and yield. Scholarly Journal of Agricultural Science, 4 (12), 583-586.

Patel, D. and Rinku, P. 2014. Influence of sett size, seed rate and sett treatment on yield and quality of sugarcane. The Bioscan, 9 (1), 55-57.

Singh, G. and Gurpreet, K. 2015. Infusion of single bud chip planting technique for sugarcane propagation. Journal of Economics and Development, 11 (1), 10-15.

Sundara, B. 1998. Sugarcane cultivation. Vikas Publishing House Pvt. Ltd., 156-234, New Delhi.

Talukderr, I.M., Begum, F. and Azad, M.K.M. 2007. Management of pineapple disease of sugarcane through biological means. J. Agric. Rural Dev., 5 (1 and 2), 79-83.

Trippi, V.S. 1961. Action of hot and cold water on the germination of cane. Sugar Azucar, 56 (10), 38.

Win, K.S. and Thein, S. 2006. Effects of variety, methods of fertilizer placement, and seed-pieces treatments

on germination response of sugarcane. Proceeding of Second Agricultural Research Conference, 236-237, Yezin, Nay Pyi Taw.

Research article

Equivalency and Similarity Assessment of Forest Ecosystem Services by a Multi-Point Field Survey in Nagoya City, Japan

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Abstract Urban forests provide a variety of benefits to citizens, including micro climate regulation, soil erosion regulation, and wildlife habitats. Under the biodiversity offset system, the equivalency and similarity of biodiversity and ecosystem services (BD/ESs) are important but controversial issues. The purpose of this study is to develop a simple method to assess aspects of the equivalency and similarity of forest BD/ESs and consider their applicability to biodiversity conservation policy. The study was conducted on a selection of 41 forests in Nagoya City. Several combinations of forests were recognized as similar providers of BD/ESs. Historical land-use change was also important in assessing forest equivalency and similarity for biodiversity conservation policy.

Keywords ecosystem service, biodiversity, forest, Japan, GIS

INTRODUCTION

Urban forests provide many benefits to citizens, including micro climate regulation, soil erosion regulation, and habitats for wildlife. According to the Millennium Ecosystem Assessment (MA, 2005), these benefits can be summarized as ecosystem services (ESs) provided to human society. There are several types of forest, including urban parks, secondary forests, and natural forests. Each plays a different role in providing biodiversity (BD) and ESs. Despite their proven benefits, urban forests in Japan have been decreasing over the past several decades. Biodiversity offsets (BO) are a policy instrument developed to compensate for the loss of BD by development activities (BBOP, 2013). Madsen et al. (2010) summarized the global state of BO systems, and reported that the USA and Australia are experienced in this field. In contrast, there is no legal requirement to conduct BO in Japan on the national scale, although a basic guideline of the environmental impact assessment law recommends compensating for the impacts of a development project on BD (MOE-J, 2014).

Many issues related to the BO system have been identified, including metrics, ecological equivalency, and no-net loss (Maron et al., 2012; Bull et al., 2013; Koyama and Okabe, 2017). Additionally, the positive outcomes of BO have occasionally been overestimated (Pickett, 2013; Gibbons et al., 2017). Nevertheless, BO has been recognized as a biodiversity conservation policy and its potential use has been studied (MOE-J, EIA Division, 2014), with a focus on important issues such as gains and losses of biodiversity in the BO system. Many BO related assessment methods have been implemented and studied (Quétier and Lavorel, 2011), including the Habitat Hectares method (The State of Victoria, https://www.environment.vic.gov.au/native-vegetation /native-vegetation), and the BioBanking assessment methodology (The State of New South Wales, http://www.environment.nsw.gov.au/biobanking/assessmethodology.htm), both in Australia. Another study focused on the development of objective and transparent BO assessment methods

(Gibbons et al., 2009). Koyama and Okabe (2017) summarized many issues related to the potential application of the BO system in Japan. Several case studies have also touched on the applicability of BO methods in Japan (Hasegawa and Hayashi, 2014; Ito and Hayashi, 2014). However, not only species, habitat, and ecosystems, but also the similarity of potential ESs needs to be considered in the future (MOE-J, EIA-Division, 2014; Koyama and Okabe, 2017). In the study on supporting and regulating ESs, Yonekura et al. (2014) categorized forests into several types based on a simple field survey for 52 forests in Nagoya. Hayashi and Ooba (2017) analyzed the categorization of cultural ESs (CESs) based on a multi-point field survey for 180 forest sites in Nagoya City. These studies were limited both in the scope of ESs covered and in the assessment items included in the survey. A comprehensive assessment of BD/ES potential is needed in order to develop a simple assessment method.

OBJECTIVES

The purpose of this study is to develop a simple method, one that could be used in the development of biodiversity conservation policy, to assess the equivalency and similarity aspects of forest BD/ESs. To this end, a case study was done in Nagoya City using a multi-point field survey. The scope of this study was expanded to cover a variety of BD/ESs, in contrast with the study of Hayashi and Ooba (2017), which focused only on cultural ESs.

METHODOLOGY

Study Method

Nagoya City (city hall: 35.181°N, 136.906°E) is the third largest city in Japan. The study area is presented in Fig 1. The average annual temperature and precipitation in 2017 were 15.9°C and 1701.5 mm (Japan Meteorological Agency, http://www.data.jma.go.jp/obd/stats/etrn/index.php).

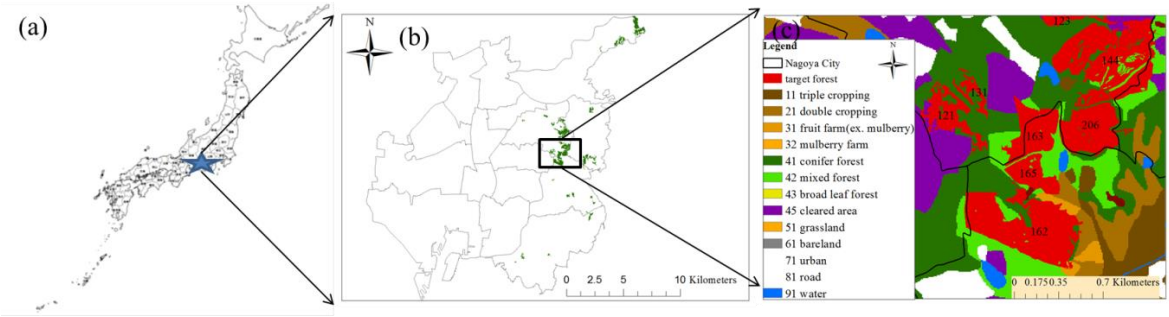

Fig. 1 Maps of (a) Japan with Nagoya City as a star symbol, (b) Nagoya City outlined in black and forest in green, and (c) a sample of targeted forests with 1955 land use map
Source: Forest by Nagoya green coverage GIS (Nagoya City) and 1955 Land-use maps by GSI (1955)

In this paper, forests were defined as the continuous tree crown area within a forest area ≥1 ha. Based on the Nagoya green coverage GIS (geographic information system) data provided by Nagoya City, around 200 forests (of around 240 total forests in the city) have been surveyed since 2012. The survey items included species; the diameter at breast height (DBH ≥ 5cm); tree height; litter thickness; over-, mid-, and understory canopy cover (assessed visually); and naturalness. The items, proxies, methods, and data are summarized in Tables 1 and 2. The carbon stock estimation method is explained below. The surveys were conducted in a similar manner to Hayashi and Ooba (2015). A second round surveys (referred to hereafter as the 2nd survey) on the same forests was begun in 2016, including additional items and expanding the survey coverage to a 300 m^2 area. In some cases, the location of the site had to be changed to allow the extension of survey coverage area. For several forests, new 200 m^2 sites were set up in addition to the original 100 m^2 sites. In

this study, the results from the 2nd survey were used along with several first round results that had enough data for this analysis. Bamboo was counted as one independent species, and the number of individual trees included the number of individual bamboo trees (counted only within 100 m^2 and converted to the 300 m^2 value). The 2nd survey is not yet complete for all targeted forest sites. For this study, 41 forest sites were selected.

Table 1 BD/ES items, proxies, methods and data

BD/ES	Item	Proxy	Method	Data
BD	Conservation area	C_A	Check special green conservation areas designated by Nagoya City and Aichi Pref.	Nagoya City urban planning information providing service, URL: http://www.tokei-gis.city.nagoya.jp/
	Habitat size	Forest area	Continuous tree crown areas (≥ 1ha)	Nagoya green coverage GIS(Nagoya City)
	Species diversity	Simpson' DI	Details in Table 2	
	Naturalness	Naturalness	Subjective judgement on a scale of 1 to 5 scale by the author	Based on field survey
RES	Micro climate regulation	Forest volume	Details in Table 2	
	Soil erosion regulation	Forest flow cover	Details in Table 2	
SES	Carbon Stock	C-Stock	Details in the main text	
	Soil formation	Litter (thickness)	Three points in each 100 m^2 area and averaging the results of several visits	Based on field survey

Table 2 BD/ES estimation methods

ESs	Description	Formula
Species diversity	The diversity of species is an important indicator for explaining the ecological community diversity. Hasegawa and Hayashi. (2014) compared several diversity related indexes including Simpson' Diversity index (*Simpson's DI*) to the results of a BO assessment methodology. In this study, *Simpson' DI* was used to explain within-habitat diversity in Formula 1 (Simpson, 1949; Morishita, 1996; Ohgaki, 2008). Individual species and the number of the species were used to calculate *Simpson' DI*.	$Simpson'DI = 1 - \Sigma\left(\frac{n_i}{N}\right)$ (1) N : number of individuals n_i : number of each species
Micro climate regulation	Hiruta and Ishikawa (2012) studied the heat-reduction effect by green spaces, which compared three indicators: forest canopy coverage, tree volume, and ground coverage. They concluded that tree volume had the largest effect on the heat-reduction, especially for daytime in summer. Our study focused on the micro climate regulation in a summer daytime. Forest volume was picked out as a proxy in this study by Formula 2 using forest cover and average tree heights (DBH ≥ 5 cm) (Kobayashi et al., 2016). The height of bamboo trees (only 5 selected bamboo trees were measured in the bamboo forest) were included in the average tree heights and forest cover.	$V_i = 10^4 * (C_{ov}H_{ov} - (1 - C_{ov})C_{mid}H_{mid}) + (1 - C_{ov})(1 - C_{mid})C_{und}H_{und}\}$ (2) Vi : forest volume in 100 m^2 site i (m^3/ha) C_{ov} : overstory cover (10 m<) C_{mid} : midstory cover (10 m≥, >5 m) C_{und} : understory cover (5 m≥, > 1m) H_{ov} : average height of overstory trees (m) H_{mid} : average height of midstory trees (m) H_{und} : average height of understory trees (m)
Soil erosion regulation	For soil erosion regulation, Chu et al. (2010) studied the relationship between forest floor cover and soil erosion. They concluded that the total forest floor cover (understory and litter cover) was correlated with soil erosion rate in the case of Tanzawa mountain area, Japan. In this study, forest floor cover was selected as a proxy for soil erosion regulation. Forest floor cover was the totaled score of understory tree (0 to 1 m height), grassland, bamboo grass and fern coverages with litter coverage averaged by several visits through the field survey in 100 m^2 site by the author's visual judgement.	$C_{forest} = C_{und} + \{(1-C_{und})C_{lit}\}$ (3) C_{forest} : forest floor cover(%) C_{lit} : litter cover(%) C_{und} : understory cover (%, understory tree (0-1m), grassland, bamboo grass and fern)

In Hayashi and Ooba (2017), CES forest use in Nagoya was evaluated subjectively (n=180). Seven CES items (CES7) were developed, taking into account four basic parameters: forest area, scenic districts (S_D), shrine or temple (S_T), and major attraction facilities listed by the city (A_F). Then a clustering analysis was conducted to categorize forests into several types. The results of the clustering analysis were used as the CES values in this study.

For the carbon stock survey, DBH (≥ 5 cm) and the tree height (*H*) were measured by a 15 m tree height pole (SK measurement pole AT-15, Senshin Industry Co.) supported by a Laser range finder (Nikon Laser 550A S) to calculate above ground biomass (*AGB*) as in Kobayashi et al. (2019). First, DBH and *H* were measured for each tree in a 100 m^2 area. *H* was only measured for 100 m^2 sites, so the *H* of the 300 m^2 sites were estimated by Formula 4 (Matsumura, 2003). The values of *a* and *b* were estimated by using the DBH and *H* values for conifer-, deciduous- and evergreen broad leaf trees measured in the 100 m^2 area. The values of DBH and *H* used to estimate *a* and *b* were taken from the 41 forests for which a 100 m^2 area had been surveyed, along with values from additional four sites in the city (in total 45 sites). Yamamoto (1985) and Matsumura (2003) compared several tree height curves including Näslund, Allometry referring to Nishizawa (1972). In this study, the Näslund equation was used for coniferous, deciduous, and evergreen forests based on Matsumura (2003). These results are summarized in Table 3. By using DBH and *H*, the *AGBs* of each tree were estimated based on Tadaki et al. (2004) in Formulas 5 and 6. Underground biomass was assumed to be one fourth of *AGB* and the carbon content of the biomass was assumed to be 4/9 of the total biomass as in Tadaki et al. (2004). According to Tadaki et al. (2004), the AGB_{con} was estimated to apply for Japanese red pine (*Pinus densiflora*). This was tentatively used for other conifer trees in this study.

For the *AGB* of bamboo trees, Okuda et al. (2006) developed a simple estimate (Formulas 7 to 9). Averaged DBH of bamboo trees for 5 selected individuals were used for the estimation, multiplied by the number of bamboo trees in each 100 m^2 site with 4/9 of carbon content. In the case of no bamboo tree in a 100 m^2 site, a 100-300 m^2 converted figure was used as a 100 m^2 value.

Lastly, the number of dead trees was roughly estimated by Formula 5 and 7 on the 100 m^2 sites by visual estimation of the DBH (≥ 5 cm) and length of dead trees, and using the average *H* of bamboo trees. After that, all the carbon contents including tree carbon, tree *AGB* of bamboo and dead trees were summed to obtain carbon stock per ha.

Table 3 Estimated equation parameters

	a	b
Evergreen broad leaf tree (n=586)	1.4089	0.2109
Deciduous broad leaf tree (n=210)	1.2622	0.2017
Conifer tree (n=16)	1.2092	0.2161

Note: R^2 values 0.918, 0.965 and 0.937, respectively.

$$\frac{DBH}{\sqrt{H}} = a + b * DBH \quad (4)$$

H : tree height

$$AGB_{br} = 0.0601*(DBH^2 * H)^{0.901} \quad (5)$$

$$AGB_{con} = 0.0278*(DBH^2 * H)^{0.990} \quad (6)$$

a, b : parameters ; AGB_{br} : AGB of broad leaf tree

AGB_{con} : AGB of Japanese red pine (*Pinus densiflora*)

$$AGB_{bam\text{-}cul} = 0.0845 * DBH^{2.2275} \quad (7)$$

$$AGM_{bam\text{-}bra} = 0.047 * DBH^{1.5989} \quad (8)$$

$$AGM_{bam\text{-}le} = 0.0097 * DBH^{1.8388} \quad (9)$$

$AGB_{bam\text{-}cul}$: AGB of bamboo culm; $AGM_{bam\text{-}bra}$: AGB of bamboo branch

$AGM_{bam\text{-}le}$: AGB of bamboo leaf

The proxies defined above were normalized by dividing each proxy value by the maximum value of that proxy, and then the equivalency and similarity of several aspects of the forest BD/ESs were evaluated. First, correlations among the proxies were investigated by the Pearson correlation and the Spearman's rho. Second, the 41 sites were classified by forest type. Conservation areas were treated as a separate category. Third, for each forest type, forests were ordered by BD scores and categorized into four groups (A to D). Fourth, within each group forests in the same CES7 category defined by Hayashi and Ooba (2017) were compared to each other. Finally, the land-use

changes from 1955 to 2017 were taken into consideration in conjunction with the distance between sites. The land-use maps of 1955 provided by the Geospatial Information Authority of Japan (GSI) were digitized for analysis on the 10 m grid scale approximately as in Kobayashi et al. (2016, 2019). Four land-use maps were used, namely Nagoya north, Nagoya south, Koromo, and Seto.

The statistical analysis was conducted using Excel version 2010 (Microsoft) and SPSS statistics v.22 (IBM). ArcGIS 10.4.1 (ESRI Japan Inc.) was used for the spatial analysis.

RESULTS AND DISCUSSION

The results of the correlations among the proxies are presented in the Table 4. BD (C_A) was well correlated with RES (Forest_volume) and SES (C-stock and litter). RES (Forest_volume) was significantly correlated with SES (C-stock). Generally, some of the BD proxies were positively correlated with some of RES and SES proxies. BD (C_A) showed a positive correlation with CES (shrine/temple and cultural heritage value; 0.471^{**} and 0.473^{**}, respectively) and a negative correlation with CES (daily recreation, holiday recreation and education; -0.343*, -0.499** and -0.387*, respectively by the Spearman's rho). In Nagoya, conservation areas were located mostly in shrine/temple and recreational activities were not common in these as a whole.

The most frequent forest type classification was forest type 2 (secondary forest composed of deciduous broad leaf tree), with 31 sites, followed by type 5 (evergreen broad leaf forest, 8 sites). Four type 2 sites were conservation areas, which are important for the protection of natural habitats and were thus treated differently. In total, 31 type 2 sites were used for further analysis.

After ordering by BD score, these 31 sites were categorized into 4 groups: A (BD <0.30); B (0.30≦ BD <0.45); C (0.45≦ BD <0.60); and D (0.60≦ BD). Fig. 2 shows the total score of each forest ordered by total score of BD, RES and SES. Within each group, these total scores were similar. However, the CES scores of the groups were very different. Fig. 3 compares the average scores in each group from A to D. The RES and SES scores of each group were similar except for BD (C_A and forest area).

Next, we employed the CES7 categories from Hayashi and Ooba (2017) to divide group B into sub-categories (B1 to B5). Fig. 4 presents the results of this categorization. The characteristics of the BD, RES, and SES scores were similar within sub-categories (Fig. 4 (a)). However, the CES proxy scores differed by sub-category (Fig. 4 (b)).

Finally, the relative site distances were investigated using GIS, and sites within 100 m and 500 m of each other were selected for further analysis. After checking the shrine and temple location factor and the cultural heritage factor, which were traditional aspects, land-use changes from 1955 to 2017 were considered. The results are shown in Table 5. Six site combinations were recognized as being potentially similar. Referring to the old land-use maps, in several of the 100 m distance combinations, both sites were located within the same or neighboring forests in the past. This means that from the perspective of this analysis, these site

Table 4 Proxy correlations

	Forest_ volume	Forest floor cover	C-Stock	Litter
C_A	0.310 *	-0.108	0.419 **	0.353 *
Forest area	-0.001	0.079	0.243	0.175
Simpson' DI	0.047	0.301	0.242	0.305
Forest_ volume	1.000	0.062	0.532 **	0.147

*: *Pearson Correlation is significant at the 0.05 level (2-tailed).*
**: *Pearson Correlation is significant at the 0.01 level (2-tailed).*

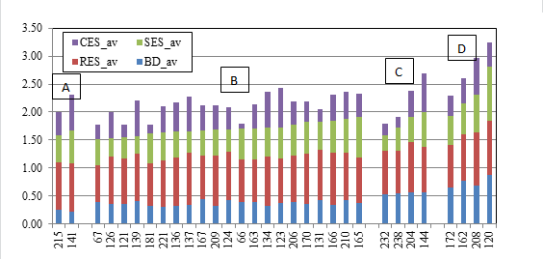

Fig. 2 BD, RES, SES and CES scores by site

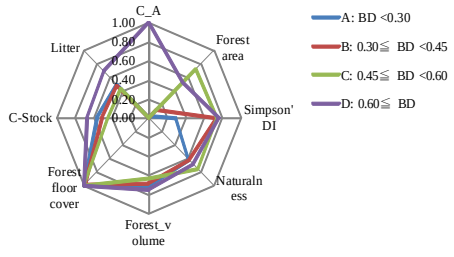

Fig. 3 Radar chart of BD, RES and SES for A to D

pairs had high similarity. Over the past several decades, these forest sites were fragmented by urbanization. Two site pairs within 500 m of each other were cemeteries in the past, according to the land-use data. More data on past forest locations (such as old aerial photographs) is needed. The equivalency and similarity assessment presented here could be used for a BO assessment once the scope of the BD/ES items has been extended.

CONCLUSION

This study focused on the development of a simple method for evaluating the equivalency and similarity aspects of forest BD/ESs through a multi-point field survey in Nagoya City. This method is potentially applicable to biodiversity conservation policy. Eight items from BD, RES, and SES, along with several CES items from Hayashi and Ooba (2017), were selected for assessment. Finally, several combinations were identified that were recognized as providing similar BD/ESs. Historical land-use change was found to be crucial to allow better judgement of forest equivalency and similarity in carrying out assessments for biodiversity conservation policy, which have been pointed out from the context of ES conservation in Ooba et al. (2015).

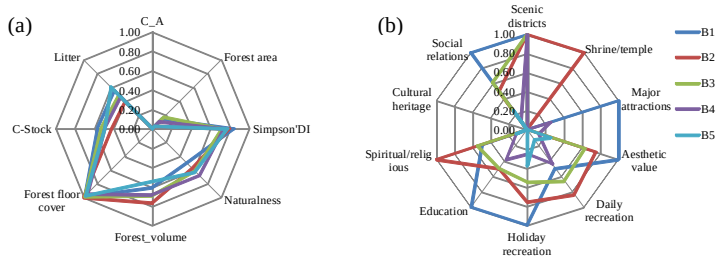

Fig. 4 Radar charts of (a) BD, RES and SES and (b) CES

Table 5 Equivalency and similarity aspects in forest type 2

Distance	Category	Sub-category	Site ID	Old land-use
≦100m	B	B3	163,165	Same mixed forest
	B	B3	163,206	Neighboring mixed and conifer forest
	B	B4	121,131	Same conifer forest
≦500m	B	B2	134,139	Same cemetery
	B	B2	137,139	Same cemetery
	B	B3	166,167	One was conifer forest with cleared area. The other was mixed forest. Both were separated by agricultural land

The remaining issues can be summarized as follows. First, this study only includes the survey results at 41 forests. Further field surveys covering the remainder of the forests in Nagoya City are needed. Second, in this study 8 BD/ESs items were used. However, after completion of the forest surveys, a wider variety of items should be considered. For example, fish-eye cameras, vegetation coverage by 50 m transect survey, and variable species distribution would be useful.

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REFERENCES

Bull, J.W., Suttle, K.B., Gordon, A., Singh, N.J. and Milner-Gulland, E.J. 2013. Biodiversity offsets in theory and practice. Oryx, 47 (3), 369-380.

Business and Biodiversity Offsets Programme (BBOP). 2013. To no net loss and beyond, An overview of the Business and Biodiversity Offsets Programme (BBOP). Washington, D.C., USA.

Chu, L., Ishikawa,Y., Shiraki, K., Wakahara T. and Uchiyama, Y. 2010. Relationship between forest floor cover percentage and soil erosion rate on the forest floor with an impoverished understory grazed by deer (*Cervus Nippon*) at Doudaira, Tanzawa mountains. J. Jap. Forest Society, 92, 261-268. (in Japanese).

Gibbons, P., Macintosh, A., Constable, A.L. and Hayashi, K. 2017. Outcomes from 10 years of biodiversity offsetting. Global Change Biology, 2018, 24, e643-e654.

Gibbons, P., Briggs, S.V., Ayers, D., Seddon, J., Doyle, S., Cosier, P., McElhinny, C., Pelly, V. and Roberts, K. 2009. An operational method to assess impacts of land clearing on terrestrial biodiversity. Ecological Indicators, 9, 26-40.

Hayashi, K. and Ooba, M. 2017. Spatial assessment of cultural ecosystem services for urban forests based on a multi-point field survey, Case in Nagoya City, Japan. Int. J. Env. Rural Dev., 8 (2), 75-81.

Hayashi, K. and Ooba, M. 2015. A framework study on the methodology of biodiversity offset assessment in Japan-Hypothetical case of GIS screening and on-site field assessment. IAIA15 Web Proceedings, http://conferences.iaia.org/2015/final_papers.php (accessed on Jan. 28, 2018).

Hasegawa, Y. and Hayashi, K. 2014. A study on the biodiversity assessment method for urban forest in Nagoya, Japan, A comparative analysis of habitat hectares scoring method in Australia to several diversity indexes. The Japan Society for Impact Assessment, Papers, 12 (2), 49-62. (in Japanese).

Hiruta, Y. and Ishikawa, M. 2012. Research on indicators for evaluating the heat-reduction effect of green spaces. Journal of the City Planning Institute of Japan, 47 (3), 259-264. (in Japanese).

Ito, H. and Hayashi, K. 2014. Forest evaluation method using integrated SI models, A case study in urban forest in Nagoya, Japan. IAIA, 14, Web Proceedings, http://conferences.iaia.org/2014/final-papers.php (accessed on Jan. 14, 2018).

Kobayashi, W., Hayashi, K. and Ooba, M. 2019. Comparative study of the ecosystem service supply potential of 1955 and the current situation using a case study in West Aichi, Japan. Journal of Human and Environmental Symbiosis. (in press, in Japanese).

Kobayashi, W., Hayashi, K. and Ooba, M. 2016. Temporal and spatial assessment of ecosystem services in 1955 and 2008, Case study in Nagoya and its suburbs, Japan. IAIA, 16, Web Proceedings, http://conferences.iaia.org/2016/ (accessed on Jan. 18, 2018).

Koyama, A. and Okabe, K. 2017. Ecological issues in achieving no net loss of biodiversity offsets. Bulletin of FFPRI, 16 (2) (No.442), 61-76. (in Japanese).

Madsen, B., Carroll, N. and Moore, B.K. 2010. State of biodiversity markets report: Offset and compensation programs worldwide. http://www.ecosystemmarketplace.com/documents/acrobat/sbdmr.pdf (accessed on Jan. 18, 2018).

Maron, M., Hobbs, R.J., Moilanen, A., Matthews, J.W., Christie, K., Gardner, T.A., Keith, D.A., Lindenmayer, D.B. and McAlpine, C.A. 2012. Faustian bargains? Restoration realities in the context of biodiversity offset policies. Biological Conservation, 155, 141-148.

Matsumura, N. 2003. Applicability of height curve derived from the theory of column buckling. Proceedings of the Institute of Statistical Mathematics, 51 (1), 11-18. (in Japanese).

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

Ministry of the Environment, Japan (MOE-J). 2014. Basic matters of competent minister's guideline based on the provision of the Environmental Impact Assessment Law revised in June 2014. Ministry of the Environment, Japan. (in Japanese).

MOE-J, EIA Division. 2014. Toward implementation of biodiversity offset in environmental assessment in Japan (draft). 62, Ministry of the Environment, Japan. (in Japanese).

Morishita, M. 1996. On the influence of the sample size upon the values of species diversity. Japanese Journal of Ecology, 46, 269-289. (in Japanese).

Nishizawa, M. 1972. Forest measurement (shinrin sokuteiho). Nourin publication (nourin shupan). (in Japanese).

Ohgaki, S. 2008. Diversity and similarity, taxonomical new indicators (Tayodo to ruijido, bunruigakuteki shinshihyo). Argonauta, 15, 10-22. (in Japanese).

Okuda, S., Torii, A., Ito, T., Uemura, T., Sasaki, T., Ito, T., Kimura, M., Toyota, N., Sado, Y., Yamada, T., Yamada, M., Ito, T. and Takeuchi, I. 2006. A simple method of above ground biomass of bamboo (Take no chijyoubugenzonryo wo kani ni suitei suru). Forestry and Forest Products Research Institute, https://www.ffpri.affrc.go.jp/pubs/seikasenshu/2006/documents/p42-43.pdf (in Japanese).

Ooba, M., Hayashi, K., Suzuki, T. and Li, R. 2015. Analysis of urban ecosystem services considering conservation priority. Int. J. Env. Rural Dev., 6 (2), 66-72.

Pickett, E.J., Stockwell, M.P., Bower, D.S., Garnham, J.I., Pollard, C.J., Clulow J. and Mahony, M.J. 2013. Achieving no net loss in habitat offset of a threatened frog required high offset ratio and intensive monitoring. Biological Conservation, 157, 156-162.

Quétier, F. and Lavorel, S. 2011. Assessing ecological equivalence in biodiversity offset schemes, Key issues and solutions. Biological Conservation, 144, 12, 2991-2999.

Simpson, E.H. 1949. Measurement of Diversity. Nature, 163, 688.

Tadaki, Y., Hirano, A., Sannabe, H., Kawaguchi, J., Hiraizumi, T. and Hoshino, D. 2004. Net production of a secondary broadleaf forest on Nagoya University Campus. Nagoya University Forest Science, 23, 9-13.

Yamamoto, M. 1985. Height curve derived from the theory of column bucking. Bull, Fac. Agr. Shimane Univ, 19, 29-33 (in Japanese).

Yonekura, Y., Hayashi, K., Hasegawa, Y. and Ooba, M. 2014. Biodiversity assessment of Japanese urban forests - toward a comprehensive assessment of ecosystem services of urban forests in Nagoya, Japan -. IAIA, 14, Web Proceeding, http://conferences.iaia.org/2014/final-papers.php (accessed on Jan. 14, 2018).

Research article

Theme-Community Based Adaptation Strategies Toward Sustainable Rural Development: Case from a Local Tofu Company in Saitama Prefecture, Japan

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Abstract There are several past researches conducted on "theme-community" wherein the initiatives and/or relationship among stakeholders focus on a certain product or concept regardless of traditional political boundaries. This paper focuses on tofu or its raw material, soybean. Tofu is one of the main soybean processed products and an integral part of a traditional meal in Japan. Although the amount of its domestic production and consumption have only changed slightly, the number of tofu companies have been drastically decreased from 50,000 in 1960 to 8,000 in 2014. This can be attributed to the inability of small-scale tofu companies to compete with prevalent mass production of large-scale processing companies, and to respond to the demand of supermarkets for much lower retail price. In order to provide possible ways to gain resiliency for local small-scale companies, this study aims to determine the adaptation strategies of a local tofu company in Saitama Prefecture, Japan using the case study approach. Company visits and key informant interviews revealed that the local tofu company conducted (1) product development in accordance with season, farming community and consumer demand, (2) introduction of TEIKEI for soybean farmers, and (3) implementation of innovative selling activities. Moreover, these initiatives further paved way for sustainable rural development. For further study, there is a need to determine the development of its partnership with and its respective impact to the local soybean farmers.

Keywords organic farming, soybean, TEIKEI, product development, selling

INTRODUCTION

There are several past researches conducted on "theme-community"[1)] wherein the initiatives and/or relationship among stakeholders focus on a certain product or concept regardless of traditional political boundaries. This paper focuses on tofu or its raw material, soybean. Tofu is one of the main soybean processed products and an integral part of a traditional meal in Japan. Although the amount of its domestic production and consumption have only changed slightly, the number of tofu companies have drastically decreased from 50,000 in 1960 to 8,000 in 2014 (Zentoren, 2017). This can be attributed to the inability of small-scale tofu companies to compete with prevalent mass production of large-scale processing companies, and to respond to the demand of supermarkets for much lower retail price.

In order to provide possible ways to gain resiliency[2)] for local small-scale companies, this study aims to determine the adaptation strategies of a local tofu company (thereafter, LTC) in Saitama Prefecture, Japan using the case study approach.

METHODOLOGY

This study utilized the case study approach using both qualitative and quantitative data. This focuses on the experiences of LTC operating in Tokigawa, Saitama Prefecture, Japan since 1946. Tokigawa Town, which is located North-West of Tokyo, has a land size of 55.9 sq. km. and population of 11,488 persons (TOT, 2017). Primary data were gathered from company visits and key-informant interviews with President W (thereafter, PW) conducted in June and December 2015, and November 2016. Gathered information included company profile and vision, company development, relationship with other stakeholders, usage of locally-grown soybeans to name a few. Moreover, preliminary and additional information were also gathered from the special lectures given by PW about his tofu company during the Shimosato Farm Tour[3)] in May 2015 and 2016, respectively.

RESULTS AND DISCUSSION

Profile of LTC

Table 1 shows the highlights on how LTC developed as a company, which was initially established as a family-managed konnyaku (jelly-like cake made from konnyaku flour) store by the founder (father of PW) in 1946. Since konnyaku showed to be unsellable during summer, the family also engaged in tofu business in 1951. Selling activities was mainly conducted by peddling in 1955, and expanded to wholesale selling to local stores of food, vegetables and/or fish in 1965. PW took over the business in 1979 when he realized that the founder was heavily affected by the passing of his mother. This was also the time when PW, as then college graduate, gave up his dream to be an accountant.

Table 1 Highlights on the Development of LTC

Year	Events
1946	Founder (Father of the current president) established a family-managed konyaku store in Myokaku Village (Presently known as Tokigawa Town)
1951	Engaged in family-managed tofu business
1955	Mainly sold tofu by peddling
1965	Started wholesale selling tofu in local stores of food, vegetable and/or fish
1979	Mother of PW passed away
	Took over the business from founder
	Shifted to retail selling at supermarkets as main channel
1985	Experienced business challenges due to extreme price competition among supermarkets
1992	Started construction for tofu factory expansion
	Secured parking lots for three (3) delivery vans
1993	Met with organic farmers and consumers who prefer organic / natural produce
1997	Shifted to direct store selling with "Territorial Development with Cultural Identity" as a management policy
2002	Started being supplied by local farmers from Hatoyama Town, followed by Ogawa Town
	Made improvements in the main store
2003	Converted family business to a limited company (LTC) with 10 million yen capital
2004	Founder passed away
	Received the Saitama Governor Award for Agriculture and Forestry Division specifically for its
2005	local production-local consumption initiatives
	Moved the main store to new location for establishment of disposal facility and expansion of parking space, and improvement of production/selling operations
	Received the Minister of Agriculture, Forestry and Fisheries Prize as the Best Food Retail Store
2006	(National Competition)
2007	Reached 340 million yen in sales
2012	Received The Mainichi Newspaper Agriculture Record Award
	Started mobile store

Source: Key-Informant Interviews, June 2015, December 2015 and November 2016.

In the early 1980s, most tofu companies were mainly dependent on supermarkets as main channel. However, the price competition among supermarkets became extreme in 1985. Supermarkets lowered the price from 80 yen per to 30 yen (US$1 = 119.49 yen, Mitsui Sumitomo Bank, 1 December 2017) per pack to attract more customers. However, this resulted to great financial burden for tofu companies, including LTC. In PWs search for other business options, PW had the opportunity to start exchanging ideas with organic farmers (including Mr. Kaneko of Shimosato Farm, pioneer organic farmer in Ogawa Town, Saitama) and consumers who prefer organic/natural produce in various study groups and events since 1993. By 1997, PW reformulated its management policy to a company focusing on Territorial Development with Cultural Identity. Specifically, PW "believes that safe and good quality foods are made based on good human relationships. Thus, the store will continue to keep promises to the society and to serve as the bridge for local farmers and consumers brought together by tofu making." In order words, connectedness with and among local farmers, customers, employees and other stakeholders are significantly valued. In the same year, transactions with local farmers from Hatoyama and Ogawa Towns were initiated.

In order to fulfill the management policy, improvements were made in the main store and PW converted family business to a limited company in 2002, then the store moved to the current location in 2005 to improve its production and selling operations, and its service to valued customers.

Currently, LTC employs about 50 persons, including part-time, mostly residing within 15 km away from the store, conveying that LTC also supports local employment. In addition to its own local produce for local consumers, it also supports local farmers by allocating a corner at its store for local vegetable, flowers and other local products. Since 2006, the annual company sales have been more than 300 million yen.

In recognition to LTCs various efforts and initiatives, PW has received various awards such as Saitama Governor Award (2004), Minister of Agriculture, Forestry and Fisheries Prize as the Best Food Retail Store (2005) and The Mainichi Newspaper Agriculture Record Award (2007).

Adaptation Strategies

Soybean-based TEIKEI: In order for LTC to offer various tofu products made from locally-produced soybeans, LTC gives value and support to its soybean farmers through TEIKEI system. LTC president first heard about TEIKEI[4)] (Producer-consumer co-partnership that is not limited to buying-selling transaction) from Mr. Kaneko of Shimosato Farm and wanted to make a Soybean-Based TEIKEI. Currently, LTC's basic policy in purchasing soybeans are (1) price is set at a point wherein farmers can sustain its operations and replant for next season; (2) all harvested soybeans are purchased; and (3) all payments are made in cash only.

Table 2 Local Soybean Supply of LTC by Location and Variety, 2014[1)]

Location	Soybean variety (kg)					Total
	Aoyama Zairai[2)]	Miyagi Shiromi	Sato Irazu	Shakin Nashi	Tanba Kuromame	
Kumagawa City	48,383	0	0	360	138	48,743
Ranzan Town	0	4,350	9,900	2,730	0	16,980
Ogawa Town[3)]	13,590	0	0	0	0	13,590
Kawagoe City	7,320	0	6,240	0	0	13,560
Hatoyama Town	9,730	0	0	0	0	9,430
Total	79,023	4,350	16,140	3,090	138	102,603

Source: Key-Informant Interview, December 2015.

1) In terms of size, LTC had been supplied with extra-large, large, medium and small sizes of soybean. Large sized soybeans accounted for 95% of the total supply.

2) Aoyama Zairai accounted for 77% of total supply.

3) Ogawa Town farmers supplied organically-grown (yuuki saibai) or specially cultivated (tokubetsu saibai) soybean. Organically-grown soybeans accounted for 38% of total supply from Ogawa farmers.

Table 2 shows local soybean supply of LTC by location and variety in 2014 with a total supply of 102,603 kg. There were five (5) varieties of soybean namely *Aoyama Zairai*, *Miyagi Shiromi*, *Sato Irazu*, *Shakin Nashi* and *Tanba Kuromame*. Among them, *Aoyama Zairai* accounted for 77% of total soybean, followed by *Sato Irazu* (16,140 kg).

In terms of location, Kumagaya City supplied the highest volume, amounting to 48,743 kg (47% of total supply), followed by Ranzan Town (16,980 kg) and Ogawa Town (13,590 kg). It should be noted that Ogawa Town supplied organically-grown (yuuki saibai) and specially cultivated (tokubetsu saibai) soybean. Organically-grown soybeans accounted for 38% of total supply from Ogawa Town. In order to further promote local brands, LTC also offers special products made from certain farms, locations or varieties (e.g. Shimosato Series). Although the soybean supply fluctuates every year, volume supplied by Ogawa farmers has been increasing from 6,590 kg in 2011 to 13,590 kg in 2014.

Product development: LTC sells a total of 100 products, of which own brand accounts for about 30-50 soybean products including special products for winter and summer seasons. It also offers special local products by soybean variety (e.g. sato irazu momen tofu, sato irazu nigari tofu) and location/farmer (e.g. Shimosato tofu series, Hatoyama natto, Shimosato natto). Jimoto no daizu de tsukutta tofu is made from locally soybean produced within a 3km radius from the store. Since Japanese also have the tradition to give/send presents (e.g. mid-year gift, year-end gift) to family, friends and/or colleagues, gift sets (e.g. Tokigawa set, Organic Set by Shimosato) are also made available. In order words, LTC offers a wide-range of products.

Table 3 shows the top 10 most saleable products in 2014. According to PW, June and February are the peak and low months, respectively. Except for tofu purin (tofu flan), all listed products are LTC brand. All-year round favorites are okara donuts (donuts made from tofu leftovers), agebo (fried tofu bar) and renkon ganmo (fried tofu with lotus root). The top 10 most saleable products accounted for 42% and 40% of the total sale in June and February, respectively.

Table 3 Top 10 Most Saleable Products of LTC by Peak and Low Months, 2014[1)]

Rank	Peak Month (June)	Low Month (February)
1	*Okara* Donuts (5-pc. pack)	*Okara* Donuts (5-pc. pack)
2	*Agebo* (1 pack)	*Agebo* (1 pack)
3	*Renkon Ganmo* (1 pack)	Tokigawa Tokyo *Kata*
4	Tokigawa Tokyo *Kata*	*Onsen Yu* Tofu
5	*Kyo Nigari* Shimosato	*Renkon Ganmo* (1 pack)
6	*Shiro Zaru* Tofu	*Teage Aburaage* (1 pack)
7	*Nagoshi* Tofu	*Kyo Nigari* Shimosato
8	*Teage Aburaage* (1 pack)	*Fuwafuwa Atsuage* (3 pcs)
9	*Kurogoma* Tofu	*Shiro Zaru* Tofu
10	Tofu *Purin*[2)]	*Fuwafuwa Namaage* (3 pcs)

Source: Key-Informant Interview, December 2015.

1) LTC sells about 100 products every day, of which LTC brand accounts for about 30-50 products.

2) Among the top 10 most saleable products for both months, all products are own brand products except for tofu purin.

3) Top 10 most saleable products accounted for 42% and 40% of the total sale in June and February, respectively.

Innovative selling strategies: As mentioned earlier, LTC's selling method has continuously and proactively evolved from peddling (1955) to wholesale selling in to local food stores (1965) to retail selling in at supermarkets (1979) to direct store selling (1997-present), in response to the changing business environment. Moreover, it also organizes events (e.g. monthly Tofu Marche, in-store tofu tasting) as part of their promotion activities. The tofu processing area is also made available to customers who can view through in-store glass windows. In this way, not only the transparency of tofu making can be achieved, but also the connectedness between employees (who directly make the tofu) and customers can be spontaneously created. As a result of these initiatives,

LTC has about 400 customers in weekdays and 800 customers in weekends during summer season, while 300 customers in weekdays and 600 customers in weekends from October to March.

However, PW emphasized that the store has reached its peak in terms of sale and customer reach. Therefore, LTC has started its mobile store in 2012, which has further expanded its potential market (e.g. aging population and/or those who do not have cars to directly buy in the store). Currently, there are 3 mobile stores that offer freshly-made soybean products to customers in nearby Hatoyama Town, Ranzan Town, Higashi Matsuyama City and Sakado City following a weekly schedule.

CONCLUSION

Company visits and key informant interviews revealed that the local tofu LTC conducted (1) product development in accordance with season, farming community and consumer demand, (2) introduction of TEIKEI for soybean farmers, and (3) implementation of innovative selling activities to name a few. Moreover, these initiatives further paved way for sustainable rural development. For further study, there is a need to determine the development of its partnership with and its respective impact to the local soybean farmers.

NOTES

1) Shimoguchi and Inaizumi (2016) clarifies the relationship of a farmer and other spontaneous "organic" peers (e.g. local tofu maker) through organic farming/products. Shimoguchi (2015) explains how two Philippine provinces in the same island, however, separated by political boundaries, language and environmental conditions (e.g. mountain) sign an agreement to establish the Negros Island as the "Organic Island in Asia" towards their mutual and sustainable growth and development.
2) Milestad & Darnhofer (2003) explains that resiliency can be achieved by continuously learn and adapt to changing environment.
3) Shimoguchi et al. (2015) explains that Shimosato Farm offers farm tour six (6) times a year. Each tour includes two (2) lectures and tour around the farm. One lecture is given by Mr. Kaneko, organic pioneer and farmer in Ogawa Town, Saitama, and another lecture by his collaborators such as Reform Company for Community Supported Agriculture (CSA)-related to rice and Tofu Company for soybean.
4) Orito (2014) explains the TEIKEI experience of Shimosato Farm. In addition to stipulating the 10 principles of TEIKEI, JOAA (1978) explains that "TEIKEI is an idea to create an alternative distribution system, not depending on the conventional market. Though the forms of "teikei" vary, it is basically a direct distribution system. To carry it out, the producer(s) and the consumer(s) have talks and contact to deepen their mutual understanding: both of them provide labor and capital to support their own delivery system……. The Japanese organic agriculture movement started with this "teikei" system. "Teikei" is not only a practical idea but also a dynamic philosophy to make people think of a better way of life either as a producer or as a consumer through their interaction".

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REFERENCES

Japan Organic Agriculture Association (JOAA). 1978. Teikei of farmer and consumer (http://www. joaa.net/english/teikei.htm (accesssed on 1 December, 2017).

Milestad, R. and Darnhofer, I. 2003. Building farm resilience: The prospects and challenges of organic farming, J. Sust. Agric, 22 (3), 81-97.

Orito, E. 2014. TEIKEI as a "Morotomo" relationship embedded in agrarian rationality: The experience of the "Orei-Sei" system at Shimosato Farm (in Japanese). Jap. Assoc. of Envi. Sociology, J. Envi. Sociology, 20, 133-148.

Shimoguchi, N. 2015. Formation process of actors-network towards organic based - Island development - Focus on Negros Island sustainable agriculture and rural development foundation in the Philippines - (in Japanese). Assoc. Design about Strategy for Zone Industry and Zone Brand, J. Zone Design, 6, 63-80.

Shimoguchi, N. and Inaizumi, H. 2016. Area design based on organic farming in Ogawa Town, Saitama: Focus on the contribution of a local tofu maker (in Japanese). The Assoc. of Design about Strategy for Zone Ind. and Zone Brand, J. Zone Design, 7, 107-121.

Shimoguchi, N., Inaizumi, H., Yasue, H. and Omuro, K. 2015. Impact of farm-based learning practices on young farmers: Case from an organic farm in Ogawa town, Saitama Prefecture, Japan. Int'l Soc. for Southeast Asian Agric. Sci., J. ISSAAS, 21 (2), 143-167.

Town of Tokigawa (TOT). 2017. Tokigawa town homepage (in Japanese). http://www.town.tokigawa.lg.jp/forms/top/top.aspx (accessed on 1 December, 2017).

Zenkoku Tofu Rengokai (Zentoren). 2017. Zentoren homepage (in Japanese). http://www.zentoren.jp/ (accesssed on 1 October, 2017).

Research article

Effects of Living Conditions on Livelihood Satisfaction in Sri Lanka: Living Sectors and Tea Industry

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Abstract The purpose of this study is to identify the disparity of living conditions and the effects on the living standards' Satisfaction of the households in the Sri Lanka and on the Tea Industry. Sri Lanka has progressively developed its status as middle low income country, while regional income and social disparity has still remained, especially in estate sector. Tea is a main industry of estates. Past studies indicated that people live in the low quality of housing with low income, while different articles mentioned that number of low income family in rural area is larger than in other sectors. This analysis applies a descriptive method with binary logistic regression. Quantitative analysis relies on the secondary data and qualitative descriptions rely on the primary survey. The qualitative analysis revealed that people living on estates are more likely to feel dissatisfaction compared to those living in urban, rural, and farming areas. Alternatively, the results of the survey showed that residents in three residential areas on the tea industry are not much different regarding their livelihood satisfaction.

Keywords livelihood satisfaction, country and reginal level, disparity, capability

INTRODUCTION

The estate sector, which has been a mainstay of the economy of Sri Lanka, was developed during the colonial area and has been primarily managed by private owners until the early 1970s, before nationalization. Studies mentioned there is a historical legacy of poor living conditions with low income, poor health, and lower levels of education, especially in tea industry (Salomonsen and Gunasekera, 1995; Chandrabose, 2011), while a change to the estate sector has been recognized after being privatized again in 1992 with the effort of the government and support of international agencies. Other studies have explicated the disparity of each sector. Nine out of ten citizens live in the rural sector, 86.8% of which accounted for the poor in 2013 (UN, 2015). The farmers, who are in the rural sector, cultivate mainly paddy, vegetable, black paper, tea, and grains and are described as working from early morning until evening (Williges, 2004). The urban sector, where the poverty rate is much lower than other sectors, shows higher disparity of income among the residents (Child Activity Survey [CAS], 2009). Disparity in each sector and among sectors has been explored. Factors have been found for each issue, but not many studies have focused on the effect of each factor that has influenced residents' satisfaction and the difference of effects on living standard satisfaction between the estate and other sectors. This paper aims to identify the disparity of living conditions and the effects on the living standards of the households in the estate and in the residential sectors of the tea industry, which is the main industry of estates.

METHODOLOGY

This analysis applies a descriptive method with binary logistic regression. Quantitative analysis relies on secondary data from CAS, which was conducted by the Department of Census and

Statistics (DCS), Sri Lanka with the International Labour Organization in 2008 and 2009. Qualitative descriptions were used for substituting this study, which comes from the primary survey at the Kotapola Division of the Matara District in 2013 and 2014. The capability approach to livelihood provides a theoretical basis for identifying disparity within a multidimensional context.

Characteristics of the Country Level

The objective of the CAS data was to identify the characteristics of Sri Lankan children. It also described housing and household characteristics comprising 16,000 households covering the whole country. Living sectors were classified into three categories: urban, rural, and estate. The data selected for this study were from districts where all three sectors exist. A variety of occupations in the rural were covered but not described explicitly. The main export production from the estate sector is tea, where small holders and farmers have been increasing. Thus, the CAS data were extracted from the rural sector for the farmer. Characteristics of the farmer are living in a single house, owning land where at least one parent is working, and owning livestock of less than 10 cows or goats and less than 100 chickens.

To deepen the understanding of the livelihood of residents in the multidimensional context, examining the income and other index is necessary. Therefore, the living condition variable household income was adapted for this analysis. Living conditions were divided into two variables. One is to focus on privacy protection, and the other one focuses on housing environments. The privacy index included three indices, such as type and ownership of housing, and the number of rooms for individuals. The housing index adapted the data of access to safe drinking water, exclusive toilets, and electricity for lighting and cooking. A limitation of this analysis is that the data did not cover the health index, which is important for well-being, and no natural scientific evidence.

Characteristics of District Level and Tea Industry

Sri Lanka is geographically recognized as two zones with available rainwater. The southern parts of the country where tea lands have been extended receive ample rainfall, while the northern parts of country are the dry zone and receive scarce rain. Sri Lanka comprises 331 divisions in 25 districts. Primary data were collected at Kotapola Division of the Matara District, which is famous as a tea cultivation area located in Low-grown. The housing conditions of the survey villages are recognized as the lower rank in the Matara District (DCS, 2013).

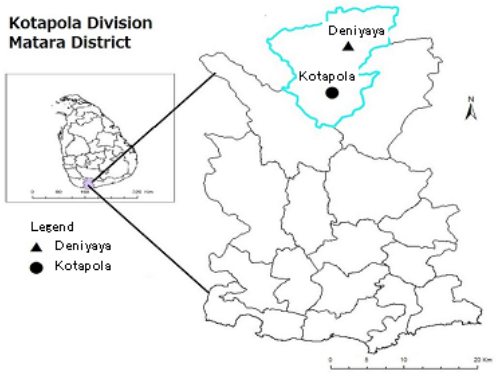


Fig. 1 Location of Deniyaya GN Division

Table 1 Number of GN Division on quality of housing

	Very Low	Low	Average	High	Very High
Sri Lanka	538	1598	3052	4500	4344
Matara District	31	86	177	216	140
Kotapola Division	10	12	14	1	---
Survey Areas	3	1	---	---	---

With the historical changes in the tea industry, its management style is classified into three categories: regional plantation companies (RPCs), private estates (PEs), and individual farmers (IFs). The government created state-owned RPCs, each of which reached an agreement with a private company to improve the efficiency of production, and their tea lands have been leased from the government for 99 years (Wenzlhuemer, 2007; Dilshan, 2012). Interviews and data collection were conducted in the villages and estates around Deniyaya and Morowaka, which are famous for

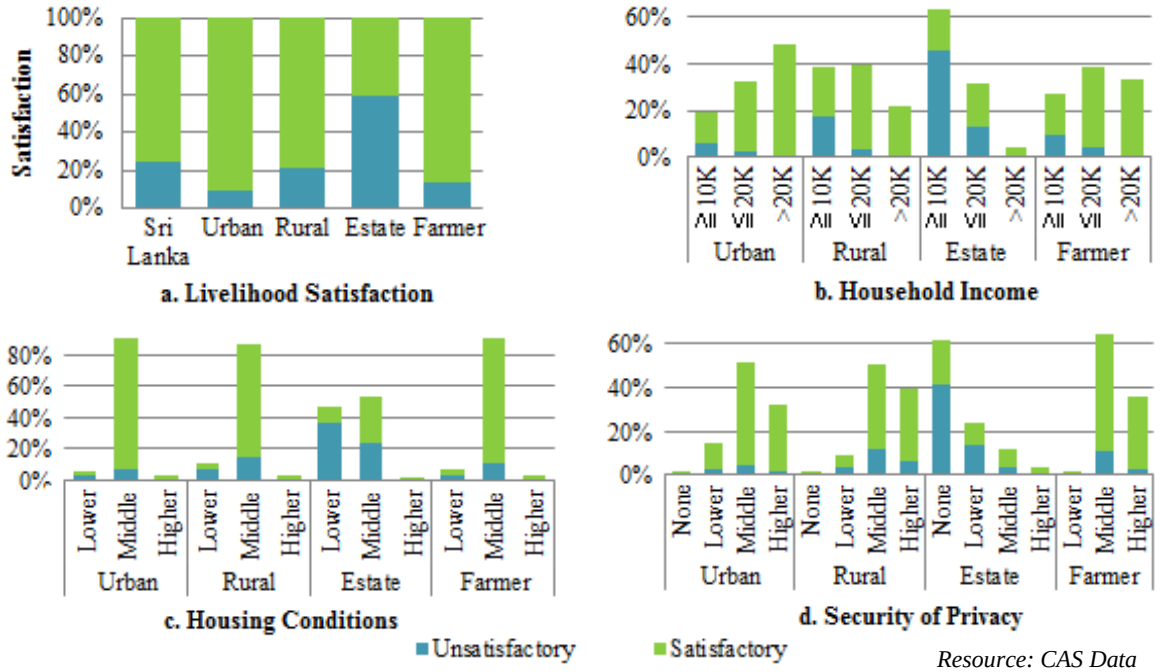
the Sinharaja Forest Reserve. The villages near Deniyaya are ranked as the lowest for housing conditions in Sri Lanka (DCS, 2013). The primary sample size is 302 housing units, which comprises 103 households at 12 divisions of RPCs, 100 households at 19 PEs, and 99 households of IFs.

RESULTS AND DISCUSSION

The results of the analysis provide a different aspect of relations between living environments and livelihood satisfaction. The satisfaction with Sri Lankan livelihood overall varies among the four sectors, while that in Kotapola was not statistically significant between the three residential areas. The previous studies indicated there were many poor in the rural areas, while the lowest level of living environment was in the estates. By focusing on the main industry of estates and the region where tea cultivation is extended, a different aspect of the past is investigated.

Livelihood in Estate Sector

The CEPA (2005) stated that residents perceived the overall living conditions on estates to have deteriorated over the last 15 years, while Ole and Hubert mentioned (1995) that positive changes to the plantation sector have occurred since 1992[1]. Housing built for temporary workers during the coffee plantation era has remained in the traditional manner. Sri Lanka has been tackling ethnic and religious conflicts, malnutrition, housing conditions, education, child labor, and other issues in the estate sector by establishing a ministry, enacting legislation, ratifying international laws, and receiving international support.



Resource: CAS Data

Fig. 2 Livelihood satisfaction and factors in country level

Fig. 2 represents the livelihood satisfaction among urban, rural, estate, and farming sectors. The average satisfaction for livelihood was approximately 25% at the country level. Comparing living sectors shows that highest unsatisfied residents were 59.2% in estates, about 20% in the rural sector, followed by residents in the farming and urban sectors. The different degrees of satisfaction

[1] A reason for the difference between the former and latter is the definition of plantations and estates. Under CAS, estate encompasses both large and small holdings managed by the state and RPCs that are individually or family managed, while the plantation is defined as being more than 20 acres with not less than 10 residential laborers.

lead us to exam the influential factors. Figs. 2a, 2b, and 2c explain the factors related to livelihood satisfaction. Fig. 2b indicates that lower income households are more likely to be unsatisfied compared to higher income households in all living sectors. Generally, in any country, the cost of living in the urban sector is higher than that of the rural sector, but Fig. 2b illustrates that the dissatisfaction rate of the lowest income range in the estate is higher than in the urban sector. Fig. 2c depicts the distribution of housing conditions. The livelihood satisfaction in all living sectors increases when the level of housing conditions is improved. A lower level of housing conditions accounted for 46% in the estate sector, while other sectors comprised 6% to 11%. Satisfaction varies by sector even at the same level. Fig. 2d delineates the distribution of the privacy index. The results of the cross-sectional analysis describe the different trends of satisfaction in each sector. In all living sectors, the more privacy is secured, the greater livelihood satisfaction has been increased. Privacy in the estate sector is more likely to not be secured, and more than 60% of households live in line rooms with no ownership and not a room per a person, while other sectors are categorized as middle or high privacy.

Comparative results of living conditions among sectors are not much different from those of past studies. Living conditions have been affected by regional characteristics. The cross-sectional analysis of each index shows that it is statistically significant at the 1% level between living sectors and each index. People in the estate sector have faced disadvantages on income, security of privacy, and housing compared to those in urban, rural, and farming sectors. The satisfaction of people in the estate sector is more likely lower than others even though each of the three indices are at the same level.

Effect of Living Conditions on Livelihood Satisfaction

This study estimated that the binary logistic regression models contained three factors as explanatory variables and the livelihood satisfaction was taken as a dependent variable. This study coded livelihood satisfaction as 0 for unsatisfactory and 1 for satisfactory. This analysis categorized house income into low, middle, and high, and coded it as 0 if the household income is not in that range or 1 if it is in that range. Thus, low-income families are a natural base group. For housing conditions, this study adopted three categories (low, middle, and high) for assessing sanitary and safety conditions, and coded it as 0 if the families are not in that rank of house conditions or 1 if the families are in that rank. Thus, low-ranking families are a natural base group. This analysis ranked privacy into none, low, middle, and high to assess the protection of privacy and coded it as 0 if the families are not ranked in that category or 1 if they are ranked in it.

Table 2 Logistic regression models

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Sector (Base: Estate)						
Urban	14.216 **	6.226 **	7.865 **	5.863 **	4.18 **	1.747 **
Rural	5.203 **	4.013 **	3.086 **	1.872 **	2.703 **	1.006
Farmer	8.869 **	5.204 **	5.032 **	2.979 **	3.399 **	1.29
Household Income (Base: Low (≦ 10KRs)						
Middle(20K≦ 10K)		6.406 **			5.47 **	6.227 **
High (>20K)		52.33 **			39.675 **	43.502 **
Housing condtions (Base:Low)						
Middle level			6.7 **		4.407 **	3.868 **
High level			101.603 **		19.524 **	15.034 **
Privacy Protection (Base: None)						
Lower level				1.714 **		2.093 **
Middle level				3.534 **		3.297 **
High level				6.266 **		7.195 **
Constant	0.689 **	.315 **	0.223 **	0.489 **	0.1420 **	0.099 **
-2log Likelihood	6834.701	5483.034	6206.679	6627.555	5180.938	5008.316
Cox & Snell R-Square	0.089	0.257	0.171	0.117	0.290	0.308
Case number	6630	6627	6630	6630	6627	6627

Resource: CAD *p<.05 ; **p<.01

Table 2 describes the outcomes of five models. Model 1 explains how much livelihood satisfaction is greater if living in urban, rural, or farming sectors compared with living in the estate sector. Residents in the urban sector have $14.216^{(e2.654)}$ times greater livelihood satisfaction than those living in the estate sector, $5.203^{(e1.649)}$ times those in the rural sector, and $8.869^{(e2.183)}$ times those in the farming sector.

Model 2 contains the household income index in Model 1. Livelihood satisfaction is $6.406^{(e1.857)}$ times greater if the resident income is in the middle level and $52.33^{(e3.958)}$ times greater if at the high-income level. Under the household income, the effect of the living sector on livelihood satisfaction is reduced but is still statistically significant at the 1% level.

Model 3 includes the housing condition index. Livelihood satisfaction is $6.7^{(e1.902)}$ times greater if at the middle level and $101.603^{(e4.621)}$ times greater if at the highest level. Under the housing conditions, the effect of the living sector on satisfaction is reduced in all three sectors, especially in the rural sector. The livelihood satisfaction is still greater in three sectors in comparison with in the estate sector. It is statistically significant at the 1% level. The effect of the living sectors remains.

Model 4 added the privacy protection index. Under the privacy index, the effect of the living sector on satisfaction in urban, rural, and farming sectors are reduced. Highly protected families have $6.266^{(e1.835)}$ greater livelihood satisfaction than those with no privacy.

Model 5 contains all indices, which indicate that livelihood satisfaction in rural and farming sectors is almost the same as living in the estate sector after the three factors are considered individually. Living in the urban sector results in a $1.7^{(e0.588)}$ times higher satisfactory level than in the estate sector, which is statistically significant at the 1% level.

The models explain the satisfaction degree of each explanatory variable based on the base group and the change of effect of the living sector on livelihood satisfaction. Model 5 shows that income, housing, and privacy are partial factors of disparity on livelihood satisfaction. Satisfaction in the estate sector is lower than in the other three living sectors, which agrees with other studies. The next section focuses on the tea industry, which has been influenced by recent developments in economic growth, social and human development, and globalization. Unlike the country-level analysis, the regional-level analysis shows a different aspect.

Livelihood of Tea Industry in Low-Country

During the colonial era, tea estates on the hillside were established by cutting through the forest, while the low country was surrounded by villages when the estates were introduced (Bronkhorst 2008). To explore the quality of life in the tea industry, this study focused on one area in the low country. When focusing on satisfaction with their living based on the tea management style, this study found a different view of aspects on residents' well-being.

Fig. 3 illustrates the difference of livelihood satisfaction between RPCs, PEs, and IFs in the tea industry based on household income, security of privacy, and housing conditions. The results of the analysis based on management style found that the difference of livelihood satisfaction cannot be observed among the three residential areas. Thus, there is no difference in livelihood satisfaction in RPCs, PEs, and IFs, even though the trends of the three indices are different among the three residential areas. Compared with the CAS data, the residents in estates (RPC and PE) are at the same or higher livelihood satisfaction, but the satisfaction of living as IFs in the survey area is lower than for farmers at the country level.

Fig. 3a shows the income distribution and satisfaction level in the three residential areas based on household income. The percentage of the lowest income families is similar in all residential areas, but the median of household income in RPCs is between 20K and 30K, while those of PEs and IFs are over 30K. It elucidates that residents in RPCs are more likely to receive lower income than others. Fig. 3c demonstrates that housing conditions for farmers are more comfortable than those in RPCs and PEs. Fig. 3d explains the satisfaction with the security of privacy in each residential sector and shows that families in RPCs and PEs face difficulty attaining privacy.

However, comparing satisfaction with privacy among each level except for none category, the cross-sectional analysis is not statistically significant.

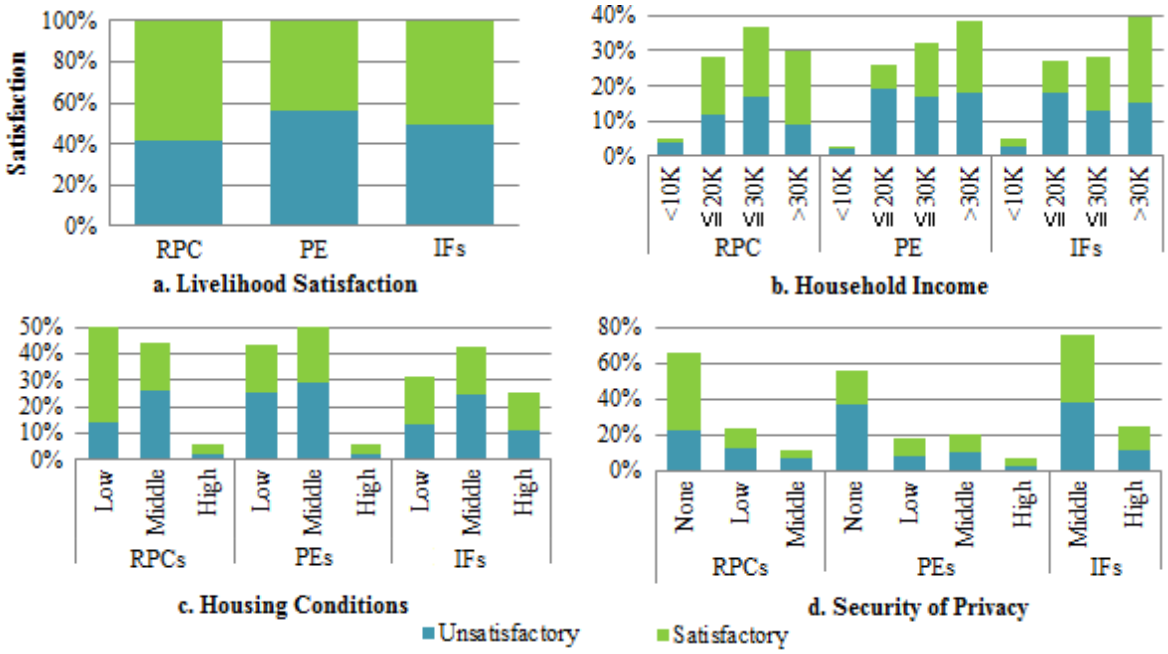


Fig. 3 Livelihood satisfaction and factors in tea industry

While conducting the survey, residents in the estates expressed their hopes to own their line room and a small amount of land in their estates and not rent it from the estate owners, even if they are satisfied with free accommodations. They mentioned that they feel free, and there is no need to care about others and worry about future if they could own it. Residents in RPCs also stated they felt satisfaction with having an exclusive toilet, but getting wood for cooking takes time, and kerosene for lighting is very dangerous. Individual farmers faced low income because of the tea disease, which reduced the production. They mentioned that their income was insufficient for their children's education and keeping their house properly.

CONCLUSION

The secondary data analysis revealed that people living on estates are more likely to feel dissatisfaction compared to those living in urban, rural, and farming areas. The effect of the privacy is greater influence on the living standard satisfaction rather than other factors. Living conditions have been influenced by the characteristics of the living sectors. People in urban can easily access a variety of jobs with higher salary and live in a single house, and infrastructures are more developed. Those living in rural and farming areas have lived under similar living environments, but farmers live in a single house that protects their privacy. Income on estates is lower than in other areas. Access to better housing conditions is also harder, and living in a line room on estates avoids isolation and tightens the solidarity, while reducing privacy.

Alternatively, focusing on the tea industry in one area drives a different viewpoint on life in the tea industry. The results of the survey showed that residents in three residential areas of different management styles are not much different regarding their livelihood satisfaction. Exploring the relations between factors and satisfaction delineates the different distribution tendencies of each factor among three residential areas, while the satisfaction level is same if families belong to the same range in each factor.

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REFERENCES

CEPA. 2005. Moving out of poverty in the estate sector in Sri Lanka, Understanding growth and freedom from the bottom up. Sri Lanka.

Chandrabose, A.S. and Sivapragasam, P.P. 2011. Red colour of tea-central issues that impact the tea plantation community in Sri Lanka. Human Development Organization, Sri Lanka.

DCS, Government of Sri Lanka. 2013. Classification of administrative divisions by quality of housing. DCS, Government of Sri Lanka, Sri Lanka.

Dilshan, A. 2012. Sri Lanka: Conflict mitigation through community-based water resource management, A case study of tea plantation community Sri Lanka. CPCS Peace Practitioners' Research Conference, 2012.

Johannes, B. 2008. From coffee to tea cultivation in Ceylon, An economic and social history. Brill's Indological Library, Netherlands, 1880-1900.

Ole, S. and Hubert, G. 1995. Housing cooperatives for plantation workers in Sri Lanka. ILO, Geneva.

Roland, W. 2007. The Shinhalese contribution to estate labour in Ceylon, 1881-1891. Journal of the Economic and Social History of the Orient, 41 (3), 442-458.

United Nations. 2015. Millennium development goals country report 2014, United Nations. Sri Lanka

Wal, S.V.D. 2008. Sustainability issues in the tea sector, A comparative analysis of six leading producing countries. Centre for Research on Multinational Corporations (SOMO), Netherlands.

Williges, U. 2004. Status of organic agriculture in Sri Lanka with special emphasis on tea production system. Ph.D. Thesis, University of Giessen, Gernany.

Research article

An Evaluation of Water Demand and Supply for a Small-scale Irrigation Scheme in Zimbabwe

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Abstract Previous studies have shown that most smallholder irrigation schemes in developing countries in Africa, have proved to be unsustainable beyond external assistance. The low performance of most smallholder irrigation schemes is largely attributable to unreliable and inadequate water delivery. This research assessed the on-farm water management performance for Fuve-Panganai irrigation scheme in Zaka District of Zimbabwe. The objective of this study is to assess the on-farm water management performance for the irrigation scheme in terms of water demand and supply. The irrigation water demand for 204 ha of dry beans for the winter irrigation season (April to August) was estimated using the FAO CROPWAT. The seasonal water supply was calculated using the 2012 to 2016 recorded canal water depths. The Relative Water Supply (RWS) index was calculated from the water demand and supply. 38 randomly selected farmers, members of the waters user's association and relevant agencies were interviewed to understand the decision-making process and the overall performance of the scheme. The results showed a stable water supply for the five years with a coefficient of variation of 0.2. The water supply was greater than water demand during the winter mid-irrigation period (May to July) with an average RWS of 1.59. The results correspond with results from the interview survey in which more than 90 percent of the farmers were satisfied with the irrigation management performance. However, 37 percent reported to have experienced water shortages. This is due to the heavy distribution losses by damaged pipes and leaking water valves. The irrigation system is in dire need for rehabilitation to minimize water losses.

Keywords performance assessment, water demand, water supply, relative water supply

INTRODUCTION

Irrigated agriculture is the most effective way of reducing crop failure, hunger and malnutrition in Africa and has the potential to increase the competitiveness of smallholder farming in most parts of Africa (World Bank, 2008). Despite these potential benefits of irrigation, smallholder irrigation schemes in most developing countries, including Zimbabwe have proved to be unsustainable beyond external assistance (Mutambara and Munodawafa, 2014). They showed that the sustainability of small-holder irrigation schemes in Zimbabwe was being affected by a complex interaction of a variety of factors which include; limited access to agricultural inputs, low educational level and/or lack of training in appropriate farming skills, lack of collateral which enables farmers to access loans or working capital and erratic irrigation water supply.

To achieve higher crop yields from irrigated agriculture it is necessary to supply the amount of water required by the crops. The amount of water required by the crops is determined by the area under cultivation, the crop water requirements and any inevitable losses incurred during the application of the water to the field (DFID, 1997).

According to Sakthivadivel et al., (1993), the two most crucial factors in irrigation planning, design and operation are the available water supply and the water demand. The two authors defined Relative Water Supply (RWS) as the ratio of water supply to the water demand associated with crops grown with the cultural practices used, and for the actual irrigated area. They underscored the usefulness of the RWS as a tool for understanding the performance of irrigation systems.

OBJECTIVES

The objective of this study is quantitatively and qualitatively assess the on-farm water management performance to identify the current problems for the small irrigation scheme, Fuve-Panganai Irrigation Scheme, Zimbabwe.

METHODOLOGY

Study Site

Fuve-Panganai irrigation scheme is in ward 15 of Zaka district, 131 km south of Masvingo City, Zimbabwe. The nearest meteorological station; Buffalo Range Airport, records a minimum temp of 8.7 ^{o}C in July and a maximum of 32.9 ^{o}C in January. Average annual rainfall received is 584 mm.

The irrigation Scheme is 283 hectares in extent comprising of four blocks, designated, A, B, C and D each with 9; 70; 54 and 150 hectares respectively. Irrigation water is conveyed by gravity from Siya dam by a 14.5 km conveyance canal that discharges into Murerezi stream and ultimately to Chiredzi River and Manjirenji Dam through a water catchment transfer. The design capacity of the main canal is 3.5 m^3/s. There is an off-take to blocks C and D at 11.5 km from the dam and it is from this off-take that a branch canal with a design capacity of 0.25 m^3/s supplies water to blocks C and D. Both the main and branch canals are lined in concrete. The off-take to block C regulation pond is 3.5 km along the branch canal. The branch canal eventually discharges into block D regulation pond at 7.5 km from the main off-take and there other two regulation ponds for the other subsections of block D. Figure 1 shows the layout of the irrigation system.

The regulation ponds receive water from the branch canal for 24 hours and store it overnight, since irrigation is practiced during the day time. Water is conveyed from the regulation pond to the field by an underground pipeline system. Farmers take water from the field hydrants using hose pipes and direct it into furrows. Each farmer is entitled to one hectare of irrigated land.

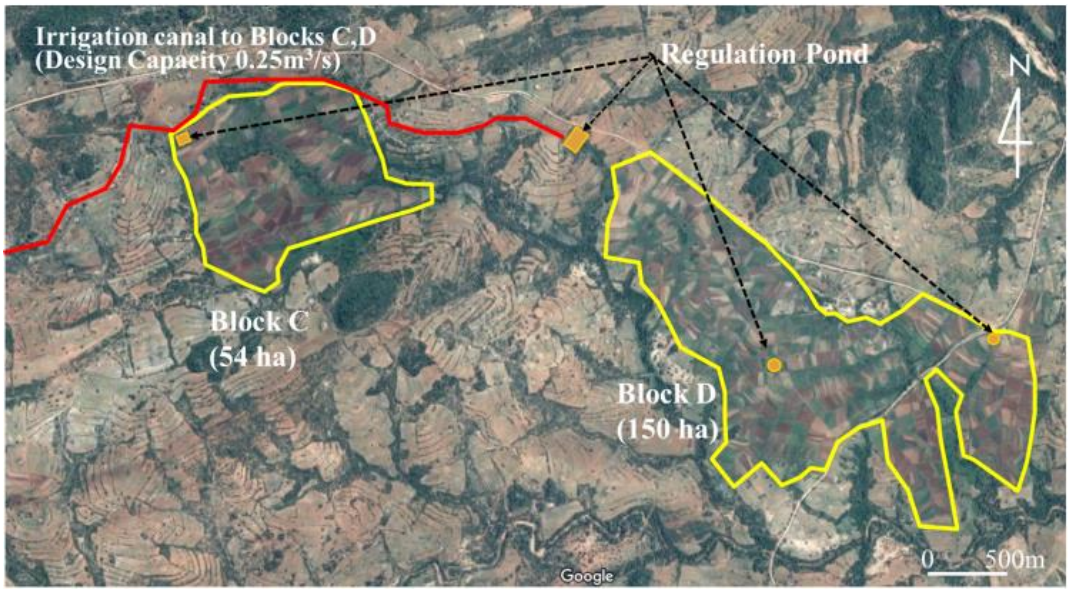

Fig. 1 Layout map of blocks C and D of Fuve Panganai Irrigation Scheme

Sections C and D with a total area of 204 ha were purposely selected as the study site because they share the same branch canal. Maize, groundnuts and sugar beans are the main crops grown. Maize and groundnuts are grown in the summer whilst sugar beans is grown in winter. It was therefore assumed that sugar beans was continuously grown in winter for the period under consideration.

Water Demand and Supply

The irrigation water demand for 204 ha of dry beans for the winter irrigation season was calculated using the FAO CROPWAT 8.0 for Windows which is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data.

The average monthly climate data for Buffalo Range Airport was accessed from FAO CLIMWAT 2.0 which is a climatic database to be used in combination with the computer program CROPWAT. The average monthly water supply for April to August which is the winter/dry season was calculated from daily irrigation water supply data for 5 years (2012-2016). The Relative Water Supply (RWS) index was calculated for dry season using the formula;

$$RWS = S/D \quad (1)$$

Where, S is an amount of water supply and D is an amount of water demand

Quessionaire Survey

A sample of 38 randomly selected farmers were interviewed to get their perception on the water management performance with 80 percent confidence interval and 10 percent margin error. The waters user's association members and key informants from Zimbabwe National Water Authority (ZINWA), Department of Irrigation (DOI) and Agricultural Research and Extension Services (AGRITEX) department were also interviewed to understand the decision-making and water allocation process.

RESULTS AND DISCUSSION

Stakeholders

There are five key stakeholders in the irrigation scheme; the farmers, the Water Users Association (WUA), ZINWA, DOI and the AGRITEX department. Their roles and responsibilities are in shown in Table 1.

The Water Allocation and Irrigation Practice

The water allocation process is in three stages; the planning stage, the negotiation stage and the implementation stage.

During the planning stage the farmers make the irrigation season plan; i.e. they come out with crop(s), the total hectarage, the planting dates, the tentative water requirements and amount of money needed to buy the water from ZINWA, etc. The WUA coordinates this process and they may also consult the AGRITEX and or the DOI officers for technical advice.

The WUA on behalf of the farmers engage the ZINWA in the negotiation stage to agree on the water contract. The water contract includes the crop, the total hectarage, the irrigation season, the amount of water needed and the payment plan amongst other factors.

During the implementation stage ZINWA supplies irrigation water to the farmers throughout the irrigation season as per the agreement in the water contract. The farmers order water as per demand by calling the ZINWA offices, the ZINWA through its resident technician, who stays in

the farm, supplies a canal water depth for a certain number of hours and or days to meet the farmers water requirements. The process of ordering and receiving water is 24 hours.

Table 1 The roles and responsibilities of key stakeholders

Name of stakeholder	Roles and responsibilities
Farmers	The main beneficiaries of the irrigation scheme. They are autonomous, and run the scheme independently. They are responsible for the operation and maintenance of the branch canal and other farm level irrigation facilities
WUA	The farmers' committee which coordinates the irrigation activities on behalf of the farmers e.g. making contract with ZINWA, collecting water fees from the farmers and holding meetings.
ZINWA	A quasi-government body managing irrigation facilities such as dams and the main canal. They supply the farmers with water based on the contract with WUAs.
DOI	A government department responsible for the supervision of irrigation projects including the operation and maintenance of the irrigation structures.
AGRITEX	The government department responsible for extension services; such as advising farmers on the best agronomic practices including irrigation scheduling

The farmers are charged by ZINWA 4.36 USD/hectare/month. Of the 4.36, 1 USD is taken by the Save Water Catchment Council and the remaining 3.36 USD is for ZINWA. This means that each farmer on average pays 22 USD per irrigation season per hectare.

As seen from the water allocation process ZINWA water supply is not limiting; the farmers can order as much as they need and since this can be done within 24 hours there is less risk of water shortage. The farmers can irrigate during the day from 0800 hours to 1600 hours, there is no strict time table hence all the farmers can irrigate whenever they need but in practice in sections where the water pressure is low, they follow a flexible irrigation time table.

The Water Supply and Demand

Fig. 2 shows the annual branch canal water discharge for the five years. The highest amount of water supply was observed in 2013 and the least amount in 2014. There is a relatively stable water supply with a coefficient of variation (CV) of 0.2. This means the ZINWA's water supply to the farmers is reliable.

The RWS for the mid-irrigation period (May, June and July) was shown in Fig. 3. It ranges from 1.28 to 2.12 with an average of 1.59. Although the irrigation season is five months from April to August, the first and last months of the irrigation season were not included in the analysis to avoid the error margin.

The RWS values at different locations of a system are closely linked to the management behavior of water managers and farmers (Sakthivadivel and Merry, 1993). Levine (1991) gave general recommendations (based on observations) that for a RWS of approximately 2.0, monitoring and control to secondary channels, daytime monitoring, limited communication between the system managers and farmers would still permit relatively high yields. Levine recommended that for a RWS of 2.5 or greater, minimal operational control at the main distribution level is enough to ensure that water will not be the limiting factor in crop production. However, considering the pipe line system is installed in the study scheme, this RWS is very high since the conveyance and distribution efficiency is theoretically very low under pipe line system.

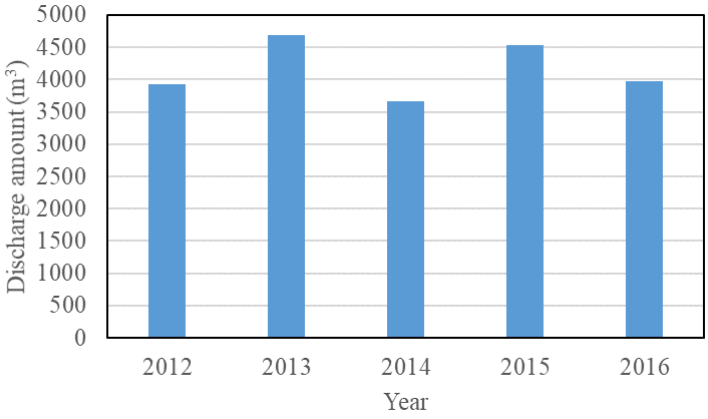

Fig. 2 Annual canal water discharge

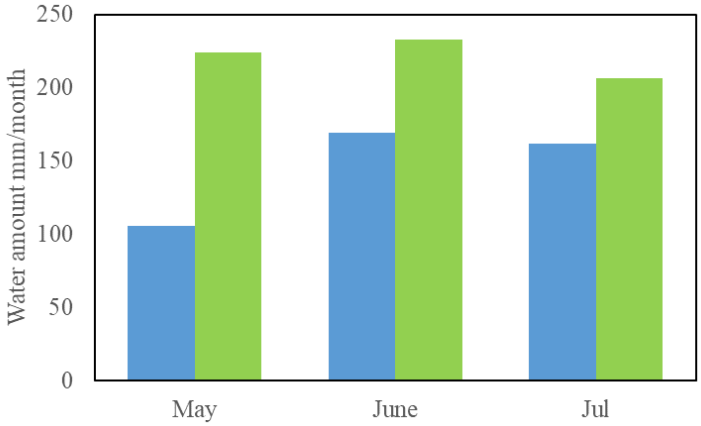

Fig. 3 Water demand and supply during mid-irrigation period

Farmers' Perceptions on Irrigation Performance

Fig. 4 shows the farmers perceptions as far as irrigation performance is concerned. Over 90 percent of the farmers are generally satisfied with the water delivery service by ZINWA. Although most of the farmers are satisfied, about 37 percent of the farmers have experienced periodical water shortages. Field observations revealed water leakages from damaged hydrants and pipes which might be the major reason for the water shortage. The high value of RWS are caused by the damaged hydrants and pipes in the study irrigation scheme. The rehabilitation of these will go a long way in improving the availability of water to all farmers.

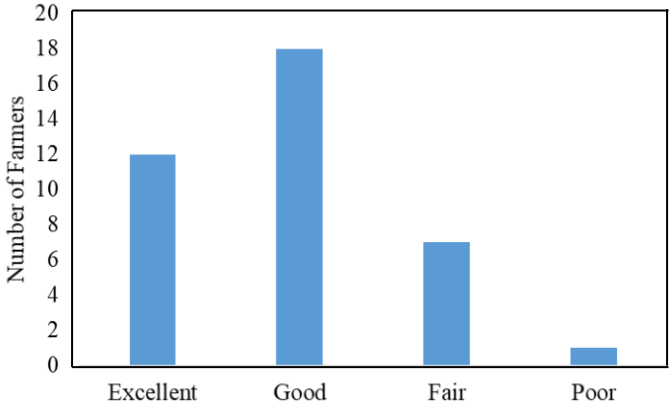

Fig. 4 Farmers' perception on irrigation performance

CONCLUSIONS

The analysis of water demand and supply revealed that the water supply from ZINWA is reliably stable as shown by a CV of 0.2. The scheme received more water than the IWR as shown by the RWS of 1.6. The water allocation system is efficient with the farmers being able to order and receive water within 24 hours. Although more than 90 percent of the farmers are generally satisfied with the water delivery performance, 37 percent are experiencing some water shortages. There are water losses due to damaged hydrants and pipes. The results of this study can contribute to the overall evaluation of the performance of the irrigation scheme and therefore help in making the necessary recommendations for improvement e.g. increasing the water supply and or rehabilitation.

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REFERENCES

DFID (Department for International Development). 1997. Smallholder irrigation: Ways forward. Guidelines for Achieving Appropriate Scheme Design, Volume 2, Summary of Case Studies, Chancellor, F.M. and Hide, J.M., Report OD 136, August 1997.

Mutambara, S. and Munodawafa, A. 2014. Production challenges and sustainability of smallholder irrigation schemes in Zimbabwe. Journal of Biology, Agriculture and Healthcare, 4, 15.

Sakthivadivel, R. and Merry, D.T. 1993. Cumulative relative water supply: A methodology for assessing irrigation system performance. Irrigation and Drainage Systems, 7, 43-67.

World Bank. 2008. Mobilizing public-private partnerships to finance infrastructure amid crisis is the focus of the World Bank Conference. World Bank Press Release, No: 2008/175/WBL.

Research article

Sustainable Development through Environmental Education: From the Perspectives of Past and Present Group and Individual Rainforestation Adopters

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Abstract Rainforestation is a Visayas State University (VSU) technology designed as an alternative method to Philippine Government's thrust for massive reforestation. Rainforestation's purpose is to plant denuded lands with Philippine Native Trees together with high value crops and fruit trees. With this, ecological functions could be re-established while subsistence farmers would be provided with a stable and sustainable income. For the past twenty plus years, the first batch of individual and group adopters have toiled to succeed in their Rainforestation efforts and are, at present, already reaping the fruits of their labors. Moreover, said adopters are also inspiring new groups of adopters to also adopt Rainforestation. Yet, such things would not be possible without environmental education that has been provided by VSU, Gesellschaft für Technische Zusammenarbeit (GTZ), and the Environment Leadership Training Initiatives (ELTI). Hence, this study aims to understand how Rainforestation has affected the adopters' lives for the past twenty years, examine how environmental education has contributed to sustainable development, and decipher how environmental education has influenced new sets of adopters to go into Rainforestation. In order to achieve the said objectives, this study makes use of hermeneutic phenomenology and focus group discussions to arrive at the adopters' points of views and sentiments towards the connection between environmental education, sustainable development, and Rainforestation. Furthermore, this study concludes that the adopters have already enjoyed economic benefits, sustainable source of water, and biodiversity restoration through Rainforestation adoption. This study also concludes that environmental education is one of the main factors why individuals and groups have adopted Rainforestation by informing them that growing native trees together with fruit trees is doable and possible. Lastly, this study further concludes that the spread of Rainforestation has been an offshoot of the greater reach of education and information dissemination.

Keywords sustainable development, environmental education, rainforestation, adopters

INTRODUCTION

The question on whether or not the natural environment could sustain the needs of the world's growing population has already been felt for quite some time. In the Philippines, Mother Nature's capacity to support the future generations of Filipinos has been challenged by indiscriminate and gross exploitation of the country's natural resources. One of the effects of this environmental abuse is the lost of biodiversity in the country which comes as an offshoot of large and small scale deforestation activities. According to Haribon foundation, biodiversity in the Philippines is one of the richest in the world. It is part of the 17 mega diverse countries which collectively claim two thirds of all global species. Yet, 70% of Philippine forests have vanished from the 1930s to 1988 (Haribon Foundation, 2016). There are two major causes of Philippine forests loss. They refer to the conversion of primary forests to secondary forests by both legal and illegal logging and the

removal of secondary forests cover by expansion of upland agriculture (Fernando, 2005). In the Visayas Region in the Philippines, the effects of environmental degradation have also been felt.

To address this problem, Visayas State University (VSU) in cooperation with the Gesellschaft für Technische Zusammenarbeit (GTZ) and the Environment Leadership Training Initiatives (ELTI) introduced and continued to propagate environmental education to interested adopters through rainforestation. Rainforestation is a technology designed to make use of unproductive lands by planting native tree species which are not widely used in the Philippine government's reforestation program (Milan and Ceniza, 2009). This technology found its way to Visayas State University since in 1990, the Gesellschaft für Technische Zusammenarbeit (GTZ) started to look into possibilities of rehabilitating former forested areas to get back the ecological functions of the degraded areas needed for poverty alleviation through sustainable rural development. This program was directed for the promotion of biodiversity rehabilitation and conservation of remaining primary forests and natural resources. The directives of the program were formulated so that Rainforestation could replace the wide spread slash-and-burn practices and protect and enhance biodiversity by using indigenous trees only. In 1994 the hypothesis was formulated that a farming system in the humid tropics would increasingly be more sustainable the closer it was in its species composition to the original local rainforest (Goltenboth and Tropentag, 2005).

Hence, at the start of the early 1990's, a number of Rainforestation sites had been established in the different parts of the country. This came as a result of massive environmental education initiatives disseminated by Visayas State University and the Gesellschaft für Technische Zusammenarbeit (GTZ). It was during these times that people, predominantly farmers, were recruited to adopt Rainforestation technology. At present, the first batch of group and individual adopters in the Visayas region in the Philippines are already reaping the fruits of their labors. Yet, Visayas State University's thrust to disseminate environmental education continued up to the present since it again partnered with Yale University's Environment Leadership Training Initiative (ELTI) to recruit and educate more rainforestation adopters so that a large number of people would be given a chance to realize the importance of environment conservation so that Mother Nature could sustain the needs of every Filipino for many years to come.

OBJECTIVE

In the thrust to determine environmental education's contribution to the attainment of sustainable development, this paper aims to understand how Rainforestation has affected the adopters' lives for the past twenty years, examine how environmental education has contributed to sustainable development, and decipher how environmental education has influenced new sets of adopters to go into Rainforestation.

METHODOLOGY

In the thrust to wholistically decipher environmental education's contribution to sustainable development, this research makes use of the qualitative research method of hermeneutic phenomenology. This phenomenological method is characterized by Martin Heidegger's interpretative approach which focuses on researcher involvement through on going interpretation which bridles researcher assumptions through questioning and critically reflecting upon one's pre understanding and involvement in the phenomenon (Dahlherg, 2006). Hermeneutic phenomenology aims at producing rich textual descriptions of the experiencing of selected phenomena in the life world of individuals that are able to connect with the experiences of people collectively. From identification of the experience of phenomena, a deeper understanding of the meaning of that experience is sought (Smith & Vandenburg, 1997). Hence, in order to have a full understanding of what this study's respondents want to convey, the use of any language that the respondents are most comfortable with is utilized. As Langdridge (2005) puts it: to understand the life world, people need to explore the stories that others tell of their experiences (Langdridge, 2005). Hence, it is in this sense that the above-mentioned method would challenge the researcher to

reflect deeply on what it is that the texts of the field have to say. Nevertheless, this research method's goal is to invite its readers to enter the world that the texts would disclose and open up in front of themselves (Kafle, 2011). With this at hand, this study could come with a broader understanding of the significance of environmental education to sustainable development

RESULTS AND DISCUSSION

The Effects of Rainforestation Adoption to the Lives of Group and Individual Adopters

The pioneering group and individual rainforestation adopters refer to the Cienda-San Vicente Farmers Association (CSVFA) of Barangay Gabas, Baybay, Leyte, Philippines and Mr. Manuel Posas of Barangay Marcos, Baybay, Leyte. These adopters were the first to adopt rainforestation in the early 1990s and have since inspired younger generations of adopters because they have demonstrated that rainforestation would eventually lead to a development that is sustainable. Moreover, the presence of the pioneering adopters' rainforestation demonstration farms have also served as models and have educated the younger generations of adopters that there is a need to educate a large number of people in order for them to arrive at a realization that conserving and protecting the natural environment would lead to sustainable development.

These things have positively affected the lives of the pioneering group and individual adopters for the past twenty plus years in the sense that it gives them a variety of benefits. For instance, the Cienda-San Vicente Farmers Association has reaped economic benefits from rainforestation adoption. In their thrust to save the trees from indiscriminate and illegal logging, they were able to preserve Philippine native mother tree species in their area. With this, the association members were able to establish a nursery for native trees which gave them the opportunity to enter into contract with the Philippine's Department of Environment and Natural Resources (DENR) as a supplier for native tree seedlings for DENR's National Greening Program (NGP). According to Victoriano Catalan, one of the pioneering members of CSVFA:

"At first, we adopted rainforestation because we only wanted to protect our trees that had been illegally and indiscriminately cut by illegal loggers. As a group, the members of our community decided to adopt the technology offered to us by Visayas State University and Gesellschaft für Technische Zusammenarbeit (GTZ) which we later know as rainforestation. With this, we organized ourselves into a people's organization and were able to convince a land owner to convert his almost empty and denuded nine thousand square meters piece of land into a demonstration farm. The owner eventually became a member of the CSVFA. Our training in Dendrology made us familiar with the characteristics of the native trees found in our area and we were also taught how to collect wildlings and establish a nursery of our own. This nursery provided us with income that was sufficient enough to compensate for our sacrifices in protecting the environment. With our contract with the DENR national Greening Program and other native tree seedling buyers, we were able to collect a sum of more than a million pesos".

Aside from economic benefits, the members of CSVFA have also noticed the return of biodiversity in their area. For Agustino Valenzona, a CSVFA member: *"A few years after we started protecting our trees in the forest near our community, we noticed the return of native birds in our area. We also experienced colder temperatures since the trees have started to grow. The fish in our rivers also returned which enabled community members to have access to free source of food. With this, I realized that if we just protect and care for Mother Nature, Mother Nature would also take good care of us in return".*

Moreover, rainforestation has also positively affected the life of the pioneering individual adopter, Mr. Manuel Posas, an Assistant Professor of Visayas State University, of Barangay Marcos, Baybay, Leyte. Having been invited to a meeting on rainforestation in the early 1990s, Mr. Posas took the opportunity to attend with the intention of just making his denuded and empty piece of land useful and productive. Yet, years after he implemented his rainforestation demonstration farm, Mr. Posas reaped a lot of benefits that he even did not think of before. First, after twelve years of establishing his rainforestation farm and planted it with a variety of more than six hundred

Philippine native trees and a few fruit trees, he noticed that a source of water emerged inside his demonstration farm. After retiring from government service, Mr. Posas established a water system that supplied him with safe and potable water all year long. Not only that, Mr. Posas also gave his neighbors access to his water system with a minimal and reasonable fee. Hence, this also gave him economic benefits. Furthermore, since Mr. Posas also planted fruit trees together with his native trees, the trees' fruits during the fruiting season gave him another additional income. According to Mr. Posas: *"When I adopted rainforestation, I only had the intention of making use of a piece of land that has been unproductive for a couple of years. Yet, years after establishing my rainforestation farm, I did not expect to gain things that nature has provided like the source of water in my demonstration farm as well as the sale of the fruit trees during the fruiting season. My newly built water system also irrigated my rice field near my demonstration farm all year long in such a way that my rainforestation did not only provide me with water, it also enabled me to regularly plant rice all year round."*

Hence, from the stories of the pioneering group and individual adopters of rainforestation, it is common among them that they already are reaping the fruits of their labors. All of the adopters have economically benefitted from rainforestation. Yet, most important of all, the adopters have made it possible to restore biodiversity in their respective areas.

The Contribution of Environmental Education to Sustainable Development

From the experiences of the group and individual rainforestation adopters, it is quite obvious that environmental education is the key element that inspired them to adopt rainforestation From the very start, the thrust of Gesellschaft für Technische Zusammenarbeit (GTZ) and Visayas State University has paved the way for the Cienda-San Vicente Farmers Association (CSVFA) and Mr. Manuel Posas to adopt rainforestation. To this day, their demonstration farms have served as a model that inspired a number of aspiring environmentalists and rainforestation adopters during cross visits conducted in different trainings. Yet, CSVFA's success is not only an offshoot of formal education provided to them by GTZ but also through informal environmental education that have been practiced in farmers' individual households. In fact, during the early years of establishing the CSVFA, Visayas State University assigned the then community organizer Dr. Marlito Bande to the village to facilitate the establishment of a pilot Rainforestation site. Dr. Bande decided to live with the community and conducted regular discussions and consultations to build consensus on key issues, strategize a plan of action, and mobilize the members based on increased awareness and commitment (Bande, Consunji, Bloomfield, and Labastilla, 2016).

Dr. Bande assisted in restructuring the group and registering them as a people's organization with the Department of Labor and Employment under the name, Cienda San Vicente Farmers' Association (CSVFA). In order to stop the destructive logging and slash and burn practices, the members trained to be deputized forests wardens, giving them the right to apprehend violators in their watershed areas. The organization came up with their organizational structures and came up with their constitution and by laws. They also came up with the outline of different environmental activities and cost-benefit scheme. CSVFA then signed a Memorandum of Agreement (MOA) with VSU, the local government unit, and the owner of the land where the Rainforestation farm would be developed. The MOA legalized the lease of the land to CSVFA for 50 years, formalized the partnership among the different stake holders, and specified the roles and responsibilities of each stake holder (Bande, Consunji, Bloomfield, and Labastilla, 2016). With this, the CSVFA Rainforestation farm was established, and at present, is one of the most successful Rainforestation Demonstration farm in Region 8, if not, the whole country.

According to Dr. Marlito Bande: *"The success of the CSVFA Rainforestation farm is a result of a collaborative efforts among the farmers themselves. It was really the farmers who initiative the move since they were the ones who were affected by the negative effects brought about by environment degradation. When I was assigned to work with the farmers, I saw their sincerity and commitment so I decided to live with the community in order to help them achieve their goal to protect their forest and at the same time teach them to establish a Rainforestation demonstration farm by teaching them the basics like the collection of wildlings from the forest, the establishment*

of a nursery, the identification of a potential Rainforestation site, and the planting of native tree seedlings. In fact, during the early years, I also helped the farmers in negotiating for the use of the lot for the demonstration farm. All in all, I can say that the success of the CSVFA Rainforestation efforts is brought about by the collaborative efforts of the farmers themselves".

One unique characteristic of CSVFA is that it gives importance and priority to family membership. This means that it is not only the father and the mother who are considered members of the association but also their children. With this, the children have been instructed at home on the significance and necessity to protect the natural environment. This is one way of inculcating to the minds of the young the importance of nature conservation. In fact, Bernie Tabaranza, an employee of the Institute of Tropical Ecology and Environmental Management and a son of one of the pioneering members of the Cienda San Vicente Farmers Association (CSVFA) also stressed that Rainforestation succeeded in Cienda since the organization's adoption of the Rainforestation is not only about the community, it is also about family involvement. According to Bernie: *"Household forms of membership by Rainforestation adopters ensures social sustainability since children are involved in the planning and are assigned task in taking good care of the existing Rainforestation demonstration farm. With this, the children are given the opportunities to feel that they also possess the Rainforestation farm since they also have invested their time and efforts in taking care of it. Family members involve in CSVFA are also actively involved in the implementation and monitoring of forest restoration activities"*

At present, GTZ's mission to proliferate environmental education to a large number of people has already ended after almost twenty years of supporting environment education related activities. Yet, this mission has been continued by the Environment Leadership Training Initiatives (ELTI) through its Leadership Program where ELTI graduates have been mandated to re-echo what they learned from the leadership training. In Leyte, ELTI has trained adopters in the town of Inopacan. It also has new adopters in Cabugcayan, Biliran Province and has established rainforestation demonstration farms in the area. This is ELTI's thrust to continue what GTZ has started so that sustainable development would be achieved through environmental education. Hence, there is no doubt that one of the potent weapons in the thrust to conserve and protect of what is left of the natural environment is environmental education. For the new sets of adopters, rainforestation have given them hope that their efforts could have a significant contribution to nature conservation. Through environmental education, people from all walks of life would be given a chance to realize Mother Nature's importance to the lives of each and every person including the future generation.

The Influence of Environmental Education to the Generation of Rainforestation Adopters

Environmental education has indubitably played a great role in protecting and conserving of what is left of the natural environment. The efforts of the Environment Leadership Training Initiatives (ELTI) have paved the way for a greater awareness of the significance of each and every person's role in taking good care of nature so that it could sustain the needs of people for a longer period of time. The establishment of a ten hectare rainforestation demonstration in Inopacan, Leyte as well as the establishment of the same demonstration farm on an eight hectare property in Cabugcayan, Biliran Province are offshoots of rainforestation leadership trainings conducted and sponsored by ELTI. These trainings have educated people of all ages on the importance of protecting Mother Nature since it is also an indirect way of protecting oneself. According to Ricardo Cabulan, a new rainforestation adopter from Cabugcayan Biliran: *"I am convinced by the ELTI Rainforestation training that taking good care of the environment is very important. My exposure to the different rainforestation farms in Baybay, Leyte has given me a strong belief that planting native trees for nature conservation is possible and very doable."*

This sentiment is re-echoed by Gerald Matinao, an adopter from Inopacan, Leyte who also happened to live within the vicinity of the Inopacan rainforestation site. According to Mr. Matinao: *"The ELTI environmental education and rainforestation training has greatly affected the mind sets of the Inopacan rainforestation adopters. The ELTI training has given them insights that it is not difficult to do our share in taking good care of Mother Nature. My and my neighbors' exposure to the different vibrant rainforestation farms in Baybay, Leyte have given us hope that*

some day, a large parcel of our unproductive and denuded land would become a green lush forest in the very near future. We believe in this since someone has already proven that rainforestation is doable and possible. Yet all this is not possible without the ELTI rainforestation training since it educated us to value what is left of Mother Nature".

CONCLUSION

This study concludes that all group and individual rainforestation adopters in the Visayas region in the Philippines have benefitted from the good things that rainforestation has given them. Economic benefits as a result from rainforestation adoption is shared by the group and individual adopters. For instance, the Cienda-San Vicente Farmers Association became a supplier of native tree seedlings to the Philippine government's National Greening Program that enabled them to earn over a million pesos in income. Not only that, rainforestation farms also serve as a good source of water as demonstrated by Mr. Manuel Posas. This not only give Mr. Posas non-stop supply of water, it also give him the opportunity to earn from his newly installed water system. Above all, rainforestation brings back and restore biodiversity which is the essence of environment conservation.

Moreover, this study also concludes that environmental education is one of the main factors why individuals and groups have adopted Rainforestation. The formal education provided by Visayas State University, Gesellschaft für Technische Zusammenarbeit (GTZ), and the Environment Leadership Training Initiatives (ELTI) has changed the mind-sets of the rainforestation adopters in such a way that it gave them meaningful realizations that Nature conservation is each and every person's moral obligation. Furthermore, the experience of the CSVFA members has also proven that informal environmental education in one's home is also effective in inculcating to the minds of the youth the importance of the natural environment to one's life. This enables the youth to care for Mother Nature by heart which leads to a development that is sustainable. Lastly, this study further concludes that the spread of Rainforestation has been an offshoot of the greater reach of education and information dissemination.

REFERENCES

Bande, M., Consunji, H., Bloomfield, G. and Labastilla, P. 2016. Rainforestation case study: The Cienda San Vicente farmers' association experience. Smithsonian Topical Research Institute, Yale University, CT and Panama City, USA and Panama.

Dhalberg, K. 2006. The essence of essences: The search for meaning structures in phenomenological analysis of lifeworld phenomena. International Journal of Qualitative Studies of Health and Well Being, 1 (1), 11-19.

Fernando, E. 2005. Restoring the Philippine rainforests. Haribon Policy Paper, No. 2, Manila, Philippines.

Goltenboth, F. and Tropentag. 2005. Ecosystem approach. Lecture presented at the Conference on International Agricultural Research for Development in Palo, Leyte, Philippines, October 13, 2005.

Haribon Foundation. 2016. Classifying natural and restored forests containing primary, secondary growth, or residual forests. PANAO Rain Forest Restoration Initiative, 3, Philippines.

Kafle, N.P. 2011. Hermeneutic phenomenological research method simplified. Bodhi. An Interdisciplinary Journal, 181-200.

Langdridge, D. 2005. Phenomenological psychology. Theory, Research, and Methods, Pearson, London, UK.

Milan, P. and Ceniza, M.J. 2009. Rainforestation trainers manual. Institute of Tropical Ecology, Visayas State University, Baybay, Leyte, Philippines.

Smith, S.J. 1997. Phenomenology of educating physically. Vandenburg, D. (Ed.) Phenomenology and Educational Discourse, 119-144.

Research article

Determination of Lethal Concentration of Copper Compounds on Nile Tilapia (*Oreochromis niloticus* Linnaeus, 1758) Larvae

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Abstract Copper is an essential element for cell organisms. However, irregularity copper level could have effect on the growth of organism. In this research, we aim at consideration of copper compounds toxicity against larvae of Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) by statistic assays. Four days old of test fish had an average 7.10±0.03 mm of length and 9.72±0.04 mg of fresh weight. All experiments were carried out for a period of 48 to 96 hours at 27–30°C. The number of dead fish was counted every 24 hours and the mortality rate was determined after 96 hours. The statistical data was evaluated by Finney's probit analysis method. The fish died 50% (LC_{50} 95% confidence limits) after 48, 72, 96 hours of concentration copper chloride ($CuCl_2$) 595.75, 231.11, 124.64 µg/L, respectively, and copper nitrate (Cu $(NO_3)_2$) 1,025.40, 588.79, 456.50 µg/L, respectively. The LC_{50} results clearly show that copper compounds toxicity for fish increased with increasing concentration and exposure time. The percentage of survival decreased with increasing of both copper compound concentrations and it was significantly different from control (p<0.01). This study showed that Nile tilapia larvae were more sensitive to copper chloride than copper nitrate. Further study needs the processes by which these chemicals affect biochemical changes of the fish.

Keywords copper, lethal concentration, LC_{50}, tilapia, toxicity

INTRODUCTION

The copper-gold (Cu-Au) has been consumed for a large quantity in Thailand. The internal main supply could be found in Loei province (Yang et al., 2014). Due to high demand, it was imported in various forms i.e. pure copper, copper matt, copper anode, unwrought and copper products in a large amount for 422,619 metric tons in 2012 (Office of Industrial Economics, 2012). Copper and its compounds has been used in various industries such as electrical products, building construction, chemical and pharmaceutical manufacturing (National Pollutant Inventory, 2014). They are directly discharged from industrial effluents and also from polluted runoff in urban and agricultural areas (FAO, 1992; Yirgu, 2011). Therefore, surface water and groundwater are being polluted from these

effluents and runoff that contains copper and its compounds. Copper has been detected in water range from 1 to 5 mg/L, which is classified as small amounts or not generally considered to be toxic. However, gradually accumulation of copper in body could become large doses enough to cause sickness, and could lead to liver damage in extreme cases. The distribution of copper ions has been determined in the aquatic system to assess the influence of biological processes on the copper estuarine behavior. The copper chloride prominently affects the fish muscles as some amino acids (Histidine, Proline, Glycine, Alanine, Methionine and Valine) are found to be reduced or even completely missing (Alkesh, 2016). Aquatic life is more sensitive 10–100 times to the hazardous effects of copper than mammals (Shah and Vyas, 2015).

Lethal concentration test measure the susceptibility and survival potential of organisms to a particular toxic substances such as heavy metals. Pollutants with higher median lethal concentration (LC_{50}) values are required to induce mortality in organisms (Eaton et al., 2005; Zahedi et al., 2012). Nile tilapia is one of the most common freshwater fish used in toxicological studies (Figueiredo-Fernandes et al., 2006a, b, 2007; Garcia-Santos et al., 2006) because it is easy handling, culture and maintenance in laboratory (Alkobaby and El-Wahed, 2017). Moreover, it promptly responds to environmental alterations so this species is also a well-established model for toxicological research (Almeida et al., 2002; Figueiredo-Fernandes et al., 2006a, 2007). Hence, the aim of this study is to determine the value of copper as chloride and nitrate lethal concentration for Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) larvae in order to determine specific times.

MATERIALS AND METHODS

The experiment was conducted at Environmental Science Laboratory, Faculty of Science and Technology, Valaya Alongkorn Rajabhat University under the Royal Patronage, Pathum Thani province, Thailand. The acute toxicity of copper compounds for Nile tilapia larvae was determined in terms of 48, 72 and 96 hours LC_{50} and lethal concentrations. The determination of lethal concentration of copper compounds on Nile tilapia larvae was the following.

Test Organism

Two days old of Nile tilapia (*Oreochromis nileticus* Linnaeus, 1758) fish larvae were obtained from the Pathum Thani Inland Aquaculture Fisheries Research and Development Center, Thailand for toxicity testing in an oxygenated plastic bag (Fig. 1). The test was conducted at the Environmental Science Laboratory, Valaya Alongkorn Rajabhat University under the Royal Patronage in January, 2017. The tested fish were acclimatized in distilled water. Each holding tray was aerated by using a portable pump and air stone for a period of 48 hours at a room temperature before experiment use. If survival rate was $\leq$10%, the entire stock was discarded (Boonsomboone, 2004). Test fish fused or toxicity tests had an average 7.10$\pm$0.03 mm of length and 9.72$\pm$0.04 mg of wet weight.

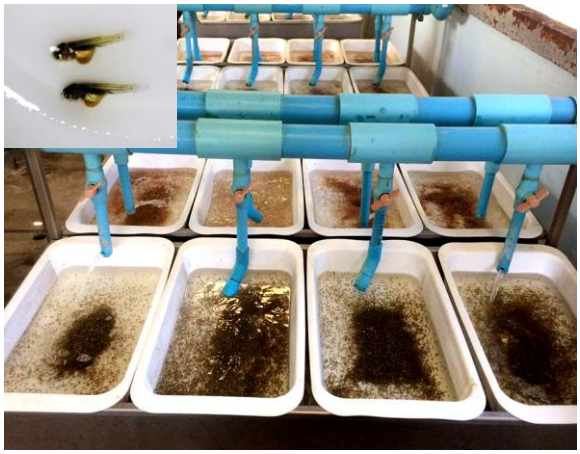

Fig. 1 The test organism, Nile tilapia (*Oreochromis nileticus* Linnaeus, 1758) larvae

Test Media

Analytical grade copper chloride ($CuCl_2 \cdot 2H_2O$) and copper nitrate ($Cu(NO_3)_2 \cdot 3H_2O$) form Sigma-Aldrich were used for preparation of stock solutions that were diluted as desired concentrations. Fish were exposed for 24 to 96 hours, separately, against different concentrations of two copper compounds at 0, 10, 50, 100, 300 and 500 µg/L. The investigation was performed in laboratory conditions at dissolved oxygen (8.06±0.05), temperature (27.77±0.76ºC) and pH (6.50±0.50). All physico-chemical parameters were performed by following APHA-AWWA-WEF (1998) on daily basic.

Determination of Lethal Concentration

Four-day static acute toxicity test was performed at five different concentrations (10, 50, 100, 300 and 500 µg/L of copper chloride and nitrate) were used in the test series (10 fish for each). A control group (10 fish) was maintained in deionized water container throughout entire experimental period, the fish were not fed. Fish mortalities were record at 48, 72 and 96 hours after starting of tests, and dead fish were removed immediately from test media. Mortality was assessed in the different copper concentrations along with the control group to determine the 96 hours median lethal concentration (LC_{50}) value by the use of Finney's probit analysis method (Finney, 1971).

Statistical Analysis

The entire experiment was analyzed using a completely randomized design (CRD) method. Mortality data for 48, 72 and 96 hours was calculated for LC_{50} values (95% confidence limits) by Finney's probit analysis (Finney 1971) using the Statistical Analysis System (SPSS) version 11.5 program. Standard error of mean value (SEM) of replication sampling (n=12) was taken for each analysis. A significantly different result was established by a one-way ANOVA, and mean comparisons of different treatments were carried out by least significant difference (LSD) on Duncan multiple test of Statistix 8 Software (Analytical Software, Tallahassee, FL). The acceptance level of significance was a probability value less than 0.05 (p<0.05).

RESULTS AND DISCUSSION

Median lethal concentration (LC_{50}, 95% confidence limits) for copper chloride and copper nitrate on the larvae of Nile tilapia (*Oreochromis nileticus* Linnaeus, 1758) calculated by Finney's probit analysis method and SPSS Statistical Software at 48, 72 and 96 hours of exposure was shown in Table 1 and Fig. 2.

Table 1 LC_{50} value with 95% confidence limit of copper chloride and copper nitrate on fish

Exposure times (hour)	Lethal concentration (µg Cu/L, lower-upper values)	
	Copper chloride ($CuCl_2$)	Copper nitrate ($Cu(NO_3)_2$)
48	595.754 (391.083 – 1,118.644)	1,025.395 (668.913 – 2,207.740)
72	231.110 (171.199 – 335.477)	588.785 (418.447 – 988.509)
96	124.637 (94.508 – 167.266)	456.504 (322.974 – 755.933)

Note: LC_{50} is concentration of copper compounds that caused dead 50% of the exposed fish at a specific time of observation (e.g. 48 hours LC_{50}), (expressed as µg/L of copper concentrations)

Results showed that the 48 hours LC_{50} (lower–upper values) for copper chloride was 595.754 (391.083–1,118.644) µg/L which sharply declined to 231.110 (171.199–335.477) and 124.637 (94.508–167.266) µg/L at 72 and 96 hours, respectively. LC_{50} value for copper chloride was lower than copper nitrate at exposure times. At 48, 72 and 96 hours LC_{50} values for copper nitrate on fish

were 1,025.395 (668.913–2,207.740), 588.785 (418.447–988.509) and 456.504 (322.974–755.933) µg/L, respectively. This study showed that copper chloride was more toxic than copper nitrate on Nile tilapia larvae.

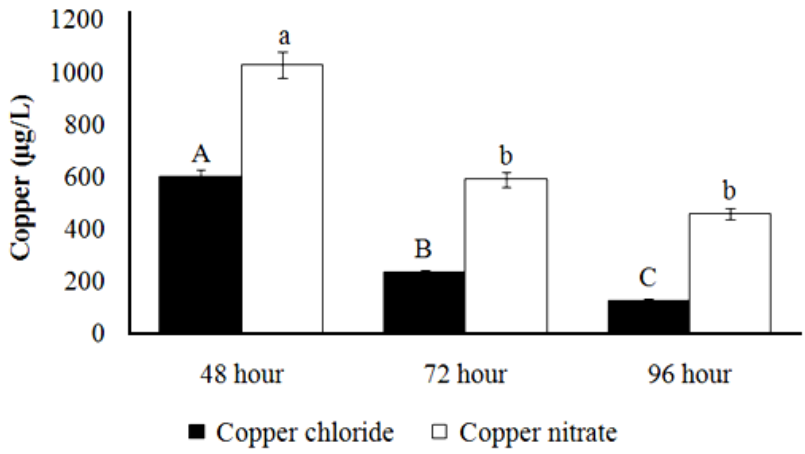

Fig. 2 Shown LC_{50} value of both copper compounds on fish

The 96 hours LC_{50} value for copper chloride in Nile tilapia larvae was found 124.637 µg/L in the present work, and here we report copper chloride to be highly toxic to fish. The Material Safety Data Sheet (MSDS) reports copper chloride acute toxicity to carp fish (*Cyprinus carpio*) in laboratory tests, in the average range LC_{50} value of 120–230 µg/L (Sigma-Aldrich Corporation, 2014). Our result is in good agreement with this report. These values are considerably lower than 96 hour LC_{50} (900 µg/L) of Bluegill (*Lepomis macrochirus*), indicating higher vulnerability to copper chloride in the former two species (Sigma-Aldrich Corporation, 2014; NTU chemistry Deportment, 2017). Conversely, Warrin et al. (2009) found that copper chloride in sediment media had higher toxic on *Chironomus tentans* than copper sulfate and copper nitrate. The results were obtained by Taweel et al. (2013) reported that mean of 48, 72 and 96 hours LC_{50} value for copper sulfate in fingerlings of Nile tilapia (*Oreochromis nileticus*) were 1,863 (1,031–5,194), 1,368 (741–2,802) and 1,093 (581–1,613) µg/L, respectively. According to Iwai et al. (2016) estimates of 48, 72 and 96 hour LC_{50} value for copper sulfate to Nile tilapia (*Oreochromis nileticus*) larvae were 1,869 (1,157–5,235), 1,740 (–) and 1,383 (859–2,718) µg/L, respectively, these results are higher than present study (Table 1). On the other hand, LC_{50} for copper oxide on Barnacle (*Balanus improvises*) was 350, 140 and 20 µg/L for 48, 72 and 96 hours, respectively (U.S.EPA, 2009a). For copper sulfate, the larva was the most sensitive stage of development of cobia (*Rachycentron canadum*): eggs, larvae (one-day-old fish), juveniles (20 days old) and young fish (40 days old) in toxicity tests, with an 96 hours LC_{50} of 91 (56–134), 60 (29–96), 87 (49–133) and 240 (119–378) µg/L, respectively as the early stages were more sensitive than the later stages, (Le et al., 2005). In addition, copper was most toxic to fingerling tilapia fish and the toxicity ranking of four heavy metals was copper > lead > cadmium > zinc (Taweel et al., 2013). Also, copper was more toxic than cadmium for common carp (*Cyprius carpio* L.) embryos and larvae (Jezierska et al., 2009).

The observed percentage of Nile tilapia mortality for copper in static tests continuous for different hours and different concentrations were shown in Table 2. There was positive relationship between the mortality and concentration levels; when concentration increased, the mortality rate increased as well. Similar, the percentage of survival decreased with increasing of both copper compound concentrations and exposure times. The result showed significant decreased percentage of fish survival in copper chloride and copper nitrate when compared with control (p<0.01). The fish tests significant responded to both copper concentrations (50 µg/L) in percent survival (72.0–85.6%) at specific times in Table 2. The copper concentrations that caused 50% of the exposed fish at 96 hour were found 100 µg/L of copper chloride and 300 µg/L of copper nitrate. Similar to Howell et al. (1984) reported that copper (94 µg/L) reduced the filtration rate of mussels (*Mytilus edulis*) by half, probably through reducing the ciliary beation via the bronchial nerves. Chen et al.

(2012) reported that even short-term pulsed exposure to low levels of copper (1.6–2.0 µg/L) reduced growth rate of tilapia (*Oreochromis mossambicus)* larvae. Shah and Vyas (2015) reported that at 2 mg/L of copper chloride concentration caused damage to cell membrane and vaculation of *Labeo rohita* on 15 day, nucleus was affected on 30 days and on 45 days the cell membrane was wrinkled and damaged.

Table 2 Percent survival of exposed Nile tilapia larvae at specific times

Concentrations (µg /L)	% Survival for Nile tilapia larvae (n=120)					
	Copper chloride ($CuCl_2$)			Copper nitrate ($Cu(NO_3)_2$)		
	48 h	72 h	96 h	48 h	72 h	96 h
0	94.7 ± 4.2a	90.2 ± 3.5a	87.4 ± 4.2a	100.0 ± 0.0a	100.0 ± 0.0a	98.9 ± 3.3a
10	90.1 ± 5.2ab	84.7 ± 3.8a	79.0 ± 6.3b	98.9 ± 3.3ab	95.6 ± 5.3ab	92.2 ± 6.7ab
50	85.6 ± 5.1b	77.3 ± 7.2b	72.0 ± 5.0c	92.2 ± 6.7bc	85.6 ± 7.3b	81.1 ± 9.2bc
100	79.0 ± 6.1c	68.6 ± 8.5c	56.6 ± 9.9d	92.2 ± 8.3bc	88.9 ± 7.8b	82.2 ± 10.9c
300	61.2 ± 7.0d	47.3 ± 6.1d	39.4 ± 8.7e	88.9 ± 7.8c	73.3 ± 13.2c	66.7 ± 14.1d
500	47.1 ± 9.8e	31.8 ± 9.7e	21.8 ± 3.9f	57.8 ± 13.0d	43.3 ± 19.4d	37.8 ± 17.2e
LSD	**	**	**	**	**	**
CV (%)	8.56	11.11	11.40	8.71	13.24	14.67

*Note: ** showed significantly different from control ($p \leq 0.01$)*

CONCLUSION

Based on the acute toxicity tests performed in this study, Nile tilapia larvae was shown to be more sensitive to copper chloride than copper nitrate which reducing LC_{50} value and survival rate of fish tests in copper chloride concentrations. The LC_{50} determination of copper compounds on fish larvae was copper toxicity increased with increasing concentration and exposure time. The copper concentrations that caused 50% of the exposed fish at 96 hours were found 100 µg/L of copper chloride and 300 µg/L of copper nitrate.

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REFERENCES

Alkesh, I.S. 2016. Impact of heavy metal copper chloride on fish *Labeo rohita*. Int. J. Adv. Res., 4 (10), 461-466.

Alkobaby, A.I. and Abd El-Wahed, R.K. 2017. The acute toxicity of copper to Nile tilapia (*Oreochromis niloticus*) fingerlings and its effects on gill and liver histology. J. Aquac. Res. Development, 8 (1), 1-6.

Almeida, J.A., Diniz, Y.S., Marques, S.F., Faine, L.A., Ribas, B.O., Burneiko, R.C. and Novelli, E.L.B. 2002. The use of the oxidative stress responses as biomarkers in Nile tilapia (*Oreochromis niloticus*) exposed to in vivo cadmium contamination. Environ. Int., 27, 673-679.

APHA-AWWA-WEF. 1998. Standard methods for the examination of water and wastewater, 20th ed. American Public Health Association, Washington DC, USA.

Boonsomboon, S. 2004. A selection of appropria test conditions for whole effluent toxicity testing with juvenile Nile tilapia (*Orecochromis niloticus*). M.Sc. Thesis, Graduated School, Mahidol University, Thailand.

Chen, W.Y., Lin, C.J., Ju, Y.R., Tsai, J.W. and Liao, C.M. 2012. Coupled dynamics of energy budget and population growth of tilapia in response to pulsed waterborne copper. Ecotoxicology, 21 (8), 2264-2275.

FAO. 1992. Committee for inland fisheries of Africa. Report of the third Session of the Working Party on Pollution and Fisheries, Accra, Ghana, 25-29 November 1991. FAO Fisheries Report, 471, Rome, FAO.

Figueiredo-Fernandes, A., Fontaínhas-Fernandes, A., Monteiro, R.A.F., Reis-Henriques, M.A. and Rocha, E. 2006a. Effects of the fungicide mancozeb in the liver structure of Nile tilapia, *Oreochromis niloticus*-Assessment and quantification of induced cytological changes using qualitative histopathology and the stereological point-sampled intercept method. Bull. Environ. Contam.Toxicol., 76 (2), 249-255.

Figueiredo-Fernandes, A., Fontaínhas-Fernandes, A., Peixoto, F., Rocha, E. and Reis-Henriques, M.A. 2006b. Effect of paraquat on oxidative stress enzymes in tilapia *Oreochromis niloticus* at two levels of temperature. Pest. Biochem. Physiol., 85 (2), 97-103.

Figueiredo-Fernandes, A., Ferreira-Cardoso, J.V., Garcia-Santos, S., Monteiro, S.M., Carrola, J. and Motos, P. 2007. Histopathological changes in liver and gill epithelium of Nile tilapia, *Oreochromis niloticus*, exposed to waterborne copper. Pesq. Vet. Bras, 27 (3), 102-109.

Gadagbui, B.K.M., Addy, M. and Goksøyr, A. 1996. Species characteristics of hepatic biotransformation enzymes in two tropical freshwater teleosts, tilapia (*Oreochromis niloticus*) and mudfish (*Clarias anguillaris*). Comp. Biochem. Physiol., 114 (3), 201-211.

Howell, R., Grant, A.M. and Maccoy, N.E. 1984. Effect of treatment with reserpine on the change in filtration rate of *Mytilus edulis* subjected to dissolved copper. Mar. Pollut. Bull., 15 (12), 436-439.

Iwai, C.B, Soeung, L. and Houng, T. 2016. Acute toxicity testing of copper on four species of tropical freshwater biota (*Moina macrocopa, Chironomus javanus, Ctenopharyngodon idella* and *Oreochromis niloticus*). Khon Kaen Agr. J., 44 (Suppl. 1), 1006-1013.

Jezierska, B., Sarnowski, P., Witeska M. and Ługowska K. 2009. Disturbances of early development of fish caused by heavy metals (a review). Electron. J. Ichthyol., 5 (2), 76-96.

Le, Q.D., Nguyen, M.C., Nguyen, T.H. and Nguyen D.C. 2005. Acute toxicity test to determine the effects of copper, zinc and cyanide on cobia (*Rachycentron canadum*) resources in North Vietnam. Australasian J. Ecotoxicol., 11, 163-166.

National Pollutant Inventory 2014. Copper and compounds. Department of the Environment and Energy, Australia Government, http://www.npi.gov.au/resource/copper-and-compounds (retrived on 27 October, 2017).

Office of Industrial Economics. 2012. Copper industrial situation 2012. http://www.oie.go.th/sites/default/files/attachments/industry_ overview/copper-industrialsituation-2555.pdf

Reddy, P.P., Jagadeshwarlu, R. and Devi, G.S. 2015. Determination of lethal concentration (LC_{50}) of copper to *Sarotherodon mossambica*. Int. J. Fish. Aqua. Stud., 4 (1), 172-175.

Shah, A.I. and Vyas, B.M. 2015. Relative study of copper toxicity on aquatic life and human health. J. Environ. Res. Develop., 9 (34A), 884-888.

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

Yang, S., Wang, G., Du, W. and Huang, L. 2014. Remote sensing and GIS-based prediction and assessment of copper-gold resources in Thailand. The 35th International Symposium on Remote Sensing of Environment (ISRSE35), 22-26 April, 2013, Beijing, China, IOP Publishing: IOP Conference Series, Earth and Environmental Science, 17 (1), 1-4.

Yirgu, Z. 2011. Accumulation of certain heavy metals in Nile tilapia (*oreochromis niloticus*), Fish species relative to heavy metal concentrations in the water of Lake Hawassa. M.Sc. Thesis, Graduate School, Addis Ababa University.

Zahedi, S., Mehrpoosh, M., Vaezzade, H., Dagesaracki, M.S. and Hosseini, S.M. 2012. LC_{50} determination and copper and cadmium accumulation in the gills of Kutum (*Rutilus frisii kutum*) fingerlings. Terr. Aquat. Environ. Toxicol., 6 (2), 71-76.

Research article

Antioxidant Activity of Crude Extract from Raw and Heat-treated *Moringa oleifera*

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Abstract The aim of this research was to investigate the effect of heat treatment on antioxidant properties of crude extract from *Moringa oleifera* (peel, pulp, and seed). Total phenolic content and antioxidant properties based on 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging, ferric reducing antioxidant power (FRAP), and metal chelating activity were investigated. Results revealed that crude extract obtained from raw moringa peel showed the highest total phenolic content and DPPH radical scavenging activity (3.65 mg gallic acid eq./g DW and 1.35 mg Trolox eq./g DW), followed by pulp (3.44 mg gallic acid eq./g DW and 1.25 mg Trolox eq./g DW) and seed (2.80 mg gallic acid eq./g DW and 0.91 mg Trolox eq./g DW), respectively. The highest FRAP were obtained from the raw moringa peel extract (3.62 mg ferrous eq./g DW), whereas the highest metal chelating activity was found in raw moringa pulp extract 0.42 mg EDTA eq./g DW). All samples with heat treatment at 100 °C for 15 min showed lower total phenolic content and antioxidant properties than crude extract from raw moringa samples ($P<0.05$).

Keywords *Moringa oleifera*, heat treatment, antioxidant activity

INTRODUCTION

In recent years, attention has been focused on antioxidants derived from natural sources, due to the fact that antioxidative activity of extracts from plants or animals, in some cases, is similar or higher than that of commonly used synthetic antioxidants such as butylated hydroxytoluene (BHA) and butylated hydroxylanisole (BHT), which are quite unsafe and their toxicity is a problem of concern (Hossain et al., 2008). Plant and its products are rich sources of a phytochemicals and have been found to possess a variety of biological activities including antioxidant potential in various oxidative reaction systems have been discovered. The antioxidant properties include scavenging or quenching of reactive oxygen species (ROS)/free radicals and inhibition of ROS induced oxidation of biological macromolecules such as lipids, proteins, and DNA. Other mechanisms of antioxidant activity include transition metal chelating activity and ferric reducing power (Arabshahi-Delouee et al, 2007).

Moringa oleifera is a widely cultivated tree considered as a multi-purpose plant which can be found in tropical and subtropical climates and contains various phytochemicals such as carotenoids, vitamins, minerals, amino acids, sterols, glycosides, alkaloids, flavonoids and phenolics (Siddhuraju and Becker, 2003; Upadhyay et al., 2015). Almost all the parts of this plant such as root, bark, gum, leaf, fruit (pods), flowers, seed and seed oil have been reported as source of different biochemical compounds with anticarcinogenic, antiinflammatory, antidiabetic, antioxidant,

and antimicrobial effects (Chuang et al., 2007; Upadhyay et al., 2015). *M. oleifera* leaf was found to have high source of protein, beta-carotene, vitamin C, iron, potassium, and other nutrients (Jongrungruangchok et al., 2010). Extracts from *M. oleifera* roots and flowers were found to have a significant hepatoprotective effect (Ruckmani et al., 1998).

The effect of food processing procedure on the antioxidant activity of foods are generally the result of different processing. Thus, the evaluation of processing factors influencing the antioxidant activity is imperative to increase or preserve their lability (Nicoli et al., 1999). Several studies have reported the antioxidant potential of *M. oleifera* leaf (Jongrungruangchok et al., 2010; Sreelatha and Padma, 2009; Verma et al., 2009; Vongsak et al., 2013). Only a few studies have reported the antioxidant activity of Moringa peel, pulp, and seed and their ability after heat process. Therefore, this research aimed to investigate the effect of heat treatment on antioxidant properties of crude extract from *Moringa oleifera* (peel, pulp, and seed).

OBJECTIVE

The objective of this study was to investigate the effect of heat treatment on antioxidant properties of crude extract from *Moringa oleifera* (peel, pulp, and seed).

METHODOLOGY

The *Moringa oleifera* pods were purchased from a commercial market in Phathumtani province, Thailand and then separated into *Moringa oleifera* peel, pulp, and seed samples and cut into small pieces (Fig. 1). Each sample was divided into raw and heat-treated samples (in a boiling water bath for 15 min.). All samples were incubated at 60 ºC for 24 hours. The dried samples were powdered and passed through sieve no. 18 and analyzed for moisture content (AOAC, 2000). Each sample was extracted with 50% ethanol at a ratio of 1:20 (w/v). The mixture was then shaken at room temperature for 24 hours with a shaking speed of 150 rpm. Supernatant was collected and filtered through Whatman No.1 filter paper. Then, this crude extract was subjected to total phenolic content and antioxidant activity assays.

(A) **(B)** **(C)**

Fig. 1 Moringa peel (A), pulp (B), and seed (C) samples used in this study

Total phenolic compound was determined by Folin-Ciocalteu method (Kähkönen et al., 1999). Briefly, 500 μL of each sample were mixed well with 2.5 mL of 0.2 M Folin–Ciocalteu reagent, followed by the addition of 2 mL of 7.5% (w/v) sodium carbonate. The mixture was allowed at room temperature for 60 min and absorbance was measured at 7650 nm. The total phenolic content was calculated from the calibration curve, and the results were expressed as mg gallic acid equivalents/g dry weight (mg gallic acid eq./g DW).

2,2-Diphenyl-1-picrylhydrazyl radical scavenging activity assay (DPPH assay) was performed according to Burits and Bucar (2000) with some modifications. Sample (1 mL) were mixed with 1 mL of 0.1 mM DPPH solution. The reaction tubes were wrapped in aluminum foil and incubated at

room temperature for 10 min in dark. The absorbance was monitored at 517 nm. DPPH assay was expressed as mg Trolox equivalents/g dry weight (mg Trolox eq./g DW).

Ferric reducing antioxidant power assay (FRAP assay) was performed according to Benzie and Strain (1996) with some modifications. Sample (100 µL) were mixed with 1900 µL of FRAP reagent. The absorbance of the reaction mixture was monitored at 593 nm after incubating at 37 ºC for 10 min. FRAP value of each sample was expressed as mg ferrous equivalents/g dry weight (mg ferrous eq./g DW).

Metal chelating activity assay was performed according to Decker and Welch (1990) with some modifications. Sample (100 µL) were mixed with 1,400 µL of distilled water and 100 µL of 2 mM $FeCl_2.4H_2O$. The reaction mixture was incubated at room temperature for 3 min. Then, the reaction mixture was added with 400 µL of 5 mM ferrozine and incubated at room temperature for 10 min. The absorbance was monitored at 562 nm. Metal chelating activity of each sample was expressed as mg EDTA equivalents/g dry weight (mg EDTA eq./g DW).

All the extraction processes and the analyses on each sample were done in duplicate. The experiments followed a completely randomized design (CRD) comprising six crude extract samples. Differences among mean values were established using Duncan Multiple Range Test (DMRT) at $P<0.05$.

RESULTS AND DISCUSSION

Moisture content of raw moringa peel, pulp, and seed powder were 9.13, 9.90, and 9.97, respectively. Whereas, moisture content of heat-treated moringa peel, pulp, and seed powder were 8.65, 8.88, and 8.92, respectively. Total phenolic content and DPPH radical scavenging activity of raw and heat-treated moringa peel, pulp, and seed extracts were shown in Table 1. The results showed that the highest total phenolic content was found in moringa peel (3.65 mg gallic acid eq./g DW), followed by pulp (3.44 mg gallic acid eq./g DW) and seed (2.85 mg gallic acid eq./g DW), respectively. After heat treatment, moringa peel, pulp, and seed samples showed lower total phenolic content than their respective raw samples. Siddhuraju and Becker (2003) reported that the main phenolic compounds in drumstick leaves and its extracts are flavonoid groups such as quercetin and kaempferol. They also contained 3-caffeoylquinic and 5-caffeoylquinic acid. The whole pods are reported to contain nitriles, isothiocyanate and thicarbamates (Faizi et al., 1995) and has antioxidant activity, which is due to the presence of carotenoid compounds (Kumar et al., 2007).

Table 1 Total phenolic content and DPPH radical scavenging activity of raw and heat-treated *Moringa oleifera* peel, pulp, and seed extracts

Sample	Total phenolic content (mg gallic acid eq./g DW)	DPPH radical scavenging activity (mg Trolox eq./g DW)
Raw moringa peel	$3.65^{a} \pm 0.03$	$1.35^{a} \pm 0.02$
Raw moringa pulp	$3.44^{b} \pm 0.25$	$1.25^{b} \pm 0.03$
Raw moringa seed	$2.80^{c} \pm 0.02$	$0.91^{c} \pm 0.04$
Heat-treated moringa peel	$1.38^{d} \pm 0.01$	$0.78^{d} \pm 0.03$
Heat-treated moringa pulp	$1.19^{de} \pm 0.02$	$0.41^{e} \pm 0.04$
Heat-treated moringa seed	$0.91^{e} \pm 0.01$	$0.23^{f} \pm 0.01$

Means of the same column with different superscripts indicate significant difference (P<0.05).

The antiradical activity was measured as ability to reduce DPPH radical by crude extract from raw and heat-treated *M. oleifera* (peel, pulp, and seed). As shown in Table 1, raw moringa peel showed the highest DPPH radical scavenging activity (1.35 mg Trolox eq./g DW), followed by pulp (1.25 mg Trolox eq./g DW) and seed (0.91 mg Trolox eq./g DW), respectively. The lower DPPH radical scavenging activity was also found in heat-treated samples. These results are in agreement with Arabshahi-Delouee et al. (2007). Incubating moringa leaves extract at 100 ºC for 15 min resulted in a significant decrease in inhibition of lipid peroxidation by 17% using

thiobarbituric acid (TBA) assay. Heat processing may have resulted in degradation of antioxidants present in moringa leaves extract, thereby decreasing the activity.

FRAP of raw and heat-treated moringa peel, pulp, and seed extracts were shown in Table 2. FRAP of raw moringa peel (3.62 mg ferrous eq./g DW), seed (3.32 mg ferrous eq./g DW), and pulp extracts (3.28 mg ferrous eq./g DW) was comparable ($P>0.05$) and showed higher FRAP than all heat-treated samples ($P<0.05$). This method is based on the ability of a compound to donate one electron to Fe^{3+} to reduce it to $Fe^{2+,}$ whereas DPPH radical scavenging assay is involved hydrogen atom transfer.

Table 2 Ferric reducing antioxidant power and metal chelating activity of raw and heat-treated *Moringa oleifera* peel, pulp, and seed extracts

Sample	Ferric reducing antioxidant power (mg ferrous eq./g DW)	Metal chelating activity (mg EDTA eq./g DW)
Raw moringa peel	3.62^{a} ±0.08	0.41^{a} ±0.04
Raw moringa pulp	3.28^{ab}±0.25	0.42^{a} ±0.06
Raw moringa seed	3.32^{ab}±0.09	0.19^{b} ±0.01
Heat-treated moringa peel	2.13^{c} ±0.28	0.15^{b} ±0.01
Heat-treated moringa pulp	2.87^{b} ±0.30	0.13^{b} ±0.01
Heat-treated moringa seed	2.05^{c} ±0.01	0.01^{c} ±0.00

Means of the same column with different superscripts indicate significant difference ($P<0.05$).

Metal chelating activity of raw moringa pulp (0.42 mg EDTA eq./g DW) showed the highest content and was comparable with the raw moringa peel (0.41 mg EDTA eq./g DW) ($P\geq0.05$). Heating proceed resulted in a significant decrease in metal chelating activity of all samples ($P<0.05$). Transition metals act as catalysts that promote the generation of the first few radicals, which initiate the oxidative chain reaction. Thus, the chelating of transition metal ions by these extracts would reduce available transition metals, rendering the inhibition of the radical-mediated oxidative chain reactions (Zaid et al., 2012).

The decrease in FRAP and metal chelating activity of all samples might be due to the loss of naturally occurring antioxidants present in the extract or formation of novel compounds having prooxidant activity upon heat processing at 100 ºC for 15 min. These results demonstrated that antioxidant activities including DPPH radical scavenging activity, FRAP, and metal chelating activity of moringa peel, pulp, and seed samples depends on heat treatment.

CONCLUSION

Crude extract obtained from raw moringa peel showed the highest total phenolic content and DPPH radical scavenging activity followed by pulp and seed, respectively. The highest FRAP were obtained from the raw moringa peel extract, whereas the highest metal chelating activity was found in raw moringa pulp extract. Moringa peel, pulp and seed samples with heat treatment at 100 °C for 15 min showed lower total phenolic content and antioxidant properties than crude extract from raw moringa samples.

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REFERENCES

AOAC. 2000. Official methods of analysis. 15th ed. Wilson Boulevard Arlington, Verginia, USA.

Arabshahi-Delouee, S., Devi, D.V. and Urooj, A. 2007. Evaluation of antioxidant activity of some plant extracts and their heat, pH and storage stability. Food Chem., 100, 1100-1105.

Benzie, I.F.F. and Strain, J.J. 1999. Ferric reducing/antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. Methods Enzymol., 299, 15-27.

Burits, M. and Bucar, F. 2000. Antioxidant activity of Nigella sativa essential oil. Phytother Res., 14, 323-328.

Chuang, P.H., Lee, C.W., Chou, J.Y., Murugan, M., Shieh, B.J. and Chen, H.M. 2007. Anti-fungal activity of crude extracts and essential oil of *Moringa oleifera* Lam. Bioresour. Technol., 98, 232-236.

Decker, E.A. and Welch, B. 1990. Role of ferritin as a lipid oxidation catalyst in muscle food. J. Agri. Food Chem., 38, 674-677.

Faizi, S., Siddiqui, B.S., Saleem, R., Siddiqui, S., Aftab, K. and Gilani, A.H. 1995. Fully acetylated carbamate and hypotensive thiocarbamate glycosides from *Moringa oleifera*. Phytochemistry, 38, 957-963.

Hossain, M.B., Brunton, N.P., Barry-Ryan, C., Martin-Diana, A.B. and Wilkinson, M. 2008. Antioxidant activity of spices extracts and phenolics in comparison to synthetic antioxidants. Rasayan J. Chem., 4, 751-756.

Jongrungruangchok, S., Bunrathep, S. and Songsak, T. 2010. Nutrients and minerals content of eleven different samples of *Moringa oleifera* cultivated in Thailand. J. Health Res., 24, 123-127.

Kähkönen, M.P., Hopia, A.I., Vuorela, J., Rauha, J.P., Pihlaja, K., Kujala, T.S. and Heinonen, M. 1999. Antioxidant activity of plant extracts containing phenolic compounds. J. Agri. Food Chem., 47 (1), 3954-3962.

Kumar, S., Kumar, D., Singh, N. and Vasisht, B.D. 2007. In-vitro free radicals scavenging and antioxidant activity of *Moringa oleifera* pods. J. Herb. Med. Toxicol., 1, 117-122.

Nicoli, M.C., Anese, M. and Parpinel, M. 1999. Influence of processing on the antioxidant properties of fruits and vegetables. Trends Food Sci. Technol., 10, 94-100.

Ruckmani, K., Kavimani, S., Anandan, R. and Jaykar, B. 1998. Effect of *Moringa oleifera* Lam on paracetamol-induced hepatoxicity. Indian J. Pharm. Sci., 60, 33-35.

Siddhuraju, P. and Becker, K. 2003. Antioxidant properties of various solvent extracts of total phenolic constituents from three different agro-climatic origins of drumstick tree (*Moringa oleifera* Lam.). J. Agr. Food Chem., 51 (8), 2144-2155.

Sreelatha, S. and Padma, P.R. 2009. Antioxidant activity and total phenolic content of *Moringa oleifera* leaves in two stages of maturity. Plant Foods Hum. Nutr., 64, 303-311.

Upadhyay, P., Yadav, M.K., Mishra, S., Sharma, P. and Purohit, S. 2015. *Moringa oleifera*: A review of the medical evidence for its nutritional and pharmacological properties. Int. J. Res. Pharm. Sci., 5 (2), 12-16.

Verma, A.R., Vijayakumar, M., Mathela, C.S. and Rao, C.V. 2009. In vitro and in vivo antioxidant properties of different fractions of *Moringa oleifera* leaves. Food Chem. Toxicol., 47, 2196-2201.

Vongsak, B., Sithisarn, P., Mangmool, S., Thongpraditchote, S., Wongkrajang, Y. and Gritsanapan, W. 2013. Maximizing total phenolics, total flavonoids contents and antioxidant activity of *Moringa oleifera* leaf extract by the appropriate extraction method, Ind. Crops Prod., 44, 566-571.

Zaid, A.A., Farooqui, M. and Janrao, D.M. 2012. Study of stability constant of biological active molecules (drug) using potentiometric titration technique. J. Chem. Bio. Phy. Sci., 2, 67-81.

Research article

Contribution of Organic Agriculture to Gross National Happiness (GNH): Bhutan

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Abstract The objective of this review was to study the contribution of organic agriculture (OA) to the development paradigm of Bhutan, Gross National Happiness (GNH). This study examined contributions of OA on GNH on each of the domains under four pillars. The impacts of OA on GNH were assessed using the GNH Project Screening Tool of Agriculture. The tool was developed based on four pillars and nine domains of GNH by Centre for Bhutan Studies (CBS). Each of the screening variable consists of a 4-pointer scale: 1 (negative), 2 (uncertain), 3 (neutral), and 4 (positive). We found that OA and GNH share comparable principles. The principles focusing on the sustainability, well-being of the people, and natural ecosystem while enhancing the economic growth. Further, the result showed a positive score of 120 out of 136 scores. This is way beyond the neutral score of 102. Scoring was from judgement based on the available literature. The apparent result shows that Bhutan has chosen a viable option.

Keywords Bhutan, development, GNH, principles of OA, IFOAM norm

INTRODUCTION

Bhutan pursues Sustainable Development through GNH (National Environment Commission Secretariat, 2012). GNH is a holistic development philosophy build upon four pillars consisting of nine domains and 33 indicators. Bhutan is promoting organic agriculture (OA) due to the entailed sustainable qualities of OA that is socially acceptable, economically sound, and environmentally benign (Tashi and Wangchuk, 2016). The former Prime Minister of Bhutan Jigme Y. Thinley stated, "going organic is living GNH" indicating the wisdom of Bhutan pledging to be 100% organic by 2020. Furthermore, researchers claimed that the principles of OA are in alignment with GNH (Tashi and Wangchuk, 2016). Thus, Bhutan is promoting OA following the guideline of International Federation of Organic Agriculture Movements (IFOAM) definition (McCrae-Hokenson, 2014),

OA is a production system that sustains the health of soils, ecosystems, and people relying on ecological processes, biodiversity, and cycles adapted to local conditions, rather than the use of inputs with adverse effects. OA combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.

Bhutan had been into OA practice since 2003 (Tashi, 2015). Since then, the various literature and the talk by the leaders of Bhutan reveals the potential contribution of OA to GNH (Halberg and Müller, 2013; Setboonsarng and Gregorio, 2017; Seufert, 2012). However, no empirical studies were done on the topic. Thus, the study was conducted to quantify the contributions of OA on GNH based on the available literature.

METHODOLOGY

The study was examined based on the performance of OA in terms of four pillars and nine domains. The pillars are (1) Sustainable and Equitable Socio-economic Development, (2) Preservation and Promotion of Culture, (3) Conservation of the Environment, and (4) Good Governance. The domains are (1) Living Standard; (2) Education; (3) Health; (4) Time Use; (5) Cultural Diversity and Resilience; (6) Community vitality; (7) Psychological Well-being; (8) Ecological diversity, and (9) Good Governance. The impacts of OA on GNH was assessed using the GNH Project Screening Tool of Agriculture consisting of 34 variables (Table 1). The tool was developed based on four pillars and nine domains by CBS. Each of the screening variable consists of 4-pointer scale: 1 (negative), 2 (uncertain), 3 (neutral), and 4 (positive). The score was given based on the concept of OA inscribed in IFOAM norm 2014, National Framework for Organic Farming in Bhutan, and the findings from the scientific papers at our disposal.

Table 1 Variables of GNH project screening tools and the scores

	Variables	Scores
1	Traditional resource management knowledge	4 (Will enhance traditional natural resource management knowledge)
2	Traditional resource management institutions	4 (Will enhance traditional natural resource management institutions)
3	Farmland availability	1 (Will encroach on farmlands)
4	Fallow land	4 (Will decrease the number of fallow agricultural acres)
5	Land degradation	4 (Will reduce soil erosion and land degradation)
6	Urban migration	4 (Will decrease rates of rural-urban migration)
7	Voluntary reciprocal labor	4 (Will strengthen voluntary reciprocal labor practices)
8	Labor-saving devices	2 (Do not know the effects on the availability of labor-saving Devices)
9	Rural credit	4 (Will increase availability of rural credit)
10	Manure and biomass inputs	4 (Will favor farmyard manure and biomass inputs)
11	Herbicide use	4 (Will decrease the use of herbicides)
12	Pesticide use	4 (Will decrease the use of pesticides)
13	Genetically modified species	4 (Will decrease importation and use of GM seeds and crops)
14	Traditional crops	4 (Will favor the use traditional crop varieties)
15	Traditional practices	4 (Will promote this variable)
16	Nutrition	4 (Will result in an improvement in nutritionally balanced diet)
17	Food self-sufficiency	2 (Do not know the effects on rural food self-sufficiency)
18	Cereal self-sufficiency	2 (Do not know the effects on national cereal self-sufficiency)
19	Agricultural productivity	2 (Do not know the effects on the productivity of crop)
20	Crop damage	4 (Will result in a net decrease in crops lost to wildlife damage)
21	Agricultural biodiversity	4 (Will result in an increase in agricultural biodiversity)
22	Mono-cropping	4 (Will result in a decrease in monocropping)
23	Agricultural exports	4 (Will result in increased diversification of agricultural exports)
24	Value-addition	4 (Will increase value addition through organic marketing strategies)
25	Farmer income	4 (Will result in a net increase in rural income levels)
26	Ecological impact	4 (Will enhance surrounding biodiversity)
27	Values	4 (Will strengthen traditional values of respect for the natural environment)
28	Water supply	4 (Will result in greater availability of water supply for irrigation)
29	Water quality	4 (Will result in an improvement in the quality of water supply for irrigation)
30	Water demand	4 (Will decrease the demand for water)
31	Water pollution	4 (Will decrease levels of water pollution)
32	Air pollution	2 (Do not know the effects on levels of air pollution)
33	Employment	4 (Will generate local employment)
34	Equity	4 (Will address rural equity)

Calculation: the score calculation was done based on the following equations:
Positive score = 4 X Number of screening questions
Neutral score = 3 X Number of screening questions

RESULTS AND DISCUSSION

We found that OA has positive impact on GNH as per the examination through GNH Project Screening Tool. OA contributes to enhancing GNH with the positive score of 120 out of 136 scores. This is way beyond the neutral score of 102. This highly significant result could be due to the comparable principles between the OA and GNH. This indicates that the adoption of organic agriculture in Bhutan is the right choice. The food self-sufficiency, cereal self-sufficiency, agricultural productivity, labor-saving devices, requirement of more farmland, and air pollution remained as contentious issues. Some studies revealed positive while some revealed negative impacts on these topics.

Sustainable and Equitable Socio-Economic Development

Living standard: OA is climate resilient and gives better yield to the changing climate (Reganold and Wachter, 2016; Seufert and Ramankutty, 2017). Moreover, the production is feasible at the minimal cost (Department of Agriculture, 2007) on which the farmers fetch premium price resulting the higher income (Annunziata and Vecchio, 2016; Cocka et al., 2016; Jouzi et al., 2017; Meng et al., 2017). The labor-intensive nature of OA has provided employment opportunities in the rural areas building financial security (Department of Agriculture, 2007; Finley, Chappell et al., 2018; Jouzi et al., 2017; Seufert and Ramankutty, 2017; Tashi and Wangchuk, 2016). Further, OA restore the degraded land (Jouzi et al., 2017) and improving other social issues (e.g., public health) (Migliorini and Wezel, 2017). The creation of accessibility to the diversity of crops is another advantage of OA (Reganold and Wachter, 2016). Thus, it will minimize the risk of having to depend on a single crop (Seufert and Ramankutty, 2017). Collectively, these studies showed its contribution to the sustainable local economy and thus, enhancing the living standard. However, the potential of OA to feed the growing population (Reganold and Wachter, 2016) and its impact on the environment (Gomiero, 2018) still remains controversial debate among researchers.

Education: OA is a knowledge-intensive system (Siddique et al., 2014). It lures participation of farmers with the other actors such as researchers, farmers' associations, consumers etc., for collective management (Ortolani et al., 2017). This encourages social learning on the values, tradition, culture, and the environment (Mercati, 2016; Padel et al., 2015). Thus, OA provides a holistic educational platform to all involved in the system. The concept is still evolving with the constant search for multiple solutions to the challenges (Migliorini and Wezel, 2017; Rahmann et al., 2017).

Health: OA has an opportunity to enhance physical, mental and social wellbeing (IFOAM, 2017; Tashi and Wangchuk, 2016). It produces safe and nutritious food (Gomiero, 2018; Seufert and Ramankutty, 2017). The risk of farmers exposure to the chemical is also reduced due to the banned of chemical inputs (Brantsæter et al., 2017; Jouzi et al., 2017). However, the production of safe and nutritious food depends on the management practice (Jouzi et al., 2017; Mie et al., 2017).

Preservation and Promotion of Culture

Time use: Since OA is a labor-intensive farming system (Finley et al., 2018; Siddique et al., 2014), the family and leisure time will have to be compromised if there is labor shortage. However, the people working together on the farm will have enough time to get together. We conclude that people working together will get more time to exchange knowledge from each other.

Cultural diversity and resilience: As per the IFOAM norm 2014, the diverse and unique sets of cultural and traditional practices should be embraced with innovation and science (IFOAM, 2017). Moreover, locally adapted cultivars are conserved which are highly adaptable to changing climate (Migliorini and Wezel, 2017; Tashi and Wangchuk, 2016). Thus, OA can ensure cultural diversity and resilience.

Community vitality: OA has an opportunity to increase the sense of belongingness to the group

(Annunziata and Vecchio, 2016; Reganold and Wachter, 2016). It provides an opportunity to work together, and exchange knowledge and experiences among the wider stakeholders (Taheri et al., 2017; Tashi and Wangchuk, 2016). Also, the farmers are able to gain customers' trust once the product is certified (Rahmann et al., 2017).

Psychological wellbeing: It is an intrinsically valuable and desired state of being defined by reflective and affective elements (Ura et al., 2012). OA addresses the (1) health of the soil, plants, animals, humans for a healthy planet; (2) protect natural systems; (3) provide equity, respect and justice for those involved in OA; and (4) care for the current and future generations, and the environment (IFOAM, 2017; Migliorini and Wezel, 2017). Thus, we conclude that OA has the potential to address both reflective and affective elements (IFOAM, 2017).

Conservation of Environment

Ecological diversity and resilience: OA is the environmentally friendly practices that protect the public goods such as prevention of air and water pollution, and enhance water quality (Jespersen et al., 2017; Mercati, 2016). Also restores degraded land, increases biodiversity and ecosystem services (Markuszewska and Kubacka, 2017; Mercati, 2016; Seufert and Ramankutty, 2017; Taheri et al., 2017). OA creates favorable conditions for living organisms to thrive which are good for soil formation (Meng et al., 2017). However, so far no studies were conducted for the impact of OA and wildlife damage to the crops.

Good Governance

Good governance: IFOAM norm of version 2014 requires OA to inculcate transparency, autonomy, equity, and equality (IFOAM, 2017). Also, OA can promote empowerment of the small-scale farmers and women (Jouzi et al., 2017; Parrott et al., 2006; Rahmann et al., 2017; Taheri et al., 2017). Also, every individual can work in the farm irrespective of age and gender. Even the pregnant women and children can work on the farm since the exposure to the chemicals is reduced (Parrott et al., 2006). Further, the transparency is ensured through certification (Parrott et al., 2006; Rahmann et al., 2017).

CONCLUSION

OA is expanding progressively despite some contentious issues. The third phase of OA "Organic Agriculture 3.0 is Innovation with Research" is in place to address the challenges of OA by incorporating the principles of OA. The principles which are comparable to GNH principle. The study revealed various contributions of OA to every domain of GNH. OA scoring positive scores of 112 from Screening Tool and further indicate that AO has the high potential to contribute to GNH. The positive impact of OA on GNH will ultimately benefit the country. However, Bhutan should work more on contentious issues: productivity, requirement of more farmland, organic manure production and reduction of air pollution.

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REFERENCES

Annunziata, A. and Vecchio, R. 2016. Organic farming and sustainability in food choices: An analysis of consumer preference in Southern Italy. Agriculture and Agricultural Science Procedia, 8, 193-200.

Brantsæter, A.L., Ydersbond, T.A., Hoppin, J.A., Haugen, M. and Meltzer, H.M. 2017. Organic food in the diet: Exposure and health implications. Annual Review of Public Health, 38, 295-313.

Cocka, L.D., Dessein, J. and de Krom, M.P. 2016. Understanding the development of organic agriculture in Flanders (Belgium): A discourse analytical approach. NJAS - Wageningen Journal of Life Sciences, 79, 1-10.

Department of Agriculture. 2007. National framework for organic farming in Bhutan. Department of Agriculture, Ministry of Agriculture, Royal Government of Bhutan.

Finley, L., Chappell, M.J., Thiers, P. and Moore, J.R. 2018. Does organic farming present greater opportunities for employment and community development than conventional farming? A survey-based investigation in California and Washington. Agroecology and Sustainable Food Systems, 42 (5), 552-752.

Gomiero, T. 2018. Food quality assessment in organic vs. conventional agricultural produce: Findings and issues. Applied Soil Ecology, 123, 714-728.

Halberg, N. and Müller, A. 2013. Organic agriculture for sustainable livelihoods. London. Routledge, UK.

IFOAM. 2017.The IFOAM norms for organic production and processing. IFOAM-Organics International.

Jespersen, L.M., Baggesen, D.L., Fog, E., Halsnæs, K., Hermansen, J.E., Andreasen, L., Strandberg, B., Sørensen, J.T. and Halberg, N. 2017. Contribution of organic farming to public goods in Denmark. Organic Agriculture, 7 (3), 243-266.

Jouzi, Z., Azadi, H., Taheri, F., Zarafshani, K., Gebrehiwot, K., Van Passel, S. and Lebailly, P. 2017. Organic farming and small-scale farmers: Main opportunities and challenges. Ecological Economics, 132, 144-154.

Markuszewska, I. and Kubacka, M. 2017. Does organic farming (OF) work in favour of protecting the natural environment? A case study from Poland. Land Use Policy, 67, 498-507.

McCrae-Hokenson, M. 2014. Organic agriculture in Bhutan: Barriers going to 100%. SIT Digital Collections.

Meng, F., Qiao, Y., Wu, W., Smith, P. and Scott, S. 2017. Environmental impacts and production performances of organic agriculture in China: A monetary valuation. Journal of Environmental Management, 188, 49-57.

Mercati, V. 2016. Organic agriculture as a paradigm of sustainability: Italian food and its progression in the global market. Agriculture and Agricultural Science Procedia, 8, 798-802.

Mie, A., Andersen, H.R., Gunnarsson, S., Kahl, J., Kesse-Guyot, E., Rembiałkowska, E., Quaglio, G. and Grandjean, P. 2017. Human health implications of organic food and organic agriculture: A comprehensive review. Environmental Health, 16 (1), 111.

Migliorini, P. and Wezel, A. 2017. Converging and diverging principles and practices of organic agriculture regulations and agroecology. A review, Agronomy for Sustainable Development, 37 (6), 63.

National Environment Commission Secretariat. 2012. Bhutan: In pursuit of sustainable development. National Report for the United Nations Conference on Sustainable Development Thimphu: National Environment Commission Secretariat, Bhutan.

Ortolani, L., Bocci, R., Bàrberi, P., Howlett, S. and Chable, V. 2017. Changes in knowledge management strategies can support emerging innovative actors in organic agriculture: The case of participatory plant breeding in Europe. Organic Farming, 3 (1), 20-33.

Padel, S., Vaarst, M. and Zaralis, K. 2015. Supporting innovation in organic agriculture: A European perspective using experience from the SOLID project. Sustainable Agriculture Research.

Parrott, N., Olesen, J.E. and Høgh-Jensen, H. 2006. Certified and non-certified organic farming in the developing world. In Halberg, N., Alrøe, H.F. Knudsen, M.T. and Kristensen, E.S. (Eds.), Gobal Development of Organic Agriculture, Challenges and Prospects, 153-179. CABI, Wallingford.

Rahmann, G., Ardakani, M.R., Bàrberi, P., Boehm, H., Canali, S., Chander, M., David, W., Dengel, L., Erisman, J.W. and Galvis-Martinez, A.C. 2017. Organic agriculture 3.0 is innovation with research. Organic Agriculture, 7 (3), 169-197.

Reganold, J.P. and Wachter, J.M. 2016. Organic agriculture in the twenty-first century. Nature Plants, 2, 15221.

Setboonsarng, S. and Gregorio, E.E. 2017. Achieving sustainable development goals through organic agriculture: Empowering poor women to build the future.

Seufert, V. 2012. Organic agriculture as an opportunity for sustainable agricultural development. Research to Practice Policy Briefs.

Seufert, V. and Ramankutty, N. 2017. Many shades of gray, The context-dependent performance of organic agriculture. Science Advances, 3 (3), e1602638.

Siddique, S., Hamid, M., Tariq, A. and Kazi, A.G. 2014. Organic farming: The return to nature. In Ahmad, P., Wani, M., Azooz, M. and Tran L.P. (Eds.), Improvement of Crops in the Era of Climatic Changes, 249-281. Springer, New York.

Taheri, F., Azadi, H. and D'Haese, M. 2017. A world without hunger: Organic or GM crops? Sustainability, 9 (4), 580.
Tashi, S. 2015. The prospects of organic farming in Bhutan. Ph. D. Dessertation, University of Bonn, Germany.
Tashi, S. and Wangchuk, K. 2016. Prospects of organic farming in Bhutan: A SWOT analysis. Advances in Agriculture, 2016.
Ura, K., Alkire, S., Zangmo, T. and Wangdi, K. 2012. An extensive analysis of GNH index.

Research article

Survey on the Slope Protection Method for Sloped Farmland Aimed at Conservation of Regional Unique Landscape

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Abstract Japan's National land has many steep mountains and few flat lands. We performed slant ground use for a long time to secure farmland, in Japan. In slope protection methods of the sloping farmland, there are fundamental two types of "slope tamping" and "stone wall". The slope protection methods of the sloping farmland are one of the elements characterizing a scene including sloping farmland as a thing peculiar to area. In this paper, we analyzed the type of the slope protection method of sloping farmland in the point of "one hundred selection of Japanese sloping farmlands" and the representative sloping farmland in Japan using a subsurface geological map drawn on a scale of 1 to 200000. The geology in each point of target area was classified into three main groups as volcanic rock, sedimentary rock and metamorphic rock. Three main groups were further classified by rock types or geological timescale. We formed clear that rock types or geological timescale of the subsurface geology in the point was related to the choice of the slope protection method of sloping farmland. We conducted a field survey based on this classification. As a result, in region where two or more subsurface geologies are adjacent, the rock of the subsurface geology next to each other in domains from the subsurface geological feature border to around 200m is used as materials of the protection method of sloping farmland.

Keywords sloping farmland, rice terrace, terraced field, stone wall, slope protection method

INTRODUCTION

Japan's National land has many steep mountains and few flat lands. We performed slant ground use for a long time to secure farmland, in Japan. In Japan, farm village landscapes with rice terrace or terraced fields are cultural landscape. The slope protection methods of the sloping farmland are one of the elements characterizing a scene including sloping farmland as a thing peculiar to area. Typical ones in the slope protection method of rice terraces and Terraced fields are stone walls and slope tamping.

In slope protection methods of the sloping farmland, there are fundamental two types of "slope tamping" and "stone wall". Some research suggested that the type of the slope protection method of sloping farmland depended on the presence or absence of unearthed rocks at the time of the paddy field reclamation; however, these are not describe detailed the kind of stones. When the slope protection methods are broken for some reason or to deteriorate over time, we may not choose appropriate slope protection method or materials. It shows the possibility that a traditional landscapes fails.

METHODOLOGY

We performed documents investigation and a field survey. In this paper, we will express Rice terrace and terraced field with sloping farmland.

Documents Investigation

In this paper, we focused on relationship between the rock types of the subsurface geology and the slope protection method and revealed tendency in choosing slope protection method. We basically used subsurface geological map drawn on a scale of 1 to 200000 published by AIST Geological Survey of Japan. In this map, the discontinuous boundaries between neighboring quadrangles were resolved using a unified legend.

We chose 464 areas registered in a prefecture or country of Japan as the sloping farmland which represented an area. Fig.1 shows the locations of the 464 areas. In the analysis, we used information on registered sloping farmland. The black dots in Fig. 1 are the target area. The rock classification and geologic time classification of the subsurface geology we used are shown in Fig. 2 (Arai et al., 2005; Itoh, 1982; Itoh and Nishiki, 1985).

Fig. 1 Distribution of Documents investigation target area

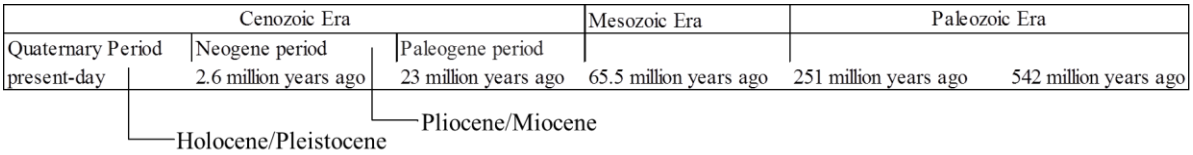

Fig. 2 Rock classification and geological time classification of subsurface geology

Field Survey

We did a field survey to more quantitatively show the relationship between the subsurface geology and the choice tendency of the slope protection method. The purpose of the survey is to clarify what kind of stone were used for stone wall of slope protection method. We grasped the subsurface geology of the target area by subsurface geological map, and we investigated how far the geological boundary of the subsurface geology affects the stone used in stone wall.

The boundary between Arita City and Yuasa Town in Wakayama Prefecture of Japan was selected as a target area where surface geology is changing within the region. We investigated the

outcrop of the geological indicator as an indicator of the survey site. And the survey point was decided by changing the distance from the outcrop. The distance between the survey points was set within 100 m. We gathered the following data at each survey point. Location data by GPS (GARMIN OREGON 300), stone used for material of stone wall types classified by reference to subsurface geological map, and photographic data as material of stone wall. From these information, the relationship between distance from outcrop or geological boundary, or elevation difference and stone used in stone wall was considered.

RESULTS AND DISCUSSION

Documents Investigation

Among the sloping farmlands in 464 areas, 293 areas selected stone wall as slope protection method, 171 areas selected slope tamping as slope protection method. In the rock classification, 157 areas have volcanic rocks, 45 areas have plutonic rocks, 115 areas have sedimentary rocks, 80 areas have accretionary prism, and 54 areas have metamorphic rocks as subsurface geology.

Fig.3 (a) shows the proportion of rock classification and geologic time classification in the study area. The rock classification and geological time classification of 464 areas and the distribution area ratio of rocks in Japan have the same tendency. Fig.3 (b) shows distribution area ratio of rocks in Japan.

Fig.4 shows the relationship between the rock classification and the slope protection method the sloping farmlands of the survey target area.

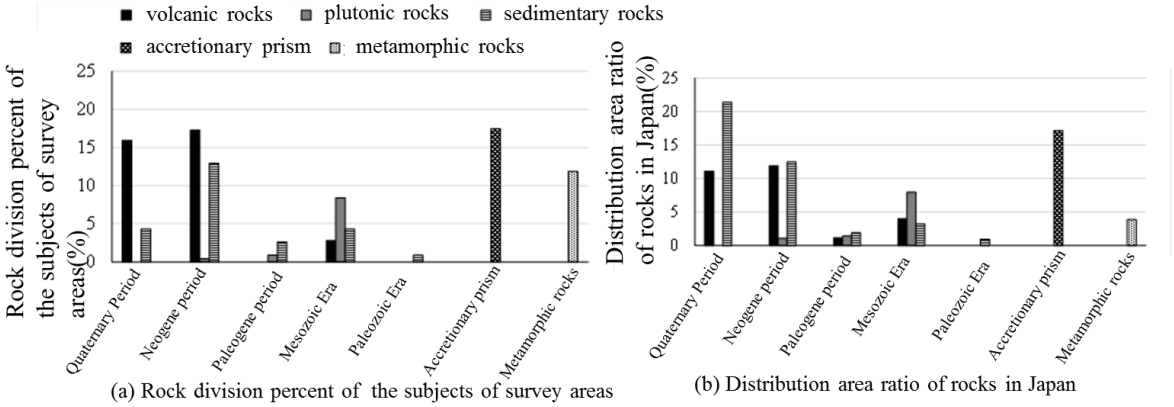

Fig. 3 Rock classification and geological age classification of survey target area and Distribution area ratio of rocks in Japan

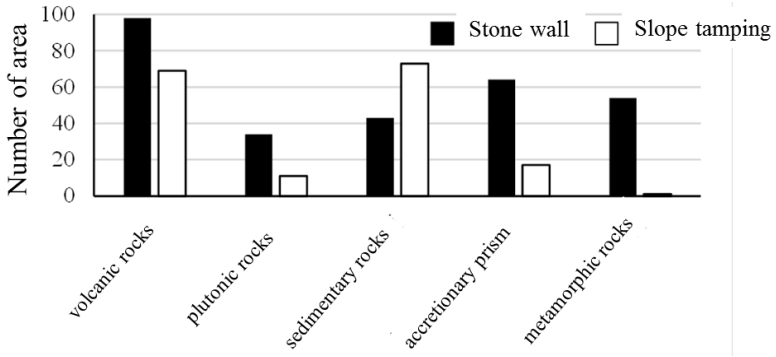

Fig. 4 Relationship between rock classification of surveyed area and slope protection method of sloping farmland

Field Survey

Table 1 shows the types of stone used at each survey points. In Table 1, ① to ④ and No.1 to No.29 correspond to numbers in Fig. 5. Fig. 5 shows the subsurface geological map around the surveyed area. In the Fig. 5, the same type of subsurface geology exists in places where the same numbers are applied. In Fig. 5, It is believed that sedimentary rocks that were made into the Holocene existed in ①. Likewise, it is supposed that ② in Fig. 5 has the accretionary prism that were made into Mesozoic Era, ③ the metamorphic rocks of about 230 million to 160 million years ago, and ④ the Mesozoic sandstone and conglomerate. Specifically, the rocks present in ② are cherts. It must be sedimentary rock in ①, but because it is somewhat unstable at the geological boundary of the surface geological map, it is the reason why the outcrop of chert exists in ①. In this survey, we considered the chert (②) as the subsurface geology at the survey points near the outcrop of the chert. The survey points were set up to traverse three subsurface geologies such as accretionary prism, metamorphic rock, sandstone and conglomerate.

Table 1 Results of each survey point

	No.	North latitude	East longitude	Limestone	Crystalline schist	Chert	Sandstone	Conglomerate	Mudstone	Total
①	No.1	34°4′ 00.71″	135°10′ 40.56″	0	0	100	0	0	0	100
	No.2	34°03′ 57.5″	135°10′ 39.5″	0	0	97	3	0	0	100
	No.3	34°03′ 54.6″	135°10′ 39.6″	0	0	97	3	0	0	100
	No.4	34°03′ 50.6″	135°10′ 39.7″	1	1	92	6	0	0	100
②	No.5	34°3′ 46.7″	135°10′ 40.6″	0	2	97	1	0	0	100
	No.6	34°03′ 43.6″	135°10′ 38.6″	0	0	98	2	0	0	100
	No.7	34°03′ 41.9″	135°10′ 40.4″	0	0	100	0	0	0	100
	No.8	34°03′ 38.5″	135°10′ 45.8″	5	0	92	3	0	0	100
	No.9	34°03′ 35.9″	135°10′ 45.6″	0	0	95	5	0	0	100
	No.10-1	34°03′ 34.7″	135°10′ 47.7″	0	0	100	0	0	0	100
	No.10-2	34°03′ 34.0″	135°10′ 48.6″	47	0	53	0	0	0	100
	No.11	34°03′ 33.6″	135°10′ 46.7″	0	0	100	0	0	0	100
	No.12	34°03′ 32.7″	135°10′ 47.5″	0	0	100	0	0	0	100
	No.13	34°03′ 28.8″	135°10′ 47.9″	0	0	71	16	0	0	87
	No.14	34°03′ 27.2″	135°10′ 46.6″	0	0	98	2	0	0	100
	No.15	34°03′ 24.4″	135°10′ 46.5″	0	0	34	3	2	0	39
	No.16	34°03′ 23.9″	135°10′ 49.0″	0	0	98	2	0	0	100
	No.17	34°03′ 23.6″	135°10′ 49.0″	0	0	100	0	0	0	100
	No.18	34°03′ 19.6″	135°10′ 53.0″	0	0	100	0	0	0	100
③	No.19	34°03′ 18.3″	135°10′ 55.1″	0	0	100	0	0	0	100
	No.20	34°03′ 16.2″	135°10′ 56.8″	0	0	0	100	0	0	100
	No.21	34°03′ 14.3″	135°10′ 57.0″	0	0	55	35	1	0	91
	No.22	34°03′ 14.4″	135°10′ 59.3″	0	0	81	11	8	0	100
④	No.23	34°03′ 12.3″	135°11′ 00.4″	0	0	1	99	0	0	100
	No.24	34°03′ 9.6″	135°10′ 59.7″	0	0	0	100	0	0	100
	No.25	34°03′ 5.2″	135°11′ 00.9″	0	0	0	100	0	0	100
	No.26	34°03′ 00.9″	135°11′ 01.6″	0	0	5	88	7	0	100
	No.27	34°02′ 54.7″	135°11′ 04.0″	0	0	1	99	0	0	100
	No.28	34°02′ 49.7″	135°11′ 03.9″	0	0	0	40	16	2	58
	No.29	34°02′ 45.7″	135°11′ 02.3″	0	0	0	80	20	0	100

In Fig. 5, it is considered that the time of sedimentation is new and it is thought that ① is not sufficiently consolidated as rocks, but the rocks of ②, ③, ④ is considered to be used as the material of stone wall. Through on the field survey, the outcrops of the chert at the subsurface geology of ① and ② was confirmed (triangle dots in Fig. 5), ③ and ④ confirmed sandstone outcrops (white triangle dots in Fig. 5). It must be sedimentary rock in ①, but because it is somewhat unstable at the geological boundary of the surface geological map, it is the reason why the outcrop of chert exists in ①. In this survey, we considered the chert (②) as the subsurface geology at the survey points near the outcrop of the chert.

At the 20 survey points in ① and ②, the chert was used as material of stone wall at a rate of 53 to 100%. Also, at all the survey points in ④, over 90% of the material rocks of stone wall were

sandstone and conglomerate. In addition, both stone materials were used at the three survey points of the survey spot (within ③) within 200 m from the geological boundary of ② and ④.

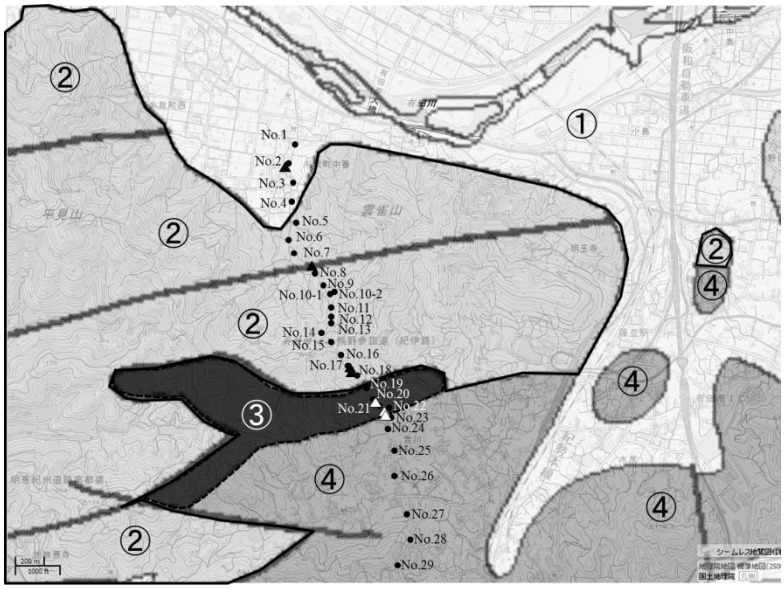

Fig. 5 Subsurface geological map around survey area and survey spot

CONCLUSION

From the above results, the following can be considered. As a result of documents investigation, when the subsurface geology is plutonic rocks, accretionary prism, or metamorphic rocks, the stone wall is strongly selected as slope protection methods. On the other hand, when the subsurface geology is volcanic rocks, slope tamping were selected in nearly half of the sloping farmland and in the case of sedimentary rocks the stone walls are selected in nearly 30% of the sloping farmland. In addition, the area where the subsurface geology is pyroclastic flow deposit among volcanic rocks selects slope tamping as slope protection methods.

Among districts where the subsurface geology is a pyroclastic flow deposit, there is a tendency to select slope tamping when the pyroclastic flow is formed in the Holocene or Neogene period. Sloping farmlands where older pyroclastic flows are located in the subsurface geology tend to select stone walls. Moreover, in the area that consolidated volcanic rocks are there to the subsurface geology, the area where the former geologic formations of the Miocene volcanic rocks where the Green Tuff is formed will tend to select the slope tamping as slope protection methods for Regardless of its composition. Among mafic volcanic rocks, there is a tendency to select slope tamping as slope protection method if the subsurface geological districts were made in the Quaternary Period, otherwise it seems to choose stone walls.

When the subsurface geology is plutonic rocks, we found out the following. When the plutonic rocks of the subsurface geology were felsic, stone walls were chosen in general, although the slope tamping was selected with 27% of the slope farm depending on the weathering degree of rocks.

Districts where sedimentary rocks in the Quaternary or New Tertiary are located in the subsurface geology select the slope tamping, but in the area with rocks consolidated where the altitude in higher than the sloping farmland, there possibility to choose stone walls. It was found from the field survey in the other area that there is a possibility of choosing stone wall as a slope protection method even if consolidated rocks located in a place where the altitude is high and sloping farmland are separated by a horizontal distance of 500 m or more.

When the surface geology is an accretionary prism, the slope tamping concentrate in the subsurface geological areas formed in the middle or late Jurassic centers called the Mino - Tanba -

Ashio Belt. In the sloping farmland where the subsurface geology is an accretionary prism and exists outside the Mino - Tanba - Ashio Belt, there is a tendency to choose stone wall as a slope protection method.

In sloping farmland whose subsurface geology is metamorphic rocks, it turned out that in most cases would choose stone wall.

In the field survey, basically we could actually confirm that stones of subsurface geology are used on the ground. Furthermore, within about 200 m of the geological boundary of the subsurface geology, it is possible that adjacent rocks will be used as materials for stone walls. In other words, in sloping farmland where several subsurface geologies are located nearby, not only the rocks of the just below subsurface geological structure but also the rocks of adjacent subsurface geology are used.

REFERENCES

Arai, T., Futatsugi, S. and Imamura, R. 2005. 2 The formation of Japanese ground. In Geology Learned by Case, The Japanese Geotechnical Society, 17-61. (in Japanese).

Geological Survey of Japan. Seamless Digital Geological Map of Japan (1:200,000). 2015. https://gbank.gsj.jp/seamless/index.html?lang=ja&

Itoh, S. 1982. Surface geological classification and its application to agricultural land conservation. Jour. of JSIDRE, 50 (6), 505-510. (in Japanese).

Itoh, S. and Nishiki, T. 1985. Surface geological map and its application to development and conservation of farmland. Jour. of JSIDRE, 53 (10), 877-884. (in Japanese).

Kamata, Y. 1977. Subsurface geology. In Nagasaki Prefecture Southern Region Integrated Development Area Land Classification Basic Survey, Land Management Office of Nagasaki Prefecture, 18-23. (in Japanese).

Kondo, Y., Kishimoto, S. and Kakuta, S. 1997. Stone. In New Edition Civil Engineering Materials Science, Corona Publishing Co., 48-89. (in Japanese).

Matsuo, K. 1953. Studies on the sloping farm-land. Journal of the Agricultural Engineering Society, 21 (4), 36-43. (in Japanese).

Mekata, M. 1973. Kitakami, Subsurface geology. In Mountains Development Area Land Classification Basic Survey, Iwate Prefecture, 18-22. (in Japanese).

Murata, Y. and Kano, K. 1995. The areas of the geologic units comparing the Japanese Islands, calculated by using Geological Map of Japan 1:1,000,000. The 3rd Edition CD-ROM Version.

Nakagawa, C. and Kanamaru, F. 1969. The factor of landslide in Shikoku. Journal of the Japan Landslide Society, 41-1, 25-33. (in Japanese).

Nakashima, M. 2002. Distribution and characteristics of rice terraces. Jour. of JSIDRE, 70 (3), 195-198. (in Japanese).

Okajima, K., Kaburagi, R. and Iida, T. 2012. Analysis of disaster factors in stone wall of paddy fields and actual situation of restoration based on the field survey. Journal of Rice Terrace Research Association, 13, 57-71. (in Japanese).

Sasaki, N. 1973. Kitakami, Soil. In Mountains Development Area Land Classification Basic Survey. Iwate Prefecture, 1973. 23-27. (in Japanese).

Sato, T., Ishimaru, T., Sugihara, K. and Shimizu, K. 1992. Data collection by literature survey on rock physical properties in Japan. Power Reactor and Nuclear Fuel Development Corporation, PNC TN7410 92-018, 1-37. (in Japanese).

The National Institute of Advanced Industrial Science and Technology. 2015. GeomapNavi. Geological map display system of Geological Survey of Japan, https://gbank.gsj.jp/geonavi/

Research article

Current Postharvest Management of Sesame Farmers in Selected Area of Myanmar

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Abstract This study was conducted at Pwintphyu and Pakokku Townships, Magway Region, Myanmar in September 2016 and January 2017. The objectives of this study were to identify the farmers' perception and knowledge about postharvest handling practices of sesame and to compare the postharvest handling practices of sesame farmers between different areas of Myanmar. Total of 136 respondents were interviewed to understand the farmers' practices for postharvest management of sesame. The results showed that all respondents harvested and threshed the seeds manually in both areas. In Pwintphyu Township, postharvest operations were done in the fields, however, in Pakokku Township farmers worked on the threshing floor harden by the pasted cow dung and soil. The postharvest practices: such as stacking, stalks drying and storage methods were different between two areas. Regarding the awareness of postharvest management, stages at which the highest postharvest losses occur were different between two townships due to different management. Good quality seed, high yield, low labour cost and easy to work were also pointed as the advantages of postharvest technology in both areas. Using the plastic net or tarpaulin under the stacking and stalks standing, making threshing floor, harvest in right time, using enough labour, using harvester and covering threshing floor with tarpaulin were the management practices mentioned by respondents as methods to reduce postharvest losses. The farmers are weak in knowledge about storage management such as store pest control and packaging materials. Although farmers have the knowledge of the advantages of postharvest technology and how to reduce the losses, they have not tried to carry out. Therefore, it is needed to train the sesame growers to improve their postharvest practices, and private sector should support to mechanize in postharvest operation.

Keywords sesame, postharvest, stacking, stalks drying, losses

INTRODUCTION

Postharvest food loss (PHL) is defined as measurable qualitative and quantitative food loss along the supply chain, starting at the time of harvest till its consumption or other end uses (Hodges et al., 2011). The largest PHLs usually occur on or near the farm, where the initial choice of crop type and variety and the success of harvesting and consolidation methods are fundamental in keeping losses low (World Bank, 2010). Agricultural commodities produced on the farm fields have to

undergo a series of operations such as harvesting, threshing, winnowing, bagging, transportation, storage, processing and exchange before they reach the consumer, and there are appreciable losses in crop output at all these stages (Basavaraja et al., 2007). In less developed countries where the supply chain is less mechanized, larger losses are incurred during drying, storage, processing and in transportation (FAO, 1980).

Developing postharvest systems has the potential to raise living standards in urban and rural areas. In urban areas, it makes food available more efficiently and at a lower cost. In rural areas, postharvest activities can benefit the poorest members of society in particular, through its contribution to farm and non-farm income (Goletti and Samman, 2002). Educating and training the farmers on post-harvest operations would greatly help in reducing the post-harvest losses in food grains (Basavaraja et al., 2007). At present, improved postharvest technology is essential to ensure high yield, quantity and quality of products in Myanmar. Minimizing postharvest losses of food crops is a very effective way of reducing the area needed for production and/or increasing food availability. And there was no previous statistical study in Myanmar on postharvest handling practices of sesame farmers.

OBJECTIVES

The objectives of this study are to determine farmers' perception and knowledge about postharvest handling practices of sesame, and to compare the postharvest handling practices of farmers between the different areas of Myanmar.

MATERIALS AND METHODS

Study Sites and Methods of Data Collection

Fig. 1 Map of study sites in Magway Region, Myanmar

This study was conducted in Pwintphyu and Pakokku Townships in Magway Region, located in central Myanmar (Fig. 1). These two study areas are the largest cultivated areas of pre-monsoon and post-monsoon sesame in Myanmar. A total of 136 sesame farmers from in two townships were interviewed by using structured interview questionnaires to elicit information from farmers. Random sampling procedure was used in this study. The structured interview questionnaire was amended based on the information collected from pilot survey, and main survey was conducted in 2016 - 2017. The data concerning with demographic data of the sample respondents in selected areas such as age, educational status, family size, landholding size and their farming experience were collected. Postharvest management of respondents, problems encountering during postharvest handling and farmers' perception and suggestion on postharvest handling practices were also collected in order to determine sesame postharvest management system in study areas.

Data Analysis

The data were transferred and analyzed by the Statistical Package for the Social Science (SPSS) version 16.0 software. Descriptive statistics were used to identify demographic characteristics and postharvest handling practices of sample respondents. In order to compare the demographic and postharvest practices of different areas, student t distribution was used.

RESULTS AND DISCUSSION

Demographic Characteristics of the Sample Respondents

Among 136 respondents, 92% was male and the remaining was female farmers. In this study, the average age of the respondents was 50 years with the minimum of 19 years and maximum of 75 years. The average schooling year of respondents was 6 years. The minimum and maximum school years were 2 years and 14 years. Average farm size of sample respondents was 5.03 hectares with the minimum of 0.24 hectare and maximum of 28.34 hectares. The farm experience of farmers in this study was 27 years in the range of 2-60 years.

Postharvest Management of Sample Respondents

All respondents harvested and threshed the seeds manually in both areas. The harvested stalks of sesame require to be piled up to a height of four to five feet. In Pwintphyu Township, the most common time for stacking was 7 days and 8 days but 5-6 days and 7 days were common in Pakokku Township and some respondents took long time (>10 days) for stacking (Table 1). Therefore, t test showed that the stacking duration (<7 days, 8 days, 10 days and >10 days) were highly significant between two study areas. Although only a few percent of respondents used the insecticide in Pakokku Township, half of the respondents used insecticide to control pest during stacking in Pwintphyu Township (Table 1). There were significant differences between the insecticide usage practices during stacking of two study areas. When piling the sesame after harvest, sometimes the insecticides are sprayed for termite control on the ground (JAICAF, 2018).

Table 1 Stacking practices by sample respondents in study area, 2016-17

		Pwintphyu (N=73)	Pakokku (N=63)	t-test
Duration	5-6 days	2 (2.74)	24 (38.10)	5.47***
	7 days	27 (36.99)	21 (33.33)	0.44^{ns}
	8 days	26 (35.62)	5 (7.94)	4.93***
	10 days	18 (4.66)	2 (3.17)	3.08***
	>10 days	-	11(17.46)	-3.62***
Insecticide usage	Beside & under the pile	31 (42.47)	1 (1.59)	7.82***
	Beside, under & inside the pile	6 (8.22)	-	2.54**
	Nil	36 (49.32)	62 (98.41)	-8.05***

*Note: Numbers in the parentheses represent percentage. *** significant at 1% level; ** significant at 5% level; ns = non- significant*

In Pwintphyu Township, 98.63% of the sample respondents practiced the threshing operation manually on the field and only 1.37% of respondents threshed on the threshing floor covered with tarpaulin. In Pakokku Township, all sample respondents made threshing floor by pasting with cow dung and soil mixture. There were two methods for drying sesame stalks: stalks standing and spreading before threshing in study areas. All respondents dried their crop by stalks standing in Pwintphyu Township but both methods were practiced in Pakokku Township (Table 2). Some

farmers in Pakokokku Township took long time for stacking and stalk drying because they made threshing floor near the house and postharvest operations were done in that place. In Pwintphyu Township, stacking and drying the stalks was done in the field where sunlight was enough to dry the stalks quickly, and it was needed to thresh the seeds as quickly as possible to reduce the losses. The t test showed that stalk drying duration (2 days, 5-7 days and >7 days) were highly significant difference between Pwintphyu and Pakokku respondents.

Table 2 Stalk drying practices by sample respondents in study area, 2016-17

		Pwintphyu (N=73)	Pakokku (N=63)	t-test
Method	Standing	73 (100)	41 (65.08)	5.77***
	Spreading	-	22 (34.92)	5.77***
Duration	2 days	56 (76.71)	1 (1.59)	14.37***
	3-4 days	15 (20.55)	8 (12.70)	1.23^{ns}
	5-7 days	2 (2.74)	23 (36.51)	-5.27***
	>7 days	-	31 (49.21)	-7.75***

*Note: Numbers in the parentheses represent percentage. *** significant at 1% level; ns=non-significant*

Table 3 Seed storage practices by sample respondents in study area, 2016-17

		Pwintphyu (N=73)	Pakokku (N=63)	t-test
Method	Woven polypropylene bag	68 (93.15)	63 (100)	-2.04**
	Woven polypropylene bag with thin plastic layer	3 (4.11)	-	1.76*
	Metal tin	1 (1.37)	-	0.93^{ns}
	Others	1 (1.37)	-	0.93^{ns}
Duration	2 months	6 (8.22)	3 (4.76)	0.41^{ns}
	3-4 months	4 (5.48)	3 (4.76)	-0.18^{ns}
	5-6 months	5 (6.85)	1 (1.59)	1.84*
	8 months	58 (79.45)	55 (87.30)	-1.62^{ns}
	Nil	9 (12.33)	1 (1.59)	1.56^{ns}
Pest control	Agrochemical	6 (8.22)	5 (7.94)	0.06^{ns}
	Organic materials	-	6 (9.52)	-2.56**
	Others	1 (1.37)	4 (6.35)	-1.47^{ns}
	Nil	66 (90.41	48 (76.19)	2.21**

*Note: Numbers in the parentheses represent percentage. ** significant at 5% level; * significant at 10% level; ns = non-significant*

Regarding to storage practices, farmers in Pakokku Township used the woven polypropylene bags for seed storage (Table 3). However, there were some farmers who used woven polypropylene bags with thin plastic layer and metal tins for seed storage in Pwintphyu Township. Eight months storage was common in both townships and farmers stored until next crop. In Ethiopia, about 61% of the respondents explain that they use polypropylene bag to store their sesame grain followed by ware houses (40%) and jute bag (28.6%). Other storages like fertilizer bags, balcony, and plastic bags are also used by few respondents. About 73% of the respondents in Ethiopia put their sesame grain in storages not for more than 3 months (The Feed the Future Innovation Lab, 2014). During storage, the majority of respondents did not control store pests except 8.22% and 7.94% of farmers who used the chemicals in Pwintphyu and Pakokku Townships respectively. About 10% of farmers used organic materials (hot pepper, neem leaves) as control measure in Pakokku Township. Other

store pest control practices, such as frequent winnowing and sun-drying during storage were also found in both areas (Table 3).

Sesame growers in both townships decided the seed dryness by hand feeling and there was no significant difference in seed moisture determination method between in both townships (Table 4). Moisture content of seed is one of the important criteria for storage, therefore, extension service should provide the knowledge regarding minimum moisture content of sesame to store safely.

Table 4 Seed dryness testing method by sample respondents in study areas, 2016-17

	Pwintphyu (N=73)	Pakokku (N=63)	t-test
By visual	3 (4.11)	6 (9.52)	-1.23^{ns}
By hand	46 (63.01)	46 (73.02)	-1.08^{ns}
By visual & hand	23 (31.51)	10 (15.87)	2.18**
By hand & others	1 (1.37)	1 (1.59)	-0.10^{ns}

*Note: Numbers in the parentheses represent percentage. ** significant at 5% level*

Awareness of Postharvest Management by Respondents in the Study Area

In Pwintphyu Township, the highest postharvest loss was occurred in threshing time whereas harvest time loss was highest in Pakokku Township (Table 5). In Pwintphyu Township, farmers dried and threshed in the field, but sesame stalks were dried and threshed on the threshing floor in Pakokku Township. Therefore, postharvest stage which causes the highest losses was significantly different between two areas (Table 5). In Ethiopia, more than 50% of the respondents explained that weather condition such as winds and intensive rainfall, insects in field, shattering, threshing, theft, harvesting, and rodents in storage are the losses causing factors (The Feed the Future Innovation Lab, 2014).

Table 5 Stages at which the highest postharvest losses occur in study area, 2016-17

	Pwintphyu (N=73)	Pakokku (N=63)	t-test
Harvest	4 (5.48)	43 (68.25)	-10.47***
Stacking	-	2 (3.17)	-1.43^{ns}
Standing/spreading	22 (30.14)	7 (11.11)	3.01***
Threshing	47 (64.38)	11 (17.46)	6.64***

*Note: Numbers in the parentheses represent percentage. *** significant at 1% level; ns=non-significant*

Table 6 Awareness of the advantages of postharvest technology by the respondents, 2016-17

	Pwintphyu (N=73)	Pakokku (N=63)	t-test
Reduce losses	52 (71.23)	33 (52.38)	2.65***
High yield	9 (12.33)	17 (26.98)	-2.14**
Good quality seed	14 (19.18)	4 (6.35)	2.30**
High income	2 (2.74)	8 (12.70)	-2.14**
Easy to work by using machine	6 (8.22)	3 (4.76)	0.65^{ns}
Low labour cost	3 (4.11)	1 (1.59)	1.56^{ns}
No answer	6 (8.22)	9 (14.29)	-1.39^{ns}

Note: Numbers in the parentheses represent percentage. ns = non-significant

Most of the respondents in Pwintphyu and Pakokku Townships mentioned that postharvest technology can reduce losses (Table 6). Good quality seed, high yield, low labour cost and easy to work were also pointed as the advantages of postharvest handling in both areas. Therefore, there was no significant difference in awareness of farmers on the advantages of postharvest handling between Pwintphyu and Pakokku Townships (Table 6).

Respondents' Suggestions to Minimize Postharvest Losses in the Study Area

In Pwintphyu Township, more than half of the respondents, (61.64%) reported that using the plastic net or tarpaulin under the stacking and stalks standing to reduce losses. Making threshing floor was suggested by 36.99% of farmers. To harvest at right time, to use enough labour and to use thresher were also pointed by 5.48%, 4.11% and 1.37% of respondents, respectively. In Pakokku Township, 34.92% of respondents believed that using harvester reduced losses while other 31.75% supposed that covering threshing floor with tarpaulin was good practice to reduce losses. Harvest at right time, make good threshing floor and use enough labour were the suggested practices of reducing postharvest losses by 23.81%, 6.35% and 1.59% of respondents. The results showed that there are small number of respondent who mentioned the storage methods, such as packaging materials and control measures to reduce losses. Hence, respondents were weak in knowledge about improved storage practices, and extension services should provide improved storage methods to them.

CONCLUSION

All respondents in study areas were practicing their traditional postharvest handling practices and did not use any machinery. Although farmers have the knowledge and awareness of postharvest technology, they have not tried to carry out. Their storage behavior disregarded quantity and quality losses during storage. Educating and training the farmers on improved storage technologies such as biological pest control or controlled atmosphere storage would greatly help in reducing the postharvest losses in food grains. Changing attitude is one of the important steps to adopt innovation in farming community of Myanmar. Therefore, it is needed to train the sesame growers for the advancement of postharvest practices, and public and private partnership should support to take action.

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REFERENCES

Basavaraja, H., Mahajanashetti, S.B. and Udagatti, N.C. 2007. Economic analysis of postharvest losses in food grains in India: A case study of Karnataka. Agri. Econ. Res. Review, 20, 117-126.

Food and Agriculture Organization. 1980. Assessment and collection of data on post-harvest food grain losses. FAO Economic and Social Development Paper, 13. Rome.

Goletti, F. and Samman, E. 2002. Storage losses. In Golob, P., Farrell, G. and Orchard, J.E. (Eds.) Post-Harvest: Science and Technology, Volume 1: Principles and Practice, Oxford: Blackwell Sciences, Ltd. 1-34. UK.

Hodges, R.J., Buzby, J.C. and Bennett, B. 2011. Postharvest losses and waste in developed and less developed countries: Opportunities to improve resource use. J. Agri. Sci., 149, 37-45.

JAICAF (Japan Association for International Collaboration of Agriculture and Forestry). 2018. Technical cooperation project for agricultural productivity and quality improvement in Myanmar. Project Report.

The Feed the Future Innovation Lab. 2014. Sesame postharvest loss study in Ethiopia. Baseline Survey Report. Project: Alliance for Food Security through Reduction of Post- Harvest Loss and Food Waste.

World Bank. 2010. Missing food: The case of postharvest grain losses in Sub-Saharan Africa. Washington, DC: The World Bank.

Research article

Farmers' Perception of Fertilizer Management Practices for Cotton Production in Magway Region of Myanmar

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Abstract Cotton production is one of the main agricultural activities in the dry zone of Myanmar. Understanding the farmers' fertilizer management practices for cotton production was important to develop appropriate technology in order to increase cotton yield and quality. The main objective of the study was to evaluate the farmers' fertilizer management practices on cotton production in Magway Region. The survey was conducted in eight villages from four districts; Magway, Minbu, Pakokku and Thayet during May to June 2017. Totally 160 famers from survey region were chosen by simple random sampling method and individually interviewed with structured questionnaires. Data were analyzed by using descriptive methods. Most of the farmers generally applied the urea fertilizer (65.6%), NPK-compound fertilizer (93.13%) and foliar fertilizers (82%) as well as farmyard manure (97.5%) in this study area. Most of the farmers interested combine application of compound and foliar fertilizer more than single nutrient fertilizer application. According to the results from the study, the cotton yields were directly related with fertilizer application practices. So, lower crop yield and less profit in cotton production were found due to inadequate amount of fertilizer applied by respondent farmers. Farmers were needed to improve the perception of fertilizer management practices in cotton production for increasing crop yield and household incomes. Farmers' agricultural knowledge is an immensely valuable resource that provides farmer-to-farmer training or local technology transfer. Therefore, the extension stuffs should be upgraded the awareness of farmers for increasing seed cotton yield and agricultural knowledge on cotton production.

Keywords nutrient management, foliar fertilizer, chemical fertilizer, cotton

INTRODUCTION

Cotton is a principal fiber crop in Myanmar. Cotton lint quantity and quality depended upon availability of nutrients and weather conditions of cultivated site. Most of the cotton grows farmers sown during monsoon and post monsoon within June – July and August –September. Harvesting practices were on October - November and December – January. Fertilizer application was an important factor in profitable cotton production in Myanmar. The main activities of cotton cultivation and production were found in Sagaing, Mandalay, Magway and Bago divisions. About 52 percent of total cotton sown area was occupied in Magway Region (DoA, 2016). The target

yield of seed cotton was 1600 kilograms per hectare (MCSE 2012). Modern agriculture provides improved technology, breeding and using most viable hybrid seed. Then optimum use of fertilizer has made waste saving in agricultural production (Nyein, 2000). Urea, triple super phosphate and muriate of potash containing major nutrients N, P and K, respectively, were mainly used for cotton production at the recommended rate ranging from 62 - 62 - 62 kg ha^{-1} for fertile soil to 124 - 62 - 62 kg ha^{-1} for poor soil depending on soil type and availability of irrigation water in Myanmar. Pye Tin (2006) reported that although only 50 percent of cotton area applied fertilizers, an average of 30 to 40 percent practiced the recommended rate for cotton production. This result pointed out that the inadequate and imbalance fertilizers application in cotton productivity.

OBJECTIVE

The objective of this study is to evaluate the farmers' fertilizer management practices on cotton production in Magway Region.

METHODOLOGY

The survey was conducted in eight villages from four districts such as Magway, Minbu, Pakokku and Thayet during May to June 2017. Totally 160 famers from survey region were chosen by simple random sampling method and interviewed individually with structured questionnaires. Descriptive statistics of demographic characteristics such as age, education level, farm size, fertilizer application practices on their cotton production fields were recorded. These data were analyzed by using SPSS (Version 16).

RESULTS AND DISCUSSION

Mayway Region situates approximately between north latitude 18° 50' to 22° 47' and east longitude 93° 47' to 95° 55'. These location is the second largest among Myanmar's seven divisions, with an area of 44,820 square kilometer (17,306 sq. mi).The demographic characteristics of the sample respondents showed that the majority of cotton farmers were male (97.5%) whereas female was only (2.5%). This indicate that women participation in cotton cultivation is low while they participate more in harvesting and post-harvest activities such as processing and marketing of farm product. Sixty one percent of total respondents were 41-60 years old. The educational level of the farmers was primary education (72%) and middle education (18%) in survey areas (Table 1).

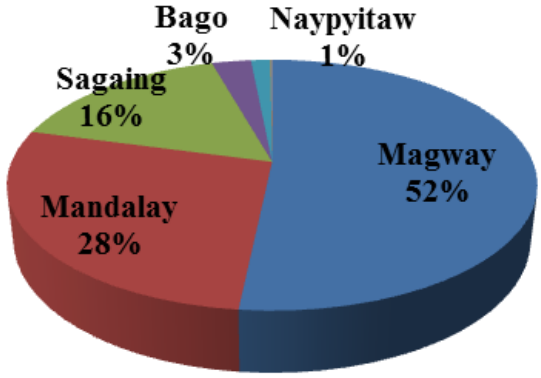

Fig. 1 Cotton cultivated areas in the Myanmar 2015-2016 (DoA, 2016)

Among the sample respondents, 95% of them cultivated cotton in which *Gossypium hirsutum* cultivated farmers were (85.63%), *G. arboreum* cotton farmers were (13.75%) and two varieties cultivated farmers were (4.37%). Ninety four percent of the cotton farmers applied fertilizer. Among them, 88.67% of the farmers practiced only basal application and a few percentages

(11.33%) were used at seedling stage. Forty four percent of the farmers applied only one time at flowering stage and (6.67%) applied two times at squaring and flowering stage (Table 2). In the study area, urea, compound fertilizer, farm yard manure and foliar fertilizer were applied by 65.6%, 93.13%, 97.5% and 82% of the sample respondents respectively (Fig. 2). Sixty five percent of the sample farmers commonly followed mono cropping (cotton) and 30% practiced intercropping with sesame, pulse, and pigeon pea.

Table 1 The demographic characteristics of the sample respondents in survey area

Item	Characters	Frequency	Percent of Respondents
Gender	Male	156	97.5
	Female	4	2.5
Age (years)	20-40	21	13.0
	41-60	96	61.0
	61 <	41	26.0
Education Level	Primary	116	72.0
	Middle	29	18.0
	High	9	6.0
	Graduate	6	4.0

Source; Survey data

Table 2 The cotton production and input application management in farmers' practices

No	Distribution categories	Used practices		Unused practices	
		frequency	Percent of respondents	frequency	Percent of respondents
1	Cotton cultivation	152	95.00	8	5.00
	G. hirsutum variety cultivated	137	85.63		
	G. arboreum variety cultivated	22	13.75		
	Two varieties cultivated	7	4.37		
2	Fertilizer using	150	93.75	10	6.25
	Basal application	133	88.67		
	DAE application	17	11.33		
	Side dress once time	66	44.00		
	Side dress two time	10	6.67		
3	Urea using	105	65.60	55	34.40
4	Compound fertilizer using	149	93.13	11	6.87
5	Foliar fertilizer using	131	82.00	29	18.00
6	F.Y.M using	156	97.50	4	2.50
7	Cropping pattern				
	Mono cropping	104	65.00	56	35.00
	Inter cropping	48	30.00	112	70.00

Farmers' Perception of Fertilizer Management Practices

Total cotton cultivated area possessed by sample respondents were ranging from 1.05 to 2.23 ha and 1.87% of the respondents occupied above 4.86 ha. Urea (62-124 kg ha^{-1}) and 15:15:15 compound fertilizer (124-248 kg ha^{-1}) was mostly used by respondents. In Table 4, it was observed that compound fertilizer usage (92.5%) with the rate of 18.52 to 248 kg ha^{-1} and unused (7.5%). Although the recommend rate of 15:15:15 compound fertilizer for cotton was 248 kg ha^{-1} (MCSE 2012), most of the fields applied the rate less than 248 kg ha^{-1}. Foliar fertilizer spraying frequency was 1-7 for the whole crop season and mostly applied 3 times. The foliar fertilizers commonly used were cotton special (11.45%), Armo 1 and 2 (23.66%), Comet plus (27.48%) and golden lion products (10.69%). Farmyard manure (5 - 7 tons ha^{-1}) was mainly used by 46.87% of the respondent farmers.

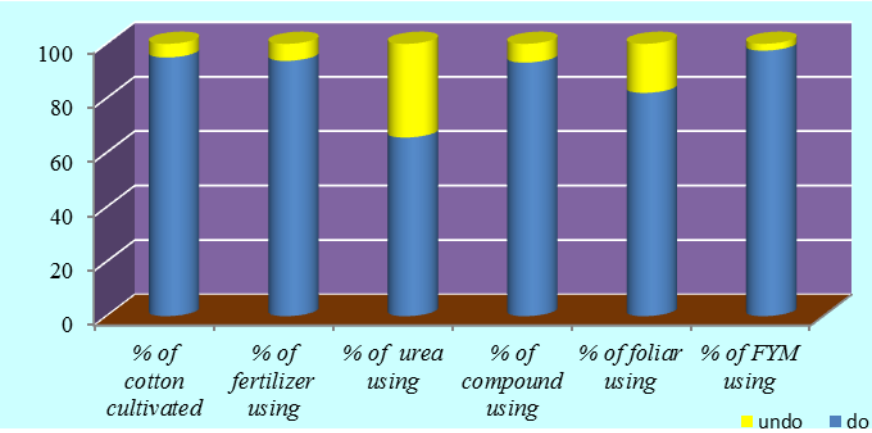

Fig. 2 Farmer's perception of fertilizers management practices in the study region

Table 3 Distribution of respondents by fertilizer management practices [n = 160]

No	Features	Categories	frequency	Respondents %
1	Cotton cultivated area (ha)	0.2 - 1	52	32.50
		1.1 -2.2	73	45.63
		2.4-4.8	24	15.00
		4.8 - above	3	1.87
2	Urea application (kg ha^{-1})	Below 62	25	15.60
		62 -124	76	47.60
		124 - 248	3	1.90
		248 above	1	0.10
3	Compound application(kg ha^{-1})	Below 62	22	13.75
		62 - 124	111	69.38
		124 -248	13	8.12
4	Foliar application (time)	1^{st}	1	0.60
		2^{nd}	24	15.00
		3^{rd}	51	31.90
		4^{th}	42	26.30
		5^{th}	10	6.30
		6^{th}	1	0.60
		7^{th}	2	1.30
5	F.Y.M application (ton ha^{-1})	Below 1.5	41	25.63
		2 - 3	75	46.87
		3.5 – 4.5	20	12.50
		5 and above	24	15.00
6	Farmers' owned area (ha)	0.4-2.0	30	18.75
		2.4-4.0	63	39.37
		4.4-6.0	34	21.25
		6.4-8.0	13	8.13
		8.5-10.0	6	3.75
		10.5-12.0	8	5.00
		12.5 & above	6	3.75

Source: Survey data

Descriptive Statistics Information of Farmers' Perception in Survey Area

The mean value of the age of respondent farmers was 53 years. Farmers' individually owned area was range from 0.6 ha to 16.19 ha. The ranges of total cotton cultivated farm size were 0.2 ha to 7.3 ha and the mean farm size was 1.59 ha. The mean value of urea usage was 55.58 kg ha^{-1} in cotton crop production in study areas. Some of the sample farmers applied as recommended rate

whereas some of them used less than it. Moreover, the mean value of compound fertilizer was 92.63 kg ha^{-1} (Table 4.).

The mean seed cotton yield was 1280 kg ha^{-1} while national target yield was 1600 kg ha^{-1}. Therefore, farmers' actual yield was less than that of target yield. Perhaps, it might be due to the application of fertilizer less than recommended rate. The proportion of farmers' income to price of seed cotton revealed that 2010 kyats per kilogram. The mean value of farmers' income was 2,152,215 kyats. Depending on cultivated area, cotton variety, seed cotton yield, and price of seed cotton in the survey areas, farmers' income was ranging between 1,782,335 kyats and 2,522,096 kyats.

Table 4 Descriptive Statistics information of farmers' perception in survey area (N =160)

Characters	Minimum	Maximum	Mean	Std. Deviation
Age (years)	30.00	79.00	53.27	10.933
Education level	1.00	4.00	1.39	0.761
Total ownership area (ha)	0.60	16.19	4.95	8.106
Cotton cultivated area (ha)	0.20	7.29	1.59	3.049
Urea (kg ha^{-1})	3.71	370.50	55.58	0.482
Compound (kg ha^{-1})	18.53	248.00	92.63	0.463
Foliar (spraying frequency)	1.00	7.00	2.75	1.590
Farm yard manure (ton ha^{-1})	2.47	14.82	6.66	2.677
Seed cotton yields (kg ha^{-1})	161.34	3226.81	1280.88	210.263
Seed cotton's Price (Kyats kg^{-1})	1306.40	2939.40	2010.63	328.602

Source: Survey data

CONCLUSION

As the study area was situated in dry zone, farmers willing to grow cotton than other crops during dry season. Most of the respondent farmers cultivated G. *hirsutum* variety and cotton sole cropping pattern in the study area of Magway Region. The results indicated that combine application of organic and inorganic fertilizers response to higher cotton yield especially cultivating G. *hirsutum.* If weather is favorable, the farmers realized that fertilizer application could increase crop yields. Results of this survey provided some valuable and applicable ideas for further fertilizer applied research. Cotton is very sensitive to fertilizer management practices. For this reason, farmers should apply fertilizers carefully and precisely. Only a few respondent aware fertilizer application management and effective application of fertilizer in crop production. It is required not only to reduce crop yield losses but also cotton quality should be improved. Therefore, fertilizers application management practices should be systematically trained to farmers in cotton production.

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REFERENCES

Department of Agriculture (DoA). 2016. Statistical yearbook. Ministry of Agriculture, Livestock and Irrigation, Myanmar.

Myanmar Cotton and Sericulture Enterprise (MCSE). 2012. Good agriculture practices in cotton production. Ministry of Agriculture, Livestock and Irrigation, Myanmar.

Nyein Zin Soe. 2000. The role of agriculture in the development of Myanmar economy. Thesis submitted to School of Public Policy and Management, Korea Development Institute, 51. Korea.

Pye Tin. 2006. Cotton in Myanmar. Myanmar Cotton and Sericulture Enterprise, 45, Ministry of Agriculture, Livestock and Irrigation, Myanmar.

Research article

Factors Affecting Farmers' Attitudes on Hybrid Rice Production in Nay Pyi Taw Area, Myanmar

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Abstract This study focus on changing attitudes of rice farmers towards hybrid rice production from the view of the theory of attitude change. This study aims to determine factors influencing the farmers' attitude to hybrid rice production with regard to farmers' personal characters, technological knowledge and access to extension services. This empirical study was conducted during May to September, 2017, in Nay Pyi Taw council area, Myanmar. Data were gathered ten variables for farmer's personal characters, fifteen variables for the farmers' technological knowledge and twelve variables for extension contacts by using interview schedule from 198 randomly selected rice farmers and were analyzed by using multiple regression models. The study revealed that 64.6% of farmers changed attitudes to hybrid rice production. It was observed that "education", "source of information from government and non government" organizations were positively significant related but "family labor" was negatively significant influence to hybrid rice production. Besides, farmers' technological knowledge such as "seed quality test", "planting density", "irrigation methods" and "pests and diseases control methods" were positively significant related to hybrid rice production. Extension contact as "training" was highly significant related to farmers' attitudes change. However, "field level extension agents", "farmer to farmer extension", "NGO" contacts were negatively significant related to attitude towards hybrid rice production. This study highlighted that most intervention factors were high seed cost, technical knowledge, low rice price, cost of production and machinery problems. Create opportunity to access micro finance and encourage to private sector participation and also market opportunity. Moreover, clear policy implication is needed and change to effective communication with training using practical design and participatory approach manner to farmers' attitudes change in Myanmar.

Keywords attitudes, hybrid rice, influencing factors, rice farmers, Nay Pyi Taw, Myanmar

INTRODUCTION

Rice remains the world's most important food commodity, particularly in Asia, but it is face changing such climate change, degradation of farming areas, decrease water availability, and increase population. In Myanmar, the agriculture sector is the largest contributor to the growth in national economy and contributes at least 24% to GDP, 25% to its export earnings and employs 60% of the labor force and rice is the most important commodity in the agricultural sector, (Ministry of Agriculture, Livestock and Irrigation, 2015). The ultimate goal of the rice sector strategy is a food-secure nation where small holder farmers have tripled their household income,

including income derived from rice and rice based farming, there by enjoying decent standard of living comparable to that of urban dwellers (Ministry of Agriculture, Livestock and Irrigation, 2015).

In Myanmar, total rice growing area was 17.17 million acres, around 1400 million baskets of production and 74.37 baskets of yield per acre in 2016-17 growing season (Rice Division, DOA, 2017). Hybrid rice cultivation was initiated in 2011, monsoon and increased year by year up to 2.1% of total rice growing area shown in Fig.4 and 7.6% for study area Fig.3. Rice production farmers' income could be increased by altering production of hybrid rice which will be the yield of hybrid rice is 15-20% better than the local variety and currently cultivated high yielding variety. Besides it could be successful 200 baskets (potential yield) per acre if it had systematic and proper care and consequently resulting in alleviating of poverty and better living standard of Myanmar farmers (DOA, 2015). Similar with other developing countries, agricultural sector, particularly the rice sector is radically changing in Myanmar. Population is gradually increasing and rice production areas are decreasing due to the so many purpose. Now, climate change situation is start affected to Myanmar rice growing farmers. Therefore, productivity of rice become low and quality is not adequate. As a result of this, there will be serious to food security and decreasing income of rice farmers. Therefore, farmer's attitude that they need to be changed and grow commercial seeds like hybrid rice seeds from inbred rice. Aims of study were: (1) to characterize farmers' attitude towards hybrid rice production with regard to personal factors, technological knowledge and access to extension contacts, (2) to identify the influencing factors of farmers' attitude towards hybrid rice production and also intervention factors.

METHODOLOGY

There was 53,876 rice growing farmers in total representing about 163,678 acres in Nay Pyi Taw area. Out of which 51,597 farmers were inbred rice growing farmers and 2,279 farmers are hybrid rice growing farmers (DOA, 2016). This study was conducted in Nay Pyi Taw council area including Pyinmana, Lewe, Dekkhinathiri, Zabuthiri, Tatkone, Pobbathiri, Zeyarthiri, and Ottarathiri Townships. Secondary data collection gathered from divisional office and township office in Nay Pyi Taw. A total 16 village tracts (two village tracts per each township) were selected to characterize and identify the farmers' attitudes towards hybrid rice production. One hundred and ninety eight farmers were randomly selected based on list of the rice growing farmers from selected village tracts, Fig. 1 (A and B).

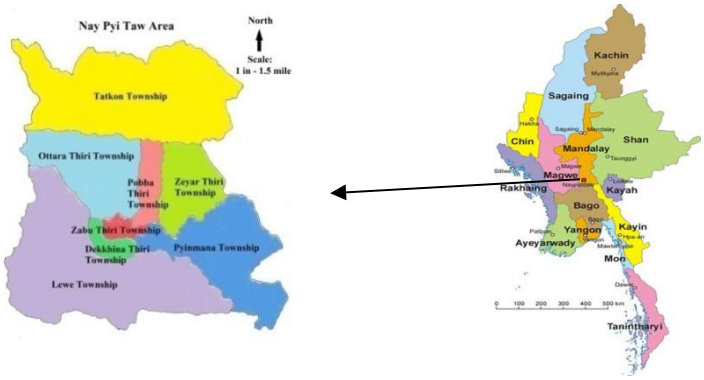

Fig. 1 (A) Study area **Fig. 1 (B) Map of Myanmar**

Attitudes are learned or established predisposition to response (Zimbardo and Leippe, 1991). (Zanna and Rempel, 1988) viewed attitude as having many causes. Attitude is not directly observable, but the action and behaviors to which they contribute may be observed (Bendar and Levie, 1993). There are factors that intervene between attitude and behavior which would cause person's behavior to be inconsistent with his or her attitude (Schafer and John, 1986). These factors

include a person's habits, social norms and expected consequences of behavior. Theoretical framework of attitudes and change to hybrid rice production was formed based on farmers' personal factors which could be influenced to change the adoptive attitudes towards hybrid rice and other novel technologies. Moreover, the differences among rice farmers' beliefs and behavior intend to identify technological knowledge and way of communication with extension personal specifically towards hybrid rice, through intervention factors as shown in Fig. 2.

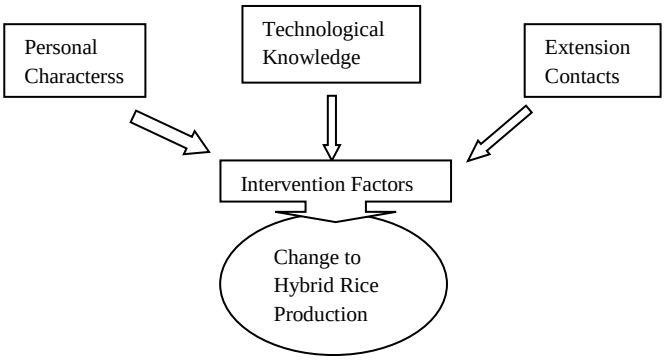

Fig. 2 Conceptual Framework

A total of 37 independent variables having some bearing on the dependent variables were identified for inclusion in the study. Ten variables of the farmer's personal characters; age, gender, marital status, and level of education, family labor, income, membership in organization, availability of credit, source of information including government and non government. Fifteen variables of the farmers' technological knowledge: varietal name, seed quality test, seed rate, sowing method, cover of seeds after sowing, seedling age, seedling per hill, planting density, fertilizer application method, irrigation method, weed control, treatment to get the effective tiller, pests and diseases control, time of water drainage before harvest, harvest time, and twelve variables of extension contacts; individual, group, mass media and farmers to farmers extension, contact with NGOs and input dealers were collected to understand and attitude towards hybrid rice. Interview schedule included open-ended and closed questions which were related to variables mentioned above were prepared and data were analyzed by using multiple regression models with SPSS ver. 16.

RESULTS AND DISCUSSION

Hybrid rice originated from breeding of two different parent types. In the process of hybrid seed production, two different parental strains bred artificially and the new generation is F_1. This improved vigor is "hybrid vigor" or "heterosis". Hybrid vigor is generally higher in agronomic characteristics, therefore they generally more yield than their parents. Broadly speaking, hybrid rice has two advantages: i) advantage in terms of high yields in comparison to inbred varieties and ii) advantage in term of economic profitability due to higher total sales (more rice to sell) for the almost the same capital investment (Pervez et al, 2016). The study revealed that 64.6% of farmers' attitudes to hybrid rice production and 35.4% of farmers had no attitudes to hybrid rice production. Adopted farmers were really accepted to hybrid rice production and non adopted farmers have given the top reasons as poor grain quality and lower market price for hybrid rice grain and lack of awareness and high cost of seed, the results of study similarly pointed out by (Spielman et al., 2013).

Demographic Characteristics of the Respondents

The findings revealed that 84.4% and 15.6% of the respondents were male farmers and female farmers. The average age of the sample farmers was 45 years in the range maximum 70 and minimum 25 years. An average farm size was 5 acres and majority of farmers have formal education and 13.1% of them possessed Bachelor Degree and Diploma education level and 51.1% of farmers were membership in organizations.

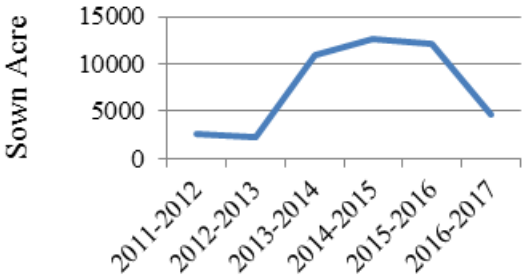

Fig. 3 Hybrid rice growing acre in Nay Pyi Taw

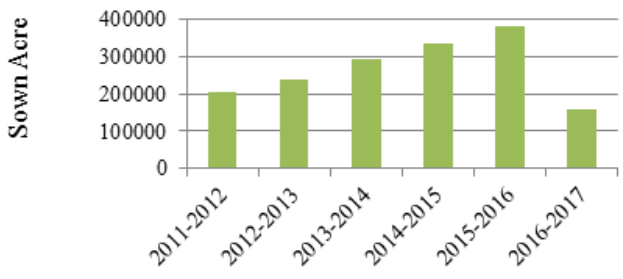

Fig. 4 Hybrid growing acre in Myanmar

Influential Farmers' Personal Characters to Hybrid Rice Production

This study also revealed that among ten of farmers' personal characters, "level of education" was highly significant to hybrid rice production. Therefore, more educated the farmer is, the more likely he/she will adopt hybrid rice, possibly because he/she can get more information and understand on hybrid production. This result was consistent with earlier literatures of (Nirmala et al., 2013). The result showed that "source of information from government" was highly significant associated and "source of information from non-government" was also high significant related to hybrid rice production. In this context, DOA was the main information source because technology trickles down to farmers and local NGO supported the awareness by doing the technical training. These findings were (Cavane, 2011) also similarly indicated that source of information supported to learn and raise awareness and particularly public extension to strengthen the farmers' attitude change. Similarly, Jegede et al., (2007) mentioned in their paper that farmers' personal characters have some influence on their perception of innovations and their decision to adopt or reject such innovation.

Table 1 Influential farmers' personal characters to hybrid rice production

Statement	Coefficient	Significant	Expected Coefficient
1. Age	-0.046	0.83	0.955
2. Gender	0.73	0.13	2.074
3. Marital status	-0.527	0.331	0.59
4. Level of education	0.476	0.009***	1.609
5. Family labor	-0.217	0.093**	0.805
6. Income	0.161	0.192	1.174
7. Membership in organization	-0.066	0.845	0.936
8. Credit	0.352	0.556	1.423
9. Source of information from government	1.507	0.004***	4.512
10. Source of information from non-government	1.066	0.065**	2.904

*Note *** ** and * indicate statistically significant at (0.001), (0.01) and (0.05) respectively*

Moreover, family labor was negatively high significant related toward hybrid rice, it implied that most of family labors were not engaged farming. Furthermore, no significant associated was observed in age, gender, marital status, income, membership organization and credit (Table 1). These findings were similarly pointed out by Ghimire et al., (2015).

Influential Farmers' Technological Knowledge to Hybrid Rice Production

The findings indicated that farmers responded to technical knowledge as "water utilization method" was highly significant and "planting density" was high significant, while "seed quality test" and "pests and diseases control" was significantly related to attitude of hybrid rice production. On the other hand, farmers could identify the "varietal name", "seed rate", "sowing method", "cover the seed after sowing" and "seedling age". Moreover, farmers have knowledge regarding as "seedling per hill", "fertilizer application method", "weed control", "time of water drainage before harvest", "treatment to get effective tillers", and "harvesting time" (Table 2). As a result, this study pointed out that high-level professional training to get more knowledge on hybrid rice, farmers who involved actively and sufficient technical assistant in the field were important factors in changing adoption behavior. In this regard, (Pervez et al., 2016) showed that Hunan and Zhejiang provinces, in China, farmers participating in rice planting technology training were more involved in rice cultivation and got the higher yield.

Table 2 Influential farmers' technological knowledge to hybrid rice production

Statement	Coefficient	Significant	Expected Coefficient
1. Varietal name	-0.104	0.8	0.902
2. Seed quality test	0.771	0.064*	2.163
3. Seed rate	0.001	0.998	1.001
4. Sowing method	-0.702	0.265	0.496
5. Cover the seed after sowing	0.661	0.283	1.938
6. Seedling age	-0.118	0.839	0.889
7. Seedling per hill	-0.077	0.86	0.926
8. Planting density	0.863	0.048**	2.37
9. Fertilizer application method	0.261	0.592	1.298
10. Water utilization method	1.551	0.002***	4.716
11.Weed control	0.058	0.896	1.06
12. Time of water drainage before harvest	-0.778	0.124	0.459
13. Treatment to get the effective tillers	-0.054	0.9	0.947
14. Harvest time	-0.028	0.953	0.972
15. Pests and diseases control method	0.726	0.081*	2.067

*Note *** ** and * indicate statistically significant at (0.001), (0.01) and (0.05) respectively*

Influential Farmers' Extension Contact to Hybrid Rice Production

The study revealed that the "training" was highly significant related to attitude change of farmers on hybrid rice production. Technical training provided to farmers to get the more knowledge and believed to extension personal and technology introduced by scientists. Similar finding was reported by (Ngoc Chi and Yamada, 2002). Contrary to this, "meeting" was negatively high significant to attitude change, because meeting was not so effectiveness for farmers to access hybrid rice technology. Next, the study indicated that the "farmer to farmer extension" was negatively high significant related to attitude change, even the farmers obtained the technological information from neighboring farmers they did not rely upon neighboring farmers for new technology. Only consulting with neighbor farmers were not enough and they should start a trial and consequently adopt the technology that finding was similarly indicated by (Shah et al., 2014). Besides, farmers rely more on peer and relatives than extension offices (Rashid and Gao, 2016). Moreover, "field level extension agents" who were negatively significant associated to attitude change, extension agents contacted to farmers through extension activities but they have low competencies in transfer of new technology. In particular, extension officers and field extension agents might be farmers to select the right variety and go through recommended procedure were also important to adopt the hybrid rice production as different finding to (Shah et al., 2014). In addition, "NGO" contacts were also negatively significant related to attitude towards hybrid rice production. On the other hand, "demonstration" and "field days" that could not persued to farmers

change attitude and also extension officer could not change farmers' attitude towards hybrid rice. "Input dealers" were not clear the technology who were only to sell out their products so they could not change farmers' attitude towards hybrid rice. In further analysis, research showed that there is no significant relationship both "radio" and "television" transmitted by broadcasting of public sector. Therefore, it is suggested that the information and presentation components of the hybrid rice programs need to be developed (Table 3).

Table 3 Influential farmers' extension contacts to hybrid rice production

Statement	Coefficient	Significant	Expected Coefficient
1. Extension officer	-0.513	0.139	0.599
2. Field extension agents	-0.379	0.096*	0.685
3. Meeting	-0.874	0.035**	0.417
4. Training	1.105	0.005***	3.019
5. Demonstration	0.258	0.522	1.294
6. Field day	0.123	0.81	1.131
7. Radio	-0.03	0.891	0.971
8. Television	0.022	0.929	1.022
9. Leaflets/Pamphlets	0.258	0.189	1.295
10. Farmer to farmer extension	-0.542	0.029**	0.581
11. NGO	-0.337	0.055*	0.714
12.Input dealers	-0.098	0.618	0.907

*Note *** ** and * indicate statisticalyl significant at (0.001), (0.01) and (0.05) respectively*

CONCLUSION

According to the research, most intervention factors on farmers' attitudes were high seed cost, access to knowledge, low rice price in markets, cost of production and machinery to solve labors scarcity problems. This study highlighted that the clear policy implication for enhancement of hybrid rice in Myanmar. Create opportunity to access micro finance and encourage to private sector to do the service providers and also market linkages are urgently needed. Hybrid rice seed Co. Ltds have more intention to quality seed and contract farming with other associated partners and farmers prefer to Public Private Partnership (PPP) approach. To get the key knowledge for farmers, extension organization need to persuade by changing the effective communication with training using practical design and participatory approach manner to farmers' attitudes change, effective and efficient training are needed to understand.

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REFERENCES

Bendar, A. and Levie, W.H. 1993. Attitude-change principle.

Cavane, E. 2011. Farmers' attitude and adoption of improved maize varieties and chemical fertilizers in Mozambique. Eduardo Mondlane University, Mozambique, 2011.

DOA Department of Agriculture. 2015. Annual report. Ministry of Agriculture, Livestock and Irrigation, Union of Myanmar.

DOA Department of Agriculture. 2017. Rice division. Ministry of Agricultural, Livestock and Irrigation, DOA, Nay Pyi Taw, Union of Myanmar.

Ghimire, R., Wen-chi, H. and Shreshta, R.B. 2015. Factors affecting adoption of improved rice varieties among rural farm households in Central Nepal. National Pingtung University of Science and Technology, Pingtung 91201, Taiwan, China.

Jegede, O.C., Bolorunduro, P.I. and Ikani, E.I. 2007. Level of awareness and adoption of disseminated livestock technologies in Enugu State, Nigera. Journal of Food, Agriculture and Economic, 5 (2), 185-188.

Ministry of Agriculture, Livestock and Irrigation. 2016. Myanmar agriculture in brief. Ministry of Agriculture, Livestock and Irrigation, Union of Myanmar.

Ministry of Agriculture, Livestock and Irrigation. 2015. Myanmar rice sector development strategy. Ministry of Agriculture and Irrigation, Union of Myanmar.

Ministry of Agriculture, Livestock and Irrigation. 2017. Monthly hand book (Unpublished report), Ministry of Agriculture, Livestock and Irrigation, DOA, Nay Pyi Taw, Union of Myanmar.

Nirmala, B., Vasudev, N. and Suhasini, K. 2013. Farmer's perceptions on hybrid rice technology: A case study of Jharkhand, Indian Res. J. Ext. Edu., 13 (3), September, 2013.

Pervez, A.K.M., Gao, Q., Zeng. Y. and Uddin, M. 2016. Hybrid rice: Bangladesh's failure and China's success. Journal of Agriculture and Ecology, Research International.

Rashid, M.U. and Gao, Q. 2016. An assessment of public and private crop extension services in Bangladesh. IOSR J. of Agril. and Vet. Sci., 9 (1), 7-16. DOI: 10.9790/2380-09120106.

Schafer, R. and John, L.T. 1986. A guide for understanding attitudes and attitude change.

Shah, M.M.I., Grant, W.J. and Stocklmayer, S. 2014. Adoption of hybrid rice in Bangladesh: Farm level experience. Journal of Agricultural Science, 6 (7).

Spielman, D., Deepthi, E., Kolady. and Ward, P. 2013. The prospects for hybrid rice in India. Springer Science Business Media Dordrecht and International Society for Plant Pathology.

Truong Thi Ngoc Chi and Yamada, R. 2002. Factors affecting farmers' adoption of technologies in farming system: A case study in OMon District, Can Tho Province, Mekong Delta.

Zanna, M.P. and Rempel, J.K. 1988. Attitude: A new look at an old concept. In Bartal, D. and Wkruglanski, A. (Eds.), The Social Psychology of Knowledge, Cambridge University Press, 315-334.

Zimbardo, P.G. and Leippe, M.R. 1991. The psychology of attitude change and social influence. McGraw-Hill, New York.

Research article

Suitability of Groundwater Use for Drinking and Irrigation Purpose, Case Study of Kien Svay District, Kandal Province, Cambodia

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Abstract In Cambodia, some studies found that groundwater in some areas was contaminated by heavy metals and chemicals. Those contaminants can harm to human health if it is not properly treated. The research aims to analyze groundwater quality to find out the suitability of parameters for drinking and irrigation purpose, and to understand the condition of groundwater quantity used by local farmers. The study was conducted in Sre Ampil II Village, Chheu Teal Commune, Kien Svay District, Kandal Province in June 2017. Water samples from 6 tube wells with the depth ≥ 20 m and ≥ 50 m were collected to analyze its water quality. The sampling sites were done at the front-part, middle-part and rare-part of the village. Some parameters of drinking water: pH, TDS, EC, turbidity, hardness, As, Fe, Mn, Cl^-, F, NO_3^-, NO_2^-, SO_4^{2-}, *Escherichia coli* and total coliform were collected to analyze its concentration while the parameters such as pH, TDS, EC, hardness, salinity, As, Mn, Fe, SO_4^{2-}, Cl^-, NO_3^-, PO_4^{3-}, NH_4^-, Ca^{2+}, Mg^{2+}, and Na^+ were collected to analyze water quality for irrigation purpose. The results showed that only three of fifteen parameters exceeded desirable limit of FAO and the national standard of Cambodia as Mn concentration averagely was surpassed the standard limits (0.4 mg/L), especially in well 6 (2.64 mg Mn/L). For the concentration of harness, it was happened only in well 1 and 2 with its concentration of 306 mg/L and 360 mg/L, respectively, which was above the national standard (300 mg/L), yet it is below the standard recommended by FAO. *E. coli* and total coliform were also presented in all wells while its concentration were highly exceeded the guideline. The results of parameters in irrigation water from three tube wells showed that Mn (2.64 mg/L) and K^+ (5.19 mg/L) surpassed the guideline of FAO as it was only 0.2 mg/L and 2 mg/L, respectively, while other parameters were below the guideline. Considering this value as standard, the waters in the well 2 and 3 could problematic for long-term irrigation. Based on the groundwater testing, it could be concluded that water quality in the study is good for drinking and irrigating purpose as most of the parameters are below the guideline of Cambodia national standard and FAO.

Keywords groundwater quality, drinking water, irrigation purpose, Cambodia

INTRODUCTION

A fresh and reliable water supply is necessary for human, animal and plants to ensure a high quality of life and to push a strong economical and agricultural development. Intensive cultivating and

urban development has caused a great demand on groundwater resources. There have been various studies on assessment of suitable groundwater quality for drinking and irrigation purposes (Aksever et al., 2016; Ziani et al., 2016; Nag and Das, 2014; Kumar et al., 2014; Kaka et al., 2011). Groundwater locates in the deep layer and penetrates into small pore space between the rocks. Due to this natural flowing process, some mineral particulate components and hardness, Fe, Mn, As, NO3- and other particulate components are transferred by the water movement to various places depending on the groundwater flow direction.

The groundwater chemistry is an essential parameter for evaluating potential exploitable water of an aquifer (Gallardo and Tase, 2007). The main factors influencing hydrochemical groundwater quality are precipitation and dissolved minerals, ion-exchange and sorption and desorption in the groundwater flow (Apodaca et al., 2002). This situation is compounded by the complexity of the mineralogy saliferous, over exploitation of the aquifer and its low recharge, which limits the usable capacity of the aquifer this because of the considerable variation in the concentration of ions and the Total Dissolved Solids (TDS) (Belkhiri et al., 2012). At the same time, the environmental impacts of human activity like unused fertilizers, pesticides, sewage water and discharge of industrial effluents are considered as potential anthropogenic sources responsible for contamination of the groundwater (Venugopal et al., 2009). The presence of different chemical and physical constituents in excess of their permissible limits for various uses can create health hazards and environmental problems (Al-Zarah, 2007) and hence the water quality analysis is critical in ensuring that water consumed by the population meets the required quality standards (Amfo-Otu et al., 2014). In Cambodia, some studies found that groundwater in some areas was contaminated by heavy metals and chemicals. Those contaminants can harm to human health if it is not properly treated.

Having lived close to the Tonle Basac River, the main occupation of the people in Kien Svay District, Kandal Province, Cambodia is agriculture and related labor. Mostly they are growing vegetables with the application of heavy amount of chemical pesticide and fertilizers for increasing crop yields. This practice leads to increased potential contamination of agro- chemicals in environment and the water sources, especially surface water and groundwater, due to the leakage of agro-chemicals through precipitation and runoff.

OBJECTIVES

The research aims 1) To analyze groundwater quality to find out the suitability of parameters for drinking and irrigation purpose and 2) To understand the condition of groundwater quantity used by local farmers.

METHODOLOGY

The study was conducted in Phum II village located in Kean Svay District, Kandal Province where the water quality in the tube wells is not yet identified for both irrigation and drinking purposes. There are 214 families with the population of 862 people living in the village. The area of household is 20 ha while the paddy rice farming areas are 110 ha including dry and wet season cultivation. Villagers in this village can do the farming third time per year.

Sampling and analysis: Six tube wells were selected to analyze groundwater parameters with different depths of 20, 25, 30, 50, 55 and 60 m (for drinking purpose) and 50, 55 and 60 m (for irrigation purpose). The samples of water quality were chosen from the family whose tube wells were used in both irrigation and drinking purpose and the samples were collected by classifying the village into three sites: the front-part, middle-part and rare-part of the village. Some parameters such as pH, EC, TDS, hardness, turbidity and salinity were analyzed at the sites to avoid the error as their values are quickly changed with the times, while the other parameters such as As, Cl^-, F, Fe, Mn, NO_3^-, NO_2^-, PO_4^{3-}, Mg^{2-}, K^+, Ca^{2+}, *Escherichia coli* and total coliform etc. were brought to analyze in the laboratory at Resource Development International-Cambodia (RDI) by using

different method of water analysis based on each parameter. These samples were taken from drinking and irrigation water wells after 5 minutes of pumping, given sufficient time for the water temperature to stabilize and become representative of the temperature of the aquifer. Those analyzed parameters were compared with the drinking water standard guideline recommended by the FAO (2003) and World Health Organization (WHO, 2011) as well as the Cambodia Drinking Water Quality Standardby the Ministry of Industry and Handicraft (MIH, 2004).

Statistical analysis: Statistical analysis was conducted in this study. Microsoft Excel program was used to analyze describtive statistic and, standard deviation, while the statistical package was used to determine Two Sample T-test in order to compare the significant differences of water quality parameters with different depth of tube wells.

RESULTS AND DISCUSSION

Water Quality for Drinking Purpose:

The quality of groundwater depends both on the substances dissolved in the water and on certain properties and characteristics that these substances impart to the water (Heath 1982). The results of the analyzed water quality of the 6 tube wells with different depths of 20, 25, 30, 50, 55 and 60 m for drinking purpose mostly do not exceed two standard maximum allowable limit values. The results of statistical analysis of the chemical compositions of the groundwater samples are shown in Table 1. The table showed that most of the average values of those parameters are substantially below the limited standards, yet Mn concentration is exceeded the standard limit.

The values of pH indicated low alkalinity in the groundwater. The pH of groundwater in the study area is within the limits (6.5 to 8.8) of WHO guideline for drinking water quality. The electrical conductivity of the water samples was rated in the category permissible to suitable (EC = 484-801 μS/cm). The concentration of TDS ranged from 324 to 537 mg/L. The water with a TDS level less than about 600 mg/L is generally considered to be good (WHO, 2011). Also, the maximum permissible limit of TDS for drinking water is 800 mg/L as per the MIH (2004) drinking water standards. Thus, according to the WHO (2011), FAO (2003) and MIH (2004), the TDS values of all wells are suitable for drinking. The concentration of harness ranged from 198 to 360 mg/L and was exceeded above the national standard limits (300 mg/L) only in well 1 and 2 with their concentration of 306 mg/L and 360 mg/L, respectively. Ninety percent of analyzed samples were not exceeded the desirable national limit (200 mg/L) of chloride (Cl^-) according to WHO guideline for drinking water. Only ten percent of samples exceed the desirable limit (250 mg/L) of sulphate (SO_4^{2-}) of WHO guideline for drinking water. The NO_3^-, NO_2^- and F could not be detected by the machine. In Table 1, it is indicated that the concentration of Mn was very high above the standard limits. Arsenic presented in all wells and above the recommended standard of the WHO (2011) which the maximum permissible limit for As concentration in drinking water is 0.01 mg/L. The mean concentration values of Fe in the wells is 0.14 mg/L. According to the WHO (2011), maximum accessible values for Fe concentration in drinking water are 0.3 mg/L. Considering this as the standard value, the Fe contained in the water is still suitable for the drinking purpose, even though the well 5 reached to the peak of the limited standard (0.3 mg/L), following by well 6 (0.28 mg/L). *E. coli* and total coliform were also presented in all wells while its concentration were highly exceeded the guideline as the numbers of coliform were too numerous to count in the machine. However, the presence of these parameters do not cause serious illness to the human health as they could be eliminated by boiling water before drinking (RDI, 2016), or by using Biosand Filter-Zeolite, *E. coli* were completely removed during the first three trials after filtering total volumes of 1120 L, 1140 L and 1220 L (Mwabi et al., 2012). Moreover, the stables or pens which are located next to the wells should be removed to build at other place to avoid contamination.

Table 1 Summary of physical, chemical, and pollution parameters of drinking water

Parameters	Unit	Mean						Ave	Max	Min	SD	n	WHO (2011)	MIH (2004)
		Well 1 (20m)	Well 2 (25m)	Well 3 (30m)	Well 4 (50m)	Well 5 (55m)	Well 6 (60m)							
pH	-	7.30	7.10	6.90	7.10	6.90	6.80	7.01	7.30	6.80	0.07	3	6.5-8.8	6.5-8.5
EC	µs/cm	624.00	801.00	728.00	491.00	500.00	558.00	616.88	801.00	484.00	3.82	3	1500	-
TDS	mg/L	418.00	537.00	487.00	329.00	335.00	374.00	413.00	537.00	324.00	2.56	3	600-1000	800
Turbidity	NTU	0.86	0.93	1.05	1.17	2.03	1.94	1.32	2.06	0.85	0.02	3	5	5
Hardness	mg/L	306.00	360.00	288.00	234.00	216.00	198.00	267.00	360.00	198.00	14.70	3	500	300
Cl^-	mg/L	28.93	27.07	38.64	17.48	18.74	45.01	28.47	45.00	17.50	10.12	1	200	250
SO_4^{2-}	mg/L	51.78	113.84	65.94	18.40	28.14	56.00	55.68	113.84	18.40	30.69	1	200	250
NO_3^-	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	1	50	50
NO_2^-	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	1	3	3
Mn	mg/L	1.60	1.90	2.10	0.25	0.47	2.64	1.50	2.75	0.24	0.06	3	0.4	0.1
As	mg/L	0.013	0.021	0.016	0.021	0.036	0.027	0.021	0.030	0.010	0.005	3	0.01	0.05
Fe	mg/L	0.01	0.07	0.01	0.16	0.30	0.28	0.14	0.31	0.01	0.13	3	0.3	0.3
F	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	1	1.5	1.5
E-coli	CFU/100mL	7.00	14.00	60.00	70.00	85.00	70.00	51.00	85.00	7.00		1	-	0
T-Coliform	CFU/100mL	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	870.00	2465.00	300.00		1	-	0

Note: n= Frequency of the testing parameters of the drinking water
DL = Detection Limit, TNTC = Too Numerous To Count

Water Quality for Irrigation Purpose:

Three wells with different depth of 50, 55 and 60 m were analyzed for its water parameter for the irrigation purpose. It is important to understand the pH in water supplies for the irrigation. As indicated in Table 2, the pH values of the wells in the investigation area ranged from 6.80 to 7.10 with an average value of 6.95. According to FAO (2003), the pH value of irrigation water should be between 6.0 and 8.5. Well 1 could be described as alkaline (pH > 7), while wells 2 and 3 are acidic (pH < 7), 6.90 and 6.80, respectively. All of the pH values of water in those wells are suitable for irrigation water standard of FAO (2003). Also, according to the Food and Agriculture Organization (FAO) (Misstear et al., 2006), permissible limit pH ranged from 6.5 to 8.4 for irrigation water is suitable. The EC values of the wells ranged from 484 to 560 µS/cm with an average value of 516.44 µS/cm (Table 2). TDS values of wells were measured, and these values varied from 324 to 375 mg/L with an average value of 345.88 mg/L (Table 2). The palatability of water with a TDS level of less than about 600 mg/L was generally considered to be good (WHO 2011). Salinity represented by the TDS, varies between 0.20 and 0.30 mg/L. Higher concentrations of salinity indicated that the ionic concentrations were more in the groundwater. The content of Ca^{2+} in water samples collected from different depth of wells varied from 60 to 69 mg/L. Irrigation waters containing less than 400 mg Ca^{2+}/L is suitable for irrigating crops (Groeneveld and Meeden, 1984). Considering this value as standard, Ca^{2+} content in 95% water samples could safely be used for irrigation and would not affect soils. The concentration of Na^+ in water samples from wells varied from 58 to 66 mg/L. Irrigation water generally containing less than 920 mg/L Na^+ is suitable for crops and soils. The observed Na^+ content in all water samples had far below this specified limit. The concentration of K^+ present in the water samples ranged from 0 to 5 mg/L. According to Groeneveld and Meeden, (1984), the recommended limit of K^+ in irrigation water is 2.0 mg/L. Considering this value as standard, the waters in the well 2 and 3 could problematic for long-term irrigation. It is noted that the concentration of K^+ value seemed increasingly parallel with the depth of the wells as the more deeper the wells are, the more K^+ concentration accumulates (Table 2). The concentration of Mg^{2+} in water samples is within the range of 32-45 mg/L. Irrigation waters

containing less than 60 mg Mg/L are suitable for irrigating crops while the analyzed water samples are below this limit and may not have a negative impact on soils or irrigating water.

Water samples collected from three wells contained a chloride concentration ranging from 17 to 45 mg/L. Maximum permissible limit of Cl^- in irrigation water is 1064 mg/L and all analyzed water samples were far below the standard limit. The SO_4^{-2} concentration in water samples ranged from 18 to 56 mg/L, while the standard limit of SO_4^{-2} in irrigation water is 960 mg/L and all water samples collected from the wells are below this acceptable limit of irrigation water quality. PO_4^{3-}, NO^{3-} and NH_4^- could not be detected by the machine as their concentration are very high exceeded the desirable limit of the FAO guideline. Thus, the irrigation water may have negative impact from these elements and might be harmful for crop production.

Table 2 Summary of physical, chemical, and pollution parameters of irrigation water

Parameters	Units	Well 1 (50 m)	Well 2 (55 m)	Well 3 (60 m)						FAO (2003)
			Mean		Max	Min	Aver	SD	n	
pH	-	7.10	6.90	6.80	7.10	6.80	6.95	0.106	3	6-8.5
EC	µs/cm	491.00	500.00	558.00	560.00	484.00	516.44	30.078	3	0-3000
TDS	mg/L	329.00	335.00	374.00	375.00	324.00	345.88	20.190	3	0-2000
Turbidity	NTU	1.17	2.03	1.94	2.06	1.15	1.71	0.385	3	-
Salinity	ppt	0.20	0.20	0.30	0.30	0.20	0.23	0.047	3	-
Ca^{2+}	mg/L	61.86	69.19	60.59	69.19	60.59	63.88	3.790	1	0-400
Na^+	mg/L	60.43	66.14	58.59	66.14	58.59	61.72	3.214	1	0-920
K^+	mg/L	0.00	2.63	5.19	5.19	0.00	2.60	2.118	1	0-2
Mg^{2+}	mg/L	32.59	33.22	45.63	45.63	32.59	37.14	6.004	1	0-60
Cl^-	mg/L	17.48	18.74	45.01	45.01	17.48	27.07	12.691	1	0-1000
SO_4^{2-}	mg/L	18.40	28.14	56.00	56.00	18.40	34.18	15.933	1	0-960
PO_4^{3-}	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	-	1	0-2
NO_3^-	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	-	1	0-10
NH_4^-	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	-	1	0-5
Mn	mg/L	0.25	0.46	2.64	2.75	0.24	1.12	1.081	3	0-0.2
As	mg/L	0.02	0.03	0.03	0.03	0.02	0.024	0.003	3	0-0.1
Fe	mg/L	0.16	0.30	0.28	0.31	0.15	0.24	0.064	3	0-5

Note: n= Frequency of the testing parameters of the irrigation water, DL = Detection Limit

Chemical elements in subsurface water come from geogenic and anthropogenic sources. The weathering of minerals is one of the major natural sources. Ion exchange is also an important process for elements. Anthropogenic sources include fertilizers, industrial effluent, and leakage from service pipes. The elements as Mn, As and Fe of well samples were determined for water quality in the study area. The maximum contents of Mn, As and Fe of well water samples were determined as 2.75, 0.03 and 0.31 mg/L, respectively, while the average values of these elements were 1.12, 0.024 and 0.24 mg/L. The Mn, As and Fe contents of the water samples are within the permissible limit of FAO (2003) and WHO (2011). Thus, the irrigation water is in a good condition for irrigating the crops. However, the suitability of groundwater for irrigation is conditional on the effects of the mineral constituents of water on both the plant and soil. The excessive amount of dissolved ions in irrigation water affects plants and agricultural soil physically and chemically, thus reducing the productivity (Ziani et al., 2016). Agriculture and related labor are the main occupation of the rural people in the Kien Svay District, Kandal Province, Cambodia. Therefore, the determination of irrigation water quality in the ground is gaining importance.

Table 3 Statistical analysis of water quality in different depth (20-30 m and 50-60 m)

Parameters	Units	Well depth (m)		Main-Whitney (P value)
		20-30	50-60	
pH	-	7.10	6.90	0.261
EC	µs/cm	717.00	516.00	0.050
TDS	mg/L	329.00	335.00	0.050
Turbidity	NTU	0.95	1.71	0.050
Harness	ppt	318.00	216.00	0.050
SO_4^{2-}	mg/L	77.19	34.18	0.127
Cl^-	mg/L	29.88	27.07	0.513
Mn	mg/L	1.86	1.12	0.513
As	mg/L	0.017	0.024	0.077
Fe	mg/L	0.03	0.25	0.040*
E. Coli	CFU/100mL	27.00	75.00	0.046*

*Note: * Significant difference at P<0.05*

Statistical analysis of some parameters such as pH, EC, TDS, turbidity, hardness, SO_4^{2-}, Cl^-, Mn, As, Fe and *E. coli* with the different depths of wells indicated that there is no significant difference (P<0.005) between the concentration of values pH, turbidity, EC, harness, TDS, Mn, SO_4^{2-}, As, Cl^-, Mn, As in the groundwater of the study area (Table 3). However, the concentration of Fe and *E. coli* in the tube wells with the depth of 20 to 30 m and 50 to 60 m illustrated that the two parameters were significantly different as the P value are P=0.040 and P=0.046, respectively. Based on this comparison, it can be concluded that the depths of the tube well are not highly related with the water parameters as they would sometimes be changed. The findings of this study are different from the RDI (2012), that collected over 1,000 water samples in five provinces since 2005 from tube wells (also known as boreholes) with the depth ranged from 15 to 80 m and open wells (also known as dug wells) with 3-15 meter depth to analyze some parameters such as pH, salinity, hardness, turbidity, As, F, NO_3^-, NO_2^-, Mn, Fe and Cl^-. The results showed that the more deeper the tube wells are, the more good quality of water would be obtained without contaminating from micro-organisms and bacteria, but it was effected from the chemical and hardness which occurs naturally while the shallow tube wells and surface water always contaminated by bacteria.

CONCLUSION

Suitability of groundwater samples according to exceeding the permissible limits prescribed by WHO and FAO for drinking purposes indicated that the groundwater in the study area are chemically suitable for drinking and irrigation purpose. Yet, Ca^{2+}, Mn, *E. coli* and total coliform were exceeded the standard limit. The Mn concentration in 6 tube wells was highly above the standard (0.1 mg/L). Moreover, the presence of *E. coli* and total coliform in these wells were high. Therefore, some measures should be applied to prevent diseases or other illness caused by the contaminated water. The results of the comparison between different well depths showed that the depth of the tube well does not clearly related with contaminant to the groundwater in the study area as some parameters of drinking and irrigation water sometimes changed and affected by the contaminant from other sources. In the study area, it can be noticed that some wells are located closely to the stables or pens; as a result, some of water parameters are changeable unexpectedly. In general, based on the observation in the village and results, the water quality in the study area is good for irrigation even though some parameters are above the limited standard of FAO. For the analyzed parameters of drinking water quality, some of them are above the standard limits of WHO (2011) and national standard of Cambodia, MIH (2004) which is not recommended to drink as it

could harm the human health. However, *E. coli* and total coliform are easy to eliminate by boiling water before drinking (RDI, 2016).

REFERENCES

Aksever, F., Davraz, A. and Bal, Y. 2016. Assessment of water quality for drinking and irrigation purposes: A case study of Başköy springs (Ağlasun/Burdur/Turkey). Arabian Journal of Geosciences, 9 (20), https://doi.org/10.1007/s12517-016-2778-y

Al-Zarah, A.I. 2007. Hydrogeochemical processes of alkhobar aquifer in Eastern region, Saudi Arabia. J. Applied Sci., 7, 3669-3677.

Amfo-Otu, R., Agyenim, J.B. and Nimba-Bumah, G.B. 2014. Correlation analysis of groundwater colouration from mountainous areas, Ghana. Environ. Res. Eng. Manage., 67, 16-24.

Apodaca, L.E., Bails, J.B. and Smith, C.M. 2002. Water quality in shallow alluvial aquifers, upper Colorado River Basin, Colorado, 1997. J. Am. Water Resour. Assoc., 38, 133-149.

Belkhiri, L., Mouni, L. and Boudoukha, A. 2012. Geochemical evolution of groundwater in an alluvial aquifer: Case of El Eulma aquifer, east Algeria. J. Afr. Earth Sci., 66-67, 46-55.

FAO (Food and Agriculture Organization). 2003. Water quality for agriculture. http://www.fao.org/docrep/ 003/ T0234E/T0234E01.htm (access on April 4, 2017).

Gallardo, A.H. and Tase, N. 2007. Hydrogeology and geochemical characterization of groundwater in a typical small-scale agricultural area of Japan. J. Asian Earth Sci., 29, 18-28.

Gowd, S.S. 2005. Assessment of groundwater quality for drinking and irrigation purposes: A case study of Peddavanka Watershed Anantapur District Andhra Pradesh India. Environ Geol, 48 (6), 702-712.

Groeneveld, R.A. and Meeden, G. 1984. Measuring skewness and kurtosis. J. Ro. Stat. Soc. Series D (The Statistician), 33, 391-399.

Heath, R.C. 1982. Basic ground-water hydrology. US Geological Survey Water Supply, Paper 2220, p. 85.

Kumar, V.S, Amarender, B., Dhakate, R., Sankaran, S. and Kumar, K.R. 2014. Assessment of groundwater quality for drinking and irrigation use in shallow hard rock aquifer of Pudunagaram Palakkad District.

Kaka, E.A., Akiti, T.T., Nartey, V.K., Bam, E.K.P. and Adomako, D. 2011. Hydrochemistry and evaluation of groundwater suitability for irrigation and drinking purposes in the southeastern Volta River basin: Manya Krobo area Ghana elixir. Agriculture, 39, 4793-4807.

MIH (Ministry of Industry and Handicrafts). 2004. Cambodia drinking water quality standard. http://www. wepa-db.net /policies/law/cambodia/07.htm (access on March 16, 2017).

Misstear, B., Banks, D. and Clark, L. 2006. Water wells and boreholes. FAO Irrigation Water Quality Guidelines, Appendix 3, 469-470.

Mwabi, J.K., Mamba, B.B. and Momba, M.N.B. 2012. Removal of *Escherichia coli* and faecal coliforms from surface water and groundwater by household water treatment devices/systems: A sustainable solution for improving water quality in rural communities of the southern African development community region. International Journal of Environmental Research and Public Health, 9 (12), 139-170. https://doi.org/10.3390/ijerph9010139

Nag, S.K. and Das, S. 2014. Quality assessment of groundwater with special emphasis on irrigation and domestic suitability in Suri I & II blocks Birbhum District West Bengal India. Am. J. Water Resour., 2 (4), 81-98.

RDI (Resource Development International). 2012. Summary of groundwater in Cambodia. Data, Map and Priority Parameters. http://rdic.org/groundwater-summary-data/ (accessed on August 21, 2017).

RDI (Resource Development International). 2016. Water contaminates descriptions on health and aesthetic handbook. Phnom Penh, Cambodia.

Spalding, R.F. and Exner, M.E. 1993. Occurrence of nitrate in groundwater-a review. J. Environ. Qual., 22, 392-402.

Venugopal, T., Giridharan, L., Jayaprakash, M. and Periakali, P. 2009. Environmental impact assessment and seasonal variation study of the groundwater in the vicinity of River Adyar, Chennai, India. Environ. Monit. Assess, 149, 81-97.

WHO (World Health Organization). 2011. Guidelines for drinking-water quality. The 4th Edn., World Health Organization, Geneva, Switzerland, ISBN: 9789241548151.

Ziani, D., Abderrahma, B., Boumazbeur, A. and Benaabidat, L. (2016). Water quality assessment for drinking and irrigation using najor ions chemistry in the semiarid region: Case of Djacer Spring, Algeria. Asian Journal of Earth Sciences, 10 (1), 9-21. https://doi.org/10.3923/ajes.2017.9.21

Research article

Utilization of Atis "*Annona squamosa* Linn" Desserts

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Abstract Atis or *Annona squamosa* Linn or Sugar Apple in English is one of the top 10 tropical and exotic fruits but one of the forgotten fruits in the Philippines. It is a sweet and creamy fruit with lots of seeds. Its flesh is sweet, white to yellow and resembles and taste like custards. The edible portion coats the seeds generously. It has a distinct sweet smelling fragrance. It is high in energy, an excellent source of Vitamin C and manganese, a good source of thiamine and Vitamin B 6, and provides Vitamin B2, B3,B9, iron, magnesium, phosphorus, and potassium in fair quantities. This study utilized this fruit as ingredient of different kinds of desserts such calamay, deep fried dessert, butter scotch and tart. These desserts are prepared in different ways using tools, utensils and equipment which are available in rural communities. Dessert is important because it can enhance ones physical and emotional wellness in numerous ways if approached properly. Hence, the objectives of this study is to determine the acceptability levels of different dessert products using atis as main ingredient in the five sensory attributes such as appearance, taste, flavour, texture and overall liking. It further aimed to determine the shelf life and the marketability of each product. This is an experimental study with 100 participants composed of food experts to judge the different products using the four point Hedonic Scale. It was found out that the four products are all acceptable in the five sensory attributes. Each product has different shelf life with calamay having the shortest shelf life and butter scotch and tart having the longest. It was also found out that all the products are marketable. It can be concluded that Atis "*Annona squamosa* Linn" can be used in producing different desserts. It is then recommended that these products be promoted so that the forgotten Atis can gain recognition as a good ingredient for dessert and not only to be eaten as raw and so can be fully utilized.

Keywords exotic, forgotten fruit, sensory attribute, acceptability

INTRODUCTION

Food is the basic necessity for all of living creature and they have to work hard to get this. It is the third most important thing for living beings to live after air and water. This shows the importance of food for life. Food can be taken through the three meals a day. Three meals a day is important to keep the body running so that daily functions can be managed properly. A meal is composed of rice or carbohydrate-rich food, soup, vegetable, main dish, salad, and dessert. This meal composition can vary depending on the choice of the diner, but usually a meal is ended with a dessert.

The tradition of eating a dessert after having a meal is being followed by many cultures across the globe. This delectable dish served at the end of a dinner signifies completion of the meal and creates a sense of goodness within a person. Apart from the cultural importance and the feel-good factor, a dessert can also offer a variety of health benefits. A healthy dessert aids in digestion, adds extra vitamins and fiber to ones diet, boosts immunity, reduces blood pressure, balances hormones in the body, lowers the levels of bad cholesterol, improves good cholesterol, and acts as an anti-depressant (Benavides, 2016).

According to the dictionary, dessert is a confectionery course that concludes a main meal. It is usually consists of sweet foods, and possibly a beverage such as dessert wine or liqueur, but may include coffee, cheese nuts, or other savory items. The term dessert can apply to many confections such as cakes, tarts, cookies, biscuits, gelatins, pastries, ice creams, pies, puddings, custards and

sweet soups. Fruit is also commonly found in dessert courses because of its naturally occurring sweetness. Some cultures sweeten foods that are more commonly savory to create desserts.

In this study, the researcher ventured to produce four kinds of desserts using Atis or *Annona squamosa* Linn as an ingredient in producing them. Atis is used to promote the fruit which is one among the top ten exotic or tropical fruit in the Philippines but is also among the forgotten fruits in this country, forgotten because atis is one among the fruits which is only produced on backyard scale and thus have limited and declining supply (Dy, 2016).

Atis fruit is from a small tree 3 to 5 meters in height with leaves which are somewhat hairy when young, oblong, 8 to 15 centimeters long, with a petiole 1 to 5 centimeters long. Its fruit is large, somewhat heart-shaped, 6 to 9 centimeters long, the outside marked with knobby polygonal tubercles. When ripe the fruit is light yellowish-green. Flesh is white, sweet, soft, and juicy, with a mild and very agreeable flavor. It is nutritious because it is rich in Vitamin C, manganese, B Vitamins, iron, magnesium, phosphorus and potassium in fair quantities (Stuart, 2016).

This study ventured to produce Atis Calamay, Atis Butter Scotch, Atis Fried Dessert, and Atis Boat Tart. Calamay is a sweet concoction of ground sticky rice, sugar, coconut milk, vanilla and some peanuts (optional). It is sealed in smooth coconut shells that are sealed shut by a characteristic band of red tape. Butter Scotch, on the other hand, is a type of confectionery whose primary ingredients are brown sugar and butter, but other ingredients are part of some recipes, such as corn syrup, cream, vanilla and salt. The earliest known recipes, in mid-19th century Yorkshire, used treacle (molasses) in place of or in addition to sugar. The Fried Dessert in this study is a modified doughnut, modified because it is with blended Atis pulp filling. According to Webster dictionary doughnut is a small fried cake of sweetened dough, typically in the shape of a ball or ring. Meanwhile a tart is a baked dish consisting of a filling over a pastry base with an open top not covered with pastry. The pastry is usually short crust pastry; the filling may be sweet or savoury, though modern tarts are usually fruit-based, sometimes with custard. A boat tart is a tart with a crust of a shape of a small boat.

OBJECTIVES

This study was conducted to produce four types of dessert such as Atis Calamay, Atis Butter Scotch, Atis Fried Dessert, and Atis Boat Tart utilizing atis as ingredient, and determine the acceptability of the four desserts in five sensory attributes such as appearance, taste, odor, texture and overall liking. It further aimed to determine the shelf life and the marketability of the products.

METHODOLOGY

This study is experimental, producing desserts with atis as ingredients. The finished products were tasted by 100 participants who are food experts to judge the products using the four point Hedonic scale. To ensure the reliability of the result in judging the taste of the products, the participants were blindfolded because the appearance of the product can insinuate the judgment of the taste. After tasting one product, the participants were asked to drink water before tasting another product to remove the taste of the next product. The rest of the sensory attributes were done removing the blind fold of the participants. The participants were asked to rate the products using the following rating scale 4- Very Acceptable, 3- Acceptable, 2 - Less Acceptable and 1 - Not Acceptable as the lowest. For purposes of interpretation, the following range were used; 3.25 - 4.00 - Very Acceptable, 2.50 - 3.24 - Acceptable, 1.75 - 2.49 - Less Acceptable and 1.00 - 1.74 - Not Acceptable.

RESULTS AND DISCUSSION

The researcher was able to produce the products by using the following recipes.

Atis Calamay

In preparing Atis Calamay, the following ingredients were used; 1 kilograms blended Atis pulp, 3 cups glutinous rice flour, 4 cans(400 ml each) coconut milk, 2 cans coconut milk for curd (latik), 3 cups brown sugar, 1 table spoon pandan or vanilla extract. This is prepared by following the procedure; Blend the Atis pulp until fine, set aside. Then prepare a pan, pour coconut milk then cook in a low heat. Keep stirring until it curdles. Set aside. In a large pan, combine the blended atis pulp, sweet rice flour, coconut milk, sugar and vanilla then cook in a low heat. Keep stirring until thicken. Prepare the cleaned coconut shell, fill it with the mixture, sprinkle with coconut curd and seal the coconut shell with a red tape. Have it ready to serve.

Atis Butter Scotch

In preparing the Atis Butter Scotch the following ingredients were used; 1/2 cup granulated sugar, 1/2 cup packed brown sugar, 1/4 cup butter or stick margarine, softened, 2 large egg whites, 1 teaspoon vanilla extract, 1 1/4 cups all-purpose flour, 1/2 teaspoon baking powder, 1/4 teaspoon salt, Cooking spray, 1/2 cup blended Atis pulp. The procedure in preparing the Atis Butter Scotch are as follows: Preheat oven to 350 °C. Beat sugars and butter at medium speed of a mixer until well-blended (about 4 minutes). Add egg whites, atis pulp and vanilla; beat well. Lightly spoon the flour into dry measuring cups, and level with a knife. Combine flour, baking powder, and salt; stir well with a whisk. Add flour mixture to sugar mixture; beat at low speed just until blended. Spread batter evenly into an 8-inch square baking pan coated with cooking spray; sprinkle evenly with morsels. Bake at 350°C for 28 minutes or until a wooden pick inserted in center comes out clean. Cool in pan on a wire rack. Slice into squares then wrap in colored water cellophane.

Atis Fried Dessert (Doughnut)

In this product, two subproducts were prepared; first was for the filling and the second was for the dough. For Atis filling, the following ingredients were used: ½ cup blended Atis pulp, ¼ cup refined sugar, ¼ cup water, 1/8 teaspoon vanilla. The Atis Filling was prepared with the following procedure followed; Mix all ingredients into a bowl and place in sauce pan. Cook under low fire until thickened. Remove from fire and let it cool ready for filling the dough. The ingredients for Atis Fried Dessert Dough are as follows; 4 cups bread flour, 1/3 cup refined sugar, ½ cup margarine, 3 pcs. Eggyolk, 1 ½ teaspoon salt, 1 ½ cup water, 5 teaspoon yeast, ¼ cup lukewarm water for yeast and 1 teaspoon sugar for yeast. The procedure in preparing Atis Fired Dessert are the following; Dissolve yeast in ¼ cup lukewarm water. Stir. Sprinkle with 1 teaspoon sugar then cover and set aside to ferment. Sift flour, measure and set aside. Mix together in a mixing bowl water, sugar, salt, eggyolk, margarine and foamy yeast. Add the flour into the mixture, mix thoroughly and knead the dough until smooth and elastic and have it rest for 20 minutes. Punch the rested dough, divide and weigh the dough into portion size. Flatten the dough with a rolling pin, fill with Atis filling then roll to close the ends, its shape is like that of a dough nut. Allow to rest for 30 minutes. Fry the dough in hot oil until golden brown. When done roll into refined sugar then have it ready to serve.

Atis Boat Tart

In preparing Atis Boat Tart, just like the doughnut two sub products were prepared the filling and the crust. For the filling the following ingredients were also used; 1 cup Atis pulp, ½ cup refined sugar, ½ cup cornstarch, ½ cup evaporated milk, 1 cup water, and 1 teaspoon vanilla. These ingredients were mixed together and cooked in sauce pan under low fire, stirred constantly until thickened. Then set aside for the crust. After the filling the next to be prepared is the crust which needed 2 cups all purpose flour, ¼ cup butter, 1 piece eggyolk, ¼ cup water, 2 tablespoon refined sugar and ¼ teaspoon salt. The following procedure was followed; Dissolve sugar and salt in ¼ cup

cold water, then add eggyolk. Cut-in flour and margarine using pastry blender until pea size. Gradually sprinkle cold water solution over it and continue cutting-in. Knead, divide the dough and place in greased boat tart molder. Place the previously prepared filling and bake in a pre-heated oven for 30minutes or until brown. Allow it to cool, when cold, wrap it in colored water cellophane.

In the preparation of the four desserts of Atis, the common tools, utensils and equipment used were measuring cup, measuring spoon, wooden ladle, mixing bowls, sauce pan, rubber scraper, stove; boat tart molder and pastry blender (specific for boat tart), oven for butter scotch and boat tart.

Table 1 Acceptability of the products in five sensory attributes

Sensory attributes	T1	T2	T3	T4	Composite mean	Description	Rank
Appearance	3.48	3.64	3.52	3.75	3.48	VA	5
Taste	3.57	3.68	3.76	3.82	3.69	VA	1
Odor	3.70	3.72	3.50	3.68	3.65	VA	2.5
Texture	3.45	3.75	3.84	3.82	3.65	VA	2.5
Overall Liking	3.48	3.60	3.54	3.70	3.58	VA	4
Composite Mean	3.54	3.68	3.63	3.75	3.60	VA	
Rank	4	2	3	1			

Legend: T1 - Atis Calamay T2 - Atis Butter Scotch T3 - Atis Fried Dessert T4 - Atis Boat Tart

Table 1 shows the acceptability levels of the four atis desserts in five sensory attributes such as appearance, taste, odor, texture and overall liking. It clearly manifests that the four products were rated Very Acceptable in all the five sensory attributes or in appearance, taste, odor, texture and overall liking but they differed in the numerical rating or the mean. In terms of Appearance, Atis Boat Tart ranked first with weighted mean 3.75, it was followed by Atis Butter Scotch, 3.64, Atis Fried Dessert and Atis Calamay followed with a weighted mean of 3.52 and 3.48 respectively. Boat Tart took a lead in taste and overall Liking whose weighted means are 3.82 and 3.70 respectively. On the other hand, Atis Butter Scotch emerged as number 1 in odor while Atis Fried Dessert ranked first in texture. Atis Fried Dessert ranked first in texture because it has very soft texture and Atis Boat Tart ranked next to Atis Fried Dessert. The flakiness, crunchiness and the tenderness of the crust of the tart were very evident in the product. These are the qualities of a good tart crust. Butter Scotch ranked first in Odor because of the nice blend of the smell of the ingredients.

Meanwhile, the overall rating of the product with reference to the composite mean of five sensory attributes of the product, Atis Boat Tart ranked first with the composite mean of 3.75 followed by Atis Butter Scotch (3.68), Atis Fried Dessert (3.63) and Atis Calamay as the last with 3.54 as the composite mean.

When comes to the five sensory attributes, the composite mean of taste of the four products was 3.69 so taste ranked first. Odor and texture of the four products got a tie with a composite mean of 3.65, while fourth is the overall liking (3.58) and the last is the appearance with 3.48 as the composite mean.

Table 2 Shelf life of Atis desserts

Products	No. of Days														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T1 - Atis Kalamay	/	/	/	/	x	x	x	x	x	x	x	x	x	x	x
T2 - Atis Butter Scotch	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
T3 - Atis Fried Dessert	/	/	/	/	/	x	x	x	x	x	x	x	x	x	x
T4 - Atis Boat Tart	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

Table 3 discloses the shelf life of the four Atis Desserts. In knowing the shelf life of the products, the products were observed daily while placed at room temperature. It shows that both Atis Butter Scotch and Atis Boat Tart lasted for 15 days. On the sixteenth day, the crust of the Atis Boat Tart started to soften, the Atis Butter Scotch also softened on the sixteenth day. Among the products, Atis Calamay was the first to spoil. On the fifth day molds were found on the product. It can be deduced that method of preparing the product is a factor that affect shelf life. Atis Butter Scotch and Boat Tart were both baked, Calamay was boiled until a thick consistency was reached while Fried Dessert as the name suggested, was fried. Baking can lessen the amount of moisture in the product, thus making the product last longer.

Marketability

In terms of marketability all the four products were marketable. The products were displayed in the school cafeteria of two nearby high schools in the City of Tagbilaran City, Bohol and also in the university cafeteria of Bohol Island State University. It was found out that the products were sold out in the first three days of the week in one month of display. Atis Fried Dessert was saleable while hot, Calamay, Butter Scotch, and Boat Tart on the other hand were not only eaten as snack item in the cafeteria but were bought as a "pasalubong" for loved ones at home. It can be deduced that these Atis Desserts were all marketable.

CONCLUSION

Based on the findings, it can be concluded that the Atis dessert are all acceptable. These can be a good part of one's meal. These products can be a source of income of the people in rural community because the ingredients are available in the locality, the tools and utensils are present in ones kitchen and the procedure of preparing the products are easy to follow. Although Atis Butter Scotch and Boat Tart used oven, these products can be baked in a clay oven which are manufactured in local community, thus it is still very much feasible for the rural community to produce these products.

RECOMMENDATION

It is recommended that Atis products be introduced to the rural community through the extension function of the university so that these can be used by them as another source of income. The university may conduct training about the preparation of these products from Atis so that they will be encouraged to produce and sell their products. Farmers should also be informed about the utilization of Atis as Desserts so that they will be motivated to plant more Atis trees in larger scale thus promoting the use of Atis and thereby excluding this fruit from the list of promising but forgotten fruits.

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REFERENCES

Benavides, R. 2016. The importance of desserts after a meal. http://johnodonnellart.com/2016/the-importance-of-desserts-after-a-meal (retrieved on August 12, 2017).

Davidson, M.J. 2011. The Importance of food in our life. http://ezinearticles.com/?The-Importance-of-Food-in-Our-Life&id=6541199 (retrieved on August 14, 2017).

Dy, R. 2016. Forgotten but promising fruits. http://www.bworldonline.com/content.php?section=Opinion &title=forgotten-but-promising-fruits&id=126524 (retrieved on October 12, 2017).

Manila Girl. 2009. Top 10 Exotic and tropical fruits in the Philippines. http://top10philippines.blogspot.com/2009/07/top-10-tropical-fruits-in-philippines.html (retrieved on April 5, 2017).

Market Man. 2005. Calamay from Bohol. http://www.marketmanila.com/archives/calamay-from-bohol (retrieved on June 20, 2017).

Only Foods. 2016. Sugar apple. http://www.onlyfoods.net/sugar-apple.html (retrieved on July 28, 2017).

Ranga, N. 2011. Importance of food-in life & health. https://www.studyread.com/importance-of-food (retrieved on August 20, 2017).

Stuart, G. 2016. Atis, Annona squamosa linn sugar apple. http://www.stuartxchange.org/Atis.html (retrieved on September 22, 2017).

Research article

Evaluation of Soil Nutrient Level in Naypyitaw Agricultural Land

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Abstract Being one of the portions of land degradation, fertility depletion is a major barrier in crop productivity in agricultural sector. While we made attempt to increase crop productivity for food security, this study focused on investigating the fertility status of the soil and the major factors that influenced the nutrient level. The studies were carried out in Naypyitaw Union Territory during 2016 - 2017. The first study emphasized on major nutrient level in Naypyitaw region. A total of 240 soil samples were collected from 8 townships of 2 districts and analyzed. Soil analyses were performed for soil acidity, organic carbon, total Nitrogen, available P and K. Using descriptive statistic, the nutrient levels were evaluated in study area. The objective of second study was to evaluate the major and minor nutrient status in prominent specific rice fields in two townships. (Pobbathiri and Zeyar Thiri). Soil samples were collected from 22 farmer's fields and analyzed to identify soil macro and specific micro nutrients content. The Chi-square test was used to analyze for different location and different cropping patterns. First study showed that about 50% of Naypyitaw agricultural lands is low in Organic Carbon, 82% and 90% of land were also deficient in total N and available P, respectively. The second study showed that the deficiencies of total N, available P, S and Zn were detected in all rice fields. These nutrient deficiencies are not totally dependent on grown crops. It may be due to insufficient application of nutrients amount and type. It was also found that no farmers apply sufficient amount of organic and inorganic fertilizers. The results of the present study suggested that the effective education system was essential for farmers to adopt the advanced fertility technology regarding balanced fertilization of macro and micro nutrient..

Keywords balanced fertilization, degradation, macro, micro, fertility depletion

INTRODUCTION

Being an Agricultural country, Myanmar tries to develop Agricultural sector through increased crop productivity. Of the two approaches to achieve the crop productivity, where there are limited in land for area expansion, increased yield is more common in Agricultural sector. Main pillar of increased yield are Varietal improvement, Agricultural practices, Systematic nutrient supply and Protection of pest and disease and post-harvest losses. Today the yield of crops especially in rice of Myanmar is lower than that of neighboring countries. The basic technique of systematic nutrient management is balanced fertilization that for plant nutrient requirement in right time and right dose. Although grower applied their land in high intensity, they never noticed removal amount of nutrient from their land. It made the soil nutrient minus day by day resulting in nutrient depletion

in Agricultural land. At present, it may be great challenges for crop productivity and its negative effect on future land too. Even growing soil improved crops such legumes need to supply required macro and micro nutrient at right dose in right time. Today Myanmar face with land degradation due to soil erosion and fertility depletion .Major causes of fertility depletion may be due to insufficient apply of nutrient in Agricultural land.

Naypyitaw, in middle part of Myanmar, was selected for this study. It consists of 8 town ships, namely Tatkon, Lewe, Pyinmana, Zeyar Thiri, Pobba Thiri, Dekkhina Thiri, Zabuthiriand Oattara Thiri. The total land area is (706,009.72 ha) and net sowing area is about (135,978 ha). Major crops grown in this area are rice, sugarcane and pulses. Most of lands are used for growing rice and cropping intensity of this area is above 150% and 176.51% in Oattara Thiri district and 169.34% in Dekkhina Thiri. Some rice growing areas have Cropping Intensity (C.I) up to 300% since farmers adopt triple cropping system where water is available. Majority of farmers depend on rice growing in this area with high C.I and improved varieties including hybrid rice and corn which are those heavy eater crop in nutrient point of view. Even then, farmer didn't apply sufficient nutrients and amount on rice land let alone in upland crop resulting in nutrient depletion in soil. Although farmers apply fertilizer in substantial amount in rice field, it doesn't cope with the removal of nutrient by grown crops especially in minor nutrients. It may be remarkably deficient. The Cropping Intensities of these area shown in Table 1.

Table 1 Cropping Intensity of Naypyitaw region

District	Crop land (ha)	1st crop	2nd crop	3rd crop	Total	C.I (%)
Oattarathiri	71359.2	71359.2	53531.6	1062.8	125953.6	176.51
Dekkhina Thiri	64619.6	64619.6	39076.8	5752.8	109427.6	169.34
Total	135978.8	135978.8	92608.4	6815.6	235381.2	173.1

Source: –Department of Agriculture, Naypyitaw Region (2016)

OBJECTIVES

The study on nutrient status in Naypyitaw region was conducted in 2016, and study of macro and micro nutrient status in rice field was conducted in Pobba Thiri and Zeyar Thiri in 2017. Two main objectives are to evaluate the nutrient status in Naypyitaw Agricultural land, to assess the macro and micro nutrient level in rice growing area of two townships, and to assess the nutrient level based on cropping pattern.

METHODOLOGY

In this study, both primary and secondary data were collected. The primary data were collected from the selected farmers who are growing rice in two town ships (Pobbathiri and Zeyar Thiri). The survey was carried out with 22 farmers and soils from 4 kwins (cadastral boundary of agricultural land parcels) of their rice field were analyzed. The study was conducted to investigate soil macro and specific micro-nutrient status in rice field in these townships. The Chi-square test was used to analyze for different location and different cropping pattern.

The secondary data included land utilization of Naypyitaw, net sown area and cropping intensity. The major source of secondary data was taken from soil analytical data of fertility status in Naypyitaw. A total of 240 soil samples were collected and analyzed from 160 villages, 8 townships of 2 districts. Soil samples were analyzed for soil acidity, organic carbon, total Nitrogen, available P and K. Using descriptive statistics, the nutrient levels were evaluated in study area. Organic carbon ranged 2-4%, which was considered medium. Total N ranged 0.2-0.5%, considered medium, available P range was determined as medium (15-50 ppm) and level for K2O was determined as medium (10-20 mg/100g).

RESULTS AND DISCUSSION

Nutrient Status of Soils in Naypyitaw Region

Forty seven percent of land was low in organic carbon content and 52% of soil had medium level of organic carbon (Table 2) and Fig. 1. Eighty two percent of soils in Naypyitaw was low in total N content as expressed in Fig. 2. And available P content was low in 90% of soil samples (Fig. 3). In this area, level of available K was found to be medium in most soil samples (53%) as shown in Fig. 4. Also, nutrient status of study areas based on district were presented in Table 3 and Fig. 5.

Table 2 Nutrient status of soils in Naypyitaw region

	No of Organic C level			No of Total N level		No of Avail P level		No of Avail K level		
	Low	Medium	High	Low	Medium	Low	Medium	Low	Medium	High
Dekkhina Thiri	40	47	2	68	21	78	11	24	43	22
Oattara Thiri	72	78	1	128	23	138	13	28	85	38
Total	112	125	3	196	44	216	24	52	128	60

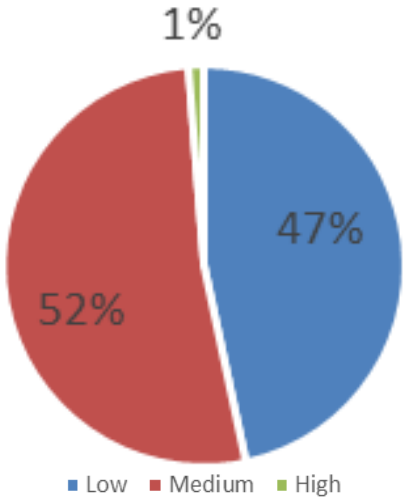

Fig. 1 Organic carbon level of agricultural land in Naypyitaw

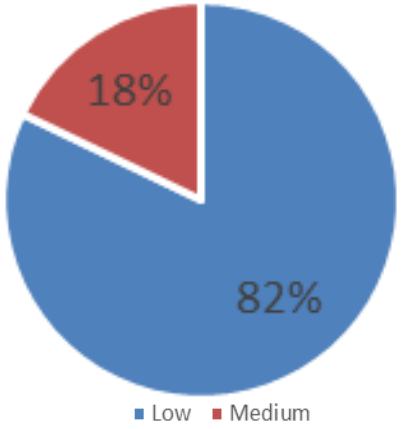

Fig. 2 Total nitrogen level of agricultural land in Naypyitaw

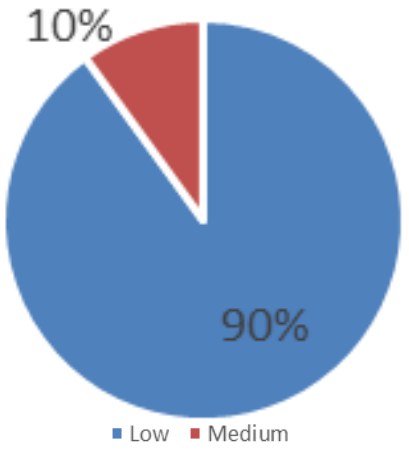

Fig. 3 Available P level of agricultural land in Naypyitaw

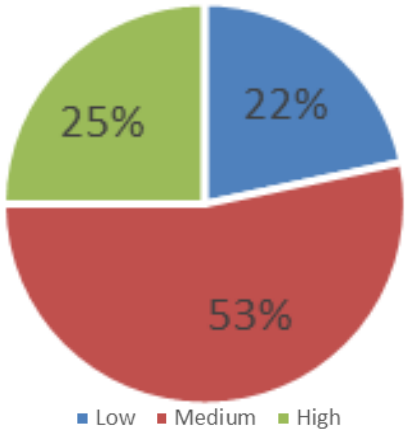

Fig. 4 Available K level of agricultural land in Naypyitaw

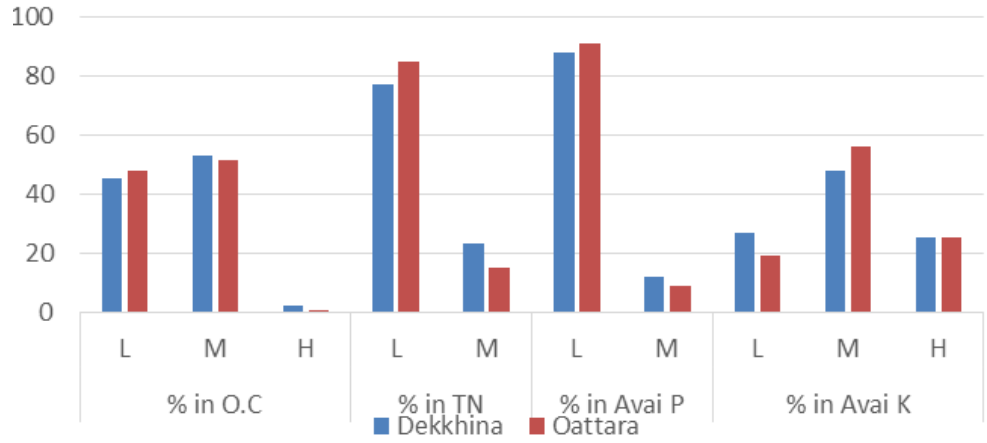

Fig. 5 Nutrient status of agricultural land in two districts in NPT

Table 3 Nutrient level percent based on district

	% in O.C level			% in N level		% in avail P level		% in avail K level		
	Low	Medium	High	Low	Medim	Low	Medium	Low	Medium	High
Dekkhina	45	53	2	77	23	88	12	27	48	25
Ottra	48	51.4	0.6	85	15	91	9	19	56	25

Macro and Micro Nutrients in Rice Field

The study was carried out in 2017 based on farmer survey and soil analytical data of their rice fields located in Oattathiri District. There are 5 major soil types in rice growing areas.

Fertility status of study areas: Fertility level based on location is shown in Table 4. Moreover, soil fertility level based on cropping system is shown in Table 5. Total Nitrogen, available S and Zn were deficient in all samples. Deficiency of organic carbon was significantly different in two areas at 0.05% level. Available P were found in low level but not significantly different between two locations. Available B was found to be in medium level in all soils of Zeyar Thiri and about 30 % of Pobba Thiri rice growing lands. Therefore, B deficiency varied with the regions and its difference was significant at 0.01 level.

Table 4 Fertility level based on location

No.	Parameter	No of soil sample Pobba Thiri		No of soil sample Zeyar Thiri		χ^2 test
		Medium	Low	Medium	Low	
1	O.C	6(8.18)	6(3.82)	9(6.82)	1(3.18)	4.01*
2	Total N	-	12	-	10	
3	Avail P	2(2.18)	10(9.82)	2(1.81)	8(8.18)	ns
4	Avail K	12	-	10	-	
5	Avail S	-	12	-	10	
6	Avail Zn	-	12	-	10	
7	Avail B	4(7.64)	8(4.36)	10(6.36)	- (3.64)	7.81**

Findings of this study indicate that fertility status in rice fields of Naypyitaw is not totally dependent on the cropping pattern. Major factors that influence fertility level may include high cropping intensity and insufficient application of nutrients as it is shown in Table 5. Bacon et al.

(1990) stated that balanced input and output is important in long-term sustainability. Although pulses help improved soil fertility, remaining nutrient is not enough to maintain fertility level unless nutrients were not applied to cover its use. Pattanayak et al. (2008) pointed out that applying inadequate and unbalanced nutrient is a major factor responsible for low productivity.

Table 5 Fertility level based on cropping pattern

No.	Parameter	No of soil sample						
		Rice, Pulses system		Rice, Rice system		Rice, Pulses, Rice system		X^2
		M	L	M	L	M	L	test
1	O.C	9(8.86)	4(4.14)	1(1.36)	1(0.64)	5(4.77)	2(2.23)	ns
2	Total N	_	13	_	2	-	7	
3	Avail P	3(2.36)	10(10.64)	_(0.36)	2(1.64)	1(1.27)	6(5.73)	ns
4	Avail K	13	_	2	_	7	_	
5	Avail S	_	13	_	2	_	7	
6	Avail Zn	_	13	_	2	_	7	
7	Avail B	8(8.27)	5(4.73)	1(1.27)	1(0.73)	5(4.45)	2(2.55)	ns

The findings showed that all farmers are lack of knowledge in soil fertility. They never know nutrient removal and recommended fertilizer rate for their crops. They apply substantial amount of fertilizers in rice field but in pulses in general. Organic matter utilization has been never met the needs of plant's micronutrients.

CONCLUSION

This study showed that about 50% of Naypyitaw Agricultural lands were low in Organic Carbon. In terms of major nutrients, 82% and 90% of land were also deficient in total N and available P respectively. It contained only K in substantial amount. In the study, Total N, available P, S and Zn were deficient in all fields. Rice fields in Zeyar Thiri had more O.C and B compared to that of Pobba Thiri. Some nutrient deficiencies were significantly different in two locations but not dependent on cropping pattern. Deficiency of nutrient in study area was not totally dependent on grown crops. It may be due to insufficient application of nutrients amount and type. According to the study no farmers apply sufficient amount of organic and inorganic fertilizers and the results of the present study pointed out that the effective education system was required for farmers to adopt the advanced fertility technology regarding balanced fertilization of macro and micro nutrients.

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REFERENCES

Bacon, S.C., Lanyan, L.E. and Schlander, R.M.Jr. 1990. Plant nutrient flow in the management pathways of an intensive dairy farm. Agron. J. 82, 755-761.

Department of Agriculture. 2016. Annual report of NPT region. Ministry of Agriculture, Livestock and Irrigation, Myanmar.

Landon, J.R. 1984. Booker Tropical Soil Manual.

Land Use Division. 2016. Annual soil survey report. Department of Agriculture, Ministry of Agriculture,

Livestock and Irrigation, Myanmar.
FAO. 2010. Proceeding of national seminar on pulses crops for better economy. 26-27 May, 2010, FAO Myanmar.
Pattanayak et al. 2008. K unlocks the potential for hybrid rice. Better Crops, 92 (2), 2.
World Bank Group. 2016. Myanmar: Analysis of farm production economic. World Bank.

Research article

Issues of Disaster Recovery Management and Application of GIS and UAV for Resilience in Agricultural Land and Infrastructure

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Abstract Natural disasters have caused enormous impacts on rural societies in both developed and developing countries for the recent years. Due to climate change, the frequency and intensity of extreme weather have increased and it is predicted to be more rampant for the coming decades. As rural societies are mainly dependent on agriculture, the rapid recovery and reconstruction of damaged agricultural lands and infrastructure is crucial to enhance their resilience. The rapid measures and actions in the post-disaster can reduce the impacts and can help farmers save their livelihoods as well as consumers ensure their provisions. This paper focuses on administrative issues in the recovery management in the post-disaster period in Japan. Especially, it takes up the underlying issues that impede the disaster recovery process and the application of Geographic Information System (GIS) and Unmanned Aerial Vehicle (UAV) in case of earthquake and flood disasters including storms and heavy rainfall. The data was collected through questionnaire survey to the agricultural departments in all the prefectural offices in Japan. From the results, the administrative issues were attributed to the complexity of project procedures and documentation, human resources, rural planning, the lack of capacity in construction companies, in most of the prefectures. The use of GIS and UAV was limited in many prefectures due to the lack of knowledge or experience. However, GIS could help the recovery processes quicken for some prefectures. Based on the findings, it is suggested to make a manual about GIS database building which can be shared among prefectural offices and farmers to inherit the past lessons and enhance resilience for the future.

Keywords disaster recovery, resilience, rural society, GIS, UAV

INTRODUCTION

The impacts of natural hazards have increased due to climate change and caused disasters all over the world. At the same time, due to the excessive land development and population increase in vulnerable areas have also increased the disaster risks. These have brought an urgent need in our

society to enhance resilience. Paying attention to resilience in rural society, the rapid recovery in agricultural land and infrastructure stricken by disasters is a key to reduce the impacts, saving farmers' livelihoods and provisions to market. This paper focuses on the administrative issues for disaster recovery in agricultural land and infrastructure, and the application of Geographic Information System (GIS) and Unmanned Aerial Vehicle (UAV) in Japan. In Japan, GIS database on agricultural information system was prepared by the Ministry of Agricultures, Forestry and Fisheries of Japan (MAFF) from 2006 to 2010 and started operating by an association of farmers in each prefecture called the Land Improvement Association since 2011. UAV has been increasingly applied in the field of civil engineering, environmental measurement and geographic survey.

In Japan, when agricultural land and infrastructure are damaged by natural disasters above the certain standards, there is a governmental system called "the Rehabilitation Project of Disaster Stricken Agricultural Land and Facilities" to support a part of the cost of disaster rehabilitation. The prefectural offices need to collect disaster information from affected municipalities and apply to the government for funding before launching the rehabilitation works. Therefore, it is important to conduct swiftly the whole process of the project for the early recovery. For this, MAFF has tried to simplify the project procedures and has worked out in some cases (Yoshikawa et al., 2007; Arita et al., 2008; Senda et al., 2013). There has been one case reported that GIS was successfully applied to the rehabilitation project for simplification of the process (Senda et al., 2013). However, there have been issues which caused the delay and lengthening of the rehabilitation project, due to various reasons such as, the inaccessibility in remote areas (Asahiro et al., 2014), the lack of capacity and limited number of construction companies (Arita et al., 2008), the lack of personnel and experience of staff in the municipality office (Miyasato, 2007; Arita, 2008), the loss of motivation of local farmers and making agreement with them about reconstruction plan (Arita et al., 2009).

These previous studies focused on one single case of a disaster rehabilitation project. Therefore, there is a need to study which covers more widely to identify the general existing issues in the rehabilitation project.

OBJECTIVES

The objective of this research is to identify the existing delay issues including the application state and usefulness of GIS and UAV in the Rehabilitation Project of Disaster Stricken Agricultural Land and Facilities by the administration of Japan. From the results, it aims to form a suggestive method for improvement of the rehabilitation management. Japan is targeted as a research site as one of the world-leading countries in the disaster prevention and mitigation measures. It is expected that the results of this research is applied to other disaster-prone countries. The kind of disaster was focused on earthquake including tsunami and flood disasters including heavy rainfall and storm.

METHODOLOGY

The research applied questionnaire survey for data collection and statistically analyzed the results. The questionnaire survey sheets were distributed to a section of the agricultural department, which is in charge of the rehabilitation project, in all the forty-seven prefectural offices and prefectural Land Improvement Association offices for a few prefectures in Japan. The questionnaire sheet was consisted of two versions, earthquake disaster including tsunami, and flood disaster including heavy rainfall and storm. The questions were mainly concerned about the existing issues that cause the disaster recovery projects delayed or lengthened in case of the last disaster that each prefecture experienced since 2000, the application state of GIS and UAV, and the useful GIS data for the rehabilitation.

The questionnaire sheets were made in Japanese and distributed by email between September and November 2017 and responded by thirty-one prefectures out of forty-seven prefectures, that is 65.9%. Among them, thirty respondents are from prefectural offices and one is from Land

Improvement Association. Prefectures which experienced the rehabilitation project for earthquake since 2000 were nineteen, and all of the thirty-one prefectures experienced the project caused by flood disasters. The number of valid response was low for some questions due to the lack of information or still being under the investigation.

The limitation of this research can be attributed to the target of respondents and the limit of the objective disasters. In Japan, each municipality including city, town or village rather than the prefectural office is more directly in charge of the rehabilitation project. Therefore, there is a possibility to obtain more detailed and accurate data from municipalities than prefectural offices. In addition to that, the questions about the cause of delay were intended to inquire only about the latest case that each prefecture experienced after 2000. As the situation and issues vary from disaster to disaster, the results can differ depending on the case of disaster selected in each prefecture.

RESULTS AND DISCUSSION

Cause of Delay and Lengthening in the Rehabilitation Project

The launching time of the first and last rehabilitation project among all the projects in each case of disaster after a disaster occurrence is as shown in Fig. 1. For the case of earthquake, most of the first disaster project is launched within four months. On the other hand, for the case of flood disasters, although many cases are implemented within fourteen days, it becomes low in 'within one month' and 'two months' but high again in 'within four" or 'six months'. For the last project, most of the cases are launched later than six months. Hence, it takes a long period to implement all the rehabilitation projects in most of the cases.

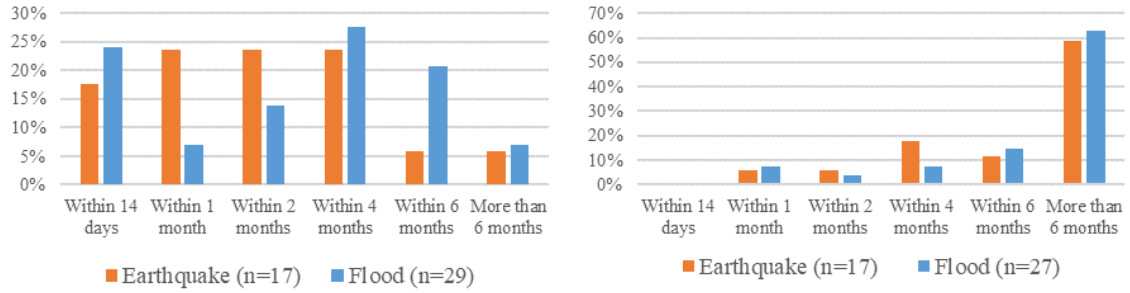
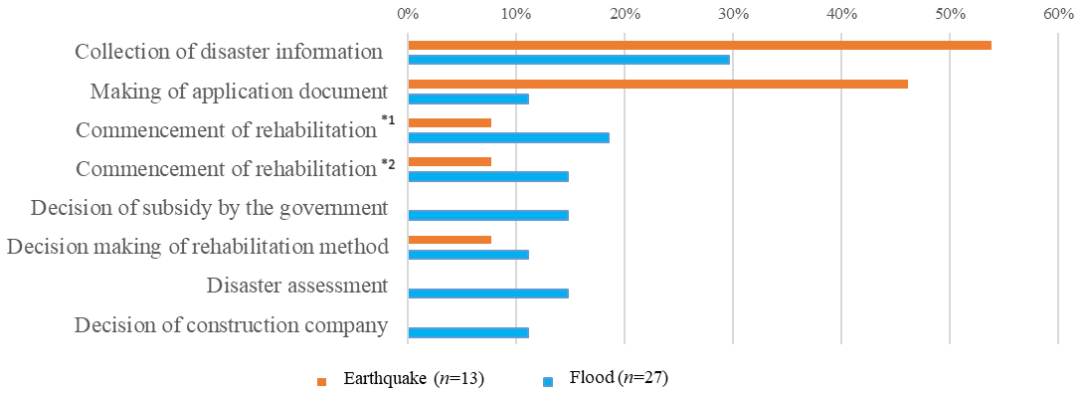


Fig. 1 Launching time of the first (left) and last (right) rehabilitation project in each case



Note. *[1] *Commencement of rehabilitation due to the lack of labor force in construction company*
*[2] *Commencement of rehabilitation due to the lack of available construction company*

Fig. 2 Procedure taken longer than expected

The procedures which took longer than predicted were as shown in Fig. 2. Collection of disaster information takes long in many prefectures for both disasters. Preparing the application document of the rehabilitation project plan also takes long due to its complexity especially in the case of earthquake. Launch of rehabilitation works also takes a long time due to the lack of capacity or availability of construction companies for both disasters. Compared to the cases of earthquake, the cases of flood are attributed to more variety of issues. It may be related to the delay of launching time of the rehabilitation work as seen in Fig. 1.

The causes of delay in the project were identified as seen in Fig. 3. Most of the causes are attributed to the limit of capacity of officers such as the lack of, knowledge about the rehabilitation project, and labor force in municipalities, and difficulty to control the project team in the time of emergency. Other main factors are response to the affected farmers such as making agreement with them for rehabilitation plans and individual response to each farmer where farmer's association is not formed. Damage which cannot be found immediately after the occurrence of disaster was also raised.

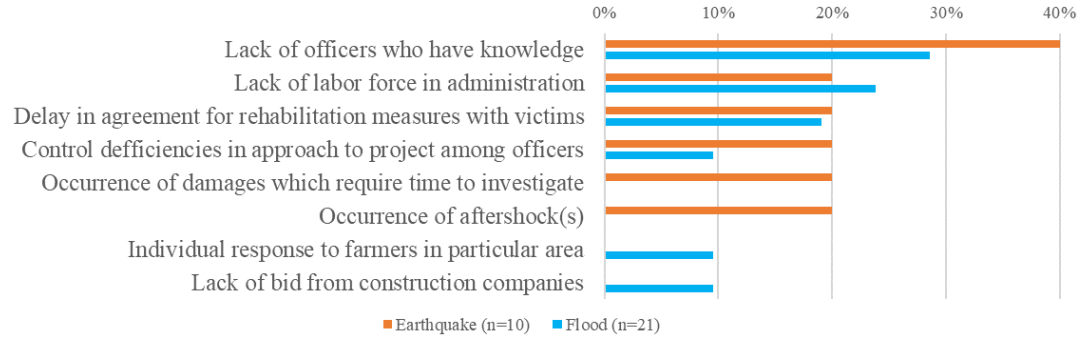


Fig. 3 Cause of delay in rehabilitation project

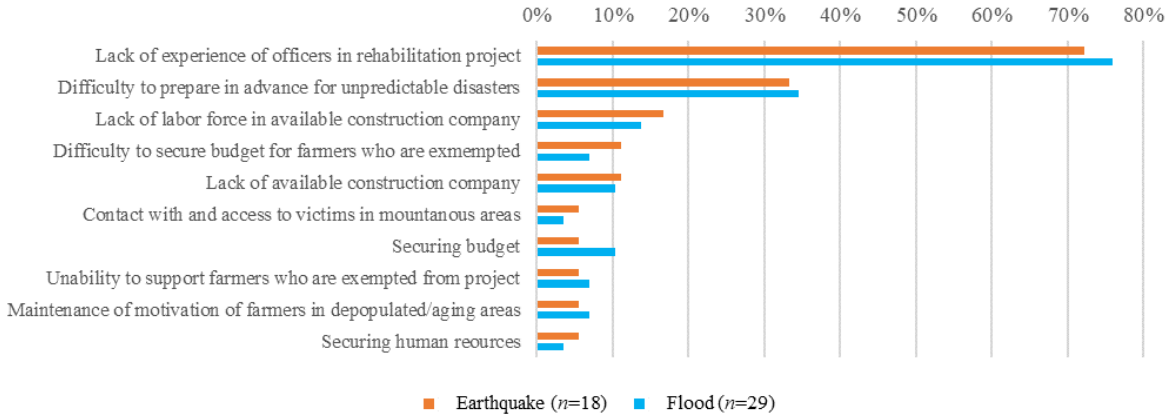


Fig. 4 Difficulty of municipalities in the disaster measures in the rehabilitation project

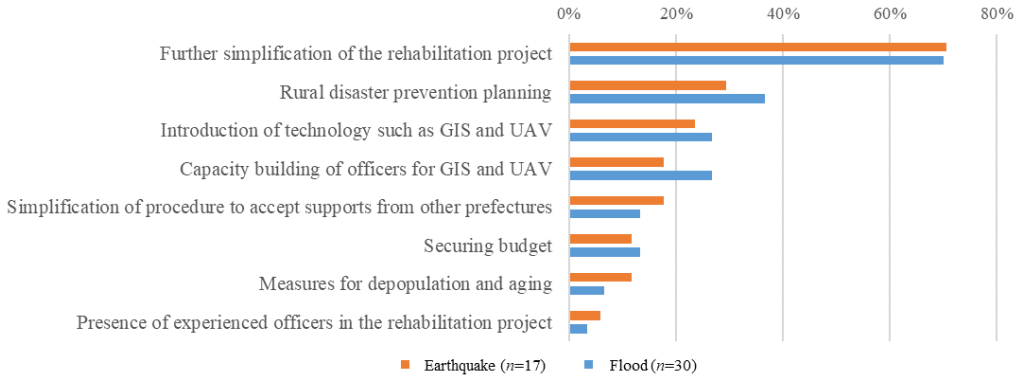


Fig. 5 Issues to be solved to make the rehabilitation project smooth and faster

Difficulties that municipalities face to cope with disasters in the rehabilitation project varied among many factors as shown in Fig. 4. The difficulty which most of the prefectures face was the lack of experience by officers in the rehabilitation project. The second highest was the unpredictability of natural disasters. Lack of capacity or availability of construction companies were also the reasons of delayed. The limit of budget in administration is also a difficulty for them to implement the project and to respond to affected farmers who were exempted from it due to the smaller scale of damages than the standard of the project regulation.

The issues that officers consider that should be solved to make the rehabilitation project smoother and faster were also identified as seen in Fig. 5. From the main answers, it can be divided into three large groups: 1) simplification of the rehabilitation project process; 2) rural planning that takes account of disaster occurrence; and 3) introduction of GIS and UAV and development of human resource in these technology.

Use of Geographic Information System and Unmanned Aerial Vehicle

Many prefectures did not apply GIS for the rehabilitation project in both earthquake and flood disasters. As seen in Table 1, the reasons whether they used GIS or not are attributed to their experience of preparedness in the pre-disaster time or the presence of skilled human resource in GIS. As the results, the number of skilled officers in GIS is still limited in the administration offices and capacity building of officers is highly needed.

Table 1 Reasons of GIS usage/non-usage in rehabilitation project by prefectures

Reasons of GIS usage/non-usage in rehabilitation		Response rate	
		Eq (n=9)	Hy (n=18)
No used/almost not	The limited number of skilled officers in GIS	22.2%	5.6%
	There was no need to use GIS	55.6%	66.7%
	Use of GIS was limited in the pre-disaster time	22.2%	11.1%
	There was no experience to use GIS in rehabilitation	44.4%	22.2%
	GIS data was not owned	11.1%	0.0%
	GIS was not popular at the time of disaster	11.1%	0.0%
		Eq (n=5)	Hy (n=10)
Used	There were enough experts on GIS	0.0%	30.0%
	GIS was regularly used in the pre-disaster time	60.0%	30.0%
	There was experience to use GIS in rehabilitation	20.0%	50.0%
	Difficulty for field survey	20.0%	0.0%
	To make report of the disaster damages	0.0%	10.0%

GIS data which were applied in the project and regarded as important to collect before and after disasters by officers are shown in Table 2. The required data were relatively similar between both disasters. Information of farmland owner, utilization of agricultural water, farmland and cadastral map, facility of agricultural water, topographical map, aerial photograph and farmland area are highly needed to collect in the pre-disaster time. To collect disaster information and identify whom to contact after the disaster occurrence, the information of farmland owner is expected to obtain in the pre-disaster and updated regularly. To identify the extent of damage, it is important to have information about the state of agricultural water utilization and the water use facilities, and farmland such as farmland map, cadastral map, and farmland area before disasters. Topographical map is also useful to compare the affected area between the pre- and post- disaster time as disasters can change topography and the surrounding environmental condition. Therefore most of these data were also recognized as the data which should be obtained immediately after the disasters. Images obtained by UAV was relatively high. In the post-disaster, some areas are not accessible immediately and it is difficult to obtain satellite images of objective area soon. Therefore, UAV is considered very helpful to collect information of various damages to humans and agricultural infrastructure. The prompt data collection is also expected to enable us to avoid the second or third disasters by finding underlying issues. In the real situation in sites, agricultural

conditions are directly affected by disasters and the pre-disaster state is not measureable anymore after stricken. Therefore, it is considered very important to obtain various related data since the pre-disaster time to identify the impact of damage and avoid the unequal treatment or relief to farmers or arguments among farmers as it causes delay in rehabilitation.

Table 2 GIS data used and considered useful in the rehabilitation project

	GIS data that had been owned in the pre-disaster time		GIS data used to collect disaster information		GIS data used rehabilitation and reconstruction		GIS data that should be prepared in the pre-disaster		GIS data that should be collected immediately after disaster	
Type of GIS data/No. of respondents	Eq (n=14)	Fl (n=30)	Eq (n=5)	Fl (n=12)	Eq (n=4)	Fl (n=7)	Eq (n=12)	Fl (n=20)	Eq (n=11)	Fl (n=21)
Farmland gradient	0%	3%	0%	0%	0%	0%	8%	10%	9%	14%
State of farmland improvement	7%	43%	20%	17%	25%	0%	25%	25%	27%	19%
Information of planting crops	0%	7%	0%	0%	0%	0%	33%	5%	9%	0%
Farming history	0%	0%	0%	0%	0%	0%	8%	5%	0%	10%
Information of land owner/cultivator	7%	13%	40%	8%	25%	14%	67%	50%	27%	29%
State of irrigation and drainage water	0%	23%	0%	8%	0%	14%	42%	55%	27%	29%
Irrigation and drainage facilities	14%	60%	40%	25%	50%	14%	42%	30%	36%	29%
Topographic map	14%	60%	60%	50%	50%	43%	42%	45%	27%	33%
Soil map	7%	13%	20%	0%	0%	0%	8%	10%	9%	10%
Land-use map	0%	17%	0%	8%	0%	14%	8%	15%	18%	19%
Farmland and cadastral map	21%	33%	80%	33%	75%	29%	42%	40%	18%	43%
Farmland area	14%	27%	40%	25%	50%	43%	42%	55%	18%	33%
Hazard map	0%	13%	0%	0%	0%	0%	0%	10%	0%	10%
Landslide prevention area	0%	17%	0%	0%	0%	0%	25%	15%	27%	14%
Laser profilerdata	7%	0%	20%	0%	25%	0%	0%	5%	9%	5%
Digital orthophoto	7%	3%	20%	0%	25%	0%	0%	0%	s	0%
Satellite image	7%	0%	0%	8%	0%	14%	0%	15%	9%	14%
Aerial photograph	21%	57%	60%	67%	75%	71%	25%	45%	36%	43%
UAV image	0%	3%	0%	17%	0%	14%	0%	10%	9%	24%

Table 3 Reason why prefectures do not introduce UAV

	No budget	No experts	No experience	No need	Other
Eq (n=25)	28%	36%	56%	8%	4%
Flood (n=22)	36%	45%	45%	14%	0%

UAV was not introduced in most of prefectures. Among thirty-one prefectures, only three prefectures use it for improvement of agricultural productivity, management of agricultural facilities, disaster mitigation, collection of disaster information or disaster rehabilitation and reconstruction. Although many prefectures understand the usefulness of UAV for the disaster management, they do not have a plan to introduce at the moment. Most of the reasons were no skilled human resource, no experience and the lack of budge as seen in Table 3. On the other hand, most of prefectures did not know the usefulness of UAV for evaluation of agricultural productivity. Therefore, if farmers, farmers' association or prefectures understand the usefulness and apply UAV in the daily basis, the data can be accumulated regularly and useful for the time of disaster recovery.

CONCLUSION

As the results are shown above, the prefectures have faced many administrative issues for disaster recovery in agricultural land and facilities. For the improvement in the administrative process, the following measures as disaster preparedness in the pre-disaster time are suggested.

1. Creation of opportunities for officers to enhance their knowledge and technique about the rehabilitation project and GIS/UAV;
2. Improvement of the rehabilitation project systems such as simplification of documents and dispatch of experienced officers from other prefectures;
3. Rural planning on the premise that disasters occur at any occasion and dissemination of the procedure of the rehabilitation project to local farmers;
4. Understanding the capacity of construction companies in each local area;
5. Preparation of manual for GIS database application for the rehabilitation project.

These measures are expected to support officers to conduct the rehabilitation process more smoothly and quickly. In the post-disaster time, as collection of disaster information needs to be done effectively and rapidly, it is suggested to collect important data quickly by field survey, GIS database, satellite image and aerial photograph, and furthermore, UAV in case that the disaster-stricken areas are not immediately accessible. In addition, to continuously improve the disaster rehabilitation process and use the past experiences, it suggests to make a GIS database manual in the model of GIS database building as shown in Fig. 6. It can be improved in a way of Plan-Do-Check-Act (PDCA) cycle as the red arrows indicate. During the pre-disaster time, information are collected in GIS database (Plan). The database is used during the rehabilitation project (Do). After the project, the method needs to be reviewed (Check) and improved and published (Act). This model and manual can be useful for not only Japan but also many countries to enhance rural resilience by expediting rehabilitation process. Capacity building of not only officers but also farmers in GIS and UAV will also be important as these technology help them for both disaster rehabilitation and the daily management of agricultural land and facilities to improve the productivity.

The future study will need to cover not only prefectural offices but municipality offices to obtain more accurate answers and abundant samples.

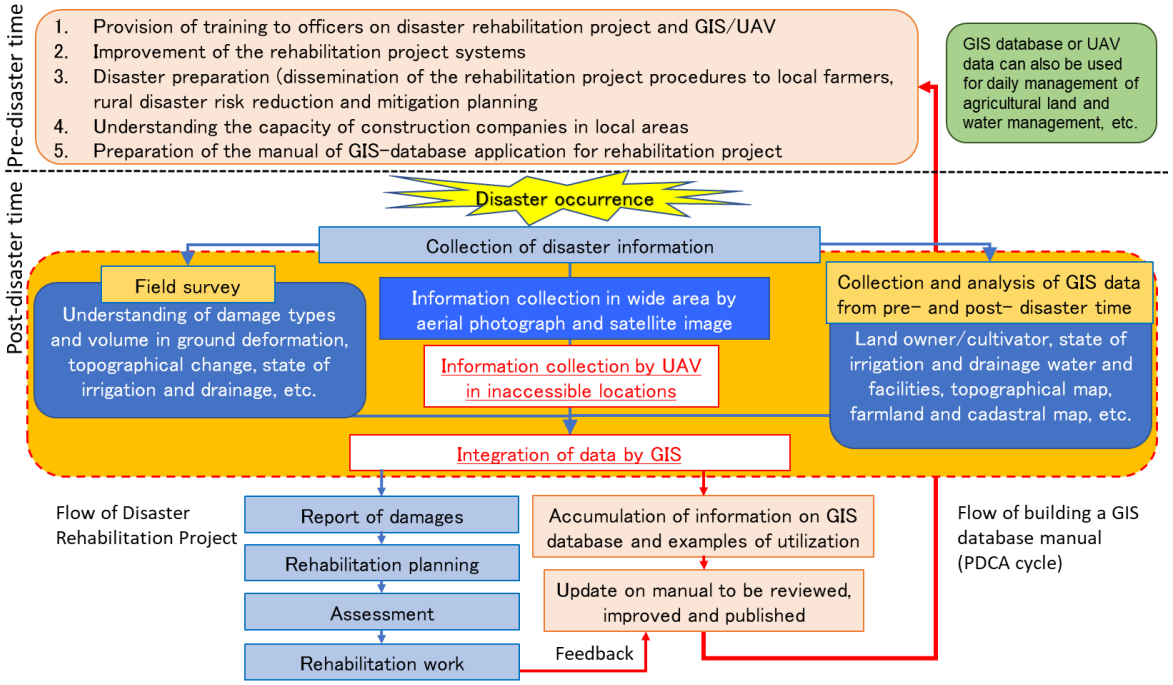


Fig. 6 Flow of a suggestive model of building a GIS database manual

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REFERENCES

Arita, H., Tamai, E. and Iida, S. 2008. Issues on administrative function in the restoration stage of a local government stricken by the Mid Niigata Prefecture Earthquake. Journal of the Japanese Society of Irrigation, Drainage and Rural Engineering, 76 (5), 437-440. (in Japanese with English abstract).

Arita, H. and Yuzawa, K. 2009. The characteristics of the small damages and the restoration measures of agricultural infrastructure in the Mid-Niigata Prefecture Earthquake in 2004. Journal of the Japanese Society of Irrigation, Drainage and Rural Engineering, 77 (4), 417-422. (in Japanese with English abstract).

Asahiro, K., Kanekiyo, H. and Tani, M. 2014. Research into the distribution of damage to farmland in Yame City, Fukuoka Prefecture, from the heavy rains in the northern part of Kyushu in 2012, and difficulties for the recovery. Journal of the Japanese Institute of Landscape Architecture, 77 (5), 649-654. (in Japanese with English abstract).

Chida, H., Sasaki, K. and Inoue, N. 2013. Utilization of the Midori information system of the Great East Japan Earthquake Disaster assessment. Journal of the Japanese Society of Irrigation, Drainage and Rural Engineering, 81 (3), 191-194. (in Japanese with English abstract).

Miyasato, K. 2007. Damage and restoration of agricultural facilities and farmland affected by the 2004 Niigata Chuetsu Earthquake. Journal of the Japanese Society of Irrigation, Drainage and Rural Engineering, 75 (3), 189-192. (in Japanese with English abstract).

Yoshokawa, N., Tamai, E., Misawa, S. and Arita, H. (2007). Simplified method for damage assessment introduced in the Niigata Chuetsu Earthquake. Journal of the Japanese Society of Irrigation, Drainage and Rural Engineering, 75 (3), 205-209. (in Japanese with English abstract).

Research article

Wheat Market Instability in Afghanistan: A Case Study of Kabul, Mazar-e-Sharif, Bamyan and Ghor Provinces

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Abstract Wheat is the major crop and staple food in Afghanistan. Though it is a strategic crop in the country, the nation has never been self-sufficient in wheat domestic production. Yet as a wheat deficit country, it has been highly reliant on wheat and flour imports together with international humanitarian food aids. Thereby, such tremendous dependency on external sources has often led to considerable wheat price fluctuations in Afghan wheat markets associated with imports superfluity or distortions over the years. However, despite the overall weak performance of wheat market in Afghanistan since 2001, the country has got somehow relative stability in this regard over the recent years. Therefore, this study was conducted to address the hurdle through a holistic fashion focusing on both wheat domestic production as well as market aspects in Afghanistan. For production, the study was designed to detect the key underlying factors behind wheat domestic production shortfalls, and for market analysis, wheat price trend was evaluated to determine better policy options so that Afghanistan can achieve better functioning wheat markets in the long run. After all, the findings of this study suggest that there are five mutually exclusive key common factors (invisible factors) behind wheat domestic production quantity and quality failure. Moreover, regarding wheat market stability, Pakistan has been identified as the key disruptive player in the beginning while the Central Asian countries particularly Kazakhstan has recently been the key contributor to wheat market stability in Afghanistan. Therefore, beside concrete policies to boost wheat domestic production within the country, stronger trade ties with Kazakhstan certainly ensure better wheat market performance in Afghanistan.

Keywords Afghanistan, wheat market, fluctuations, price stability

INTRODUCTION

According to CSO (2016-17), with an area of 2.9 million ha under cultivation, cereals production encompasses approximately 37 percent of the country's total arable land from which nearly 79 percent (2.3 million ha) is allocated for wheat production. Furthermore, with a per capita consumption of 170 kg per year mostly in the form of flatbread called "Nan" and contributing to roughly 60 percent of national daily calorie intake in average, wheat plays a vital role in terms of food security in the country (FAO and EU 2013).

Currently, food security is tremendously subject to families' access to wheat all across the nation, hence, any policy adoption to ensure its year-round availability seemingly achieves food security to a great extent in the country. A study conducted by D'Souza and Jolliffe (2012)

suggests that due to shortcomings with their own production and weak purchasing power from the market, most of the afghan families adjust themselves by wheat consumption quantity and quality decline approach in order to deal with food shortage pressures. Therefore, such adaptations entail serious food insecurity exposures particularly among the most vulnerable population portions such as pregnant and breastfeeding women, the elderly and children.

Afghanistan has been a wheat deficient country over the decades. Thus, to fill the market supply-demand gap, the country has been highly dependent on wheat and flour imports from a number of countries in the region mostly Kazakhstan and Pakistan together with huge amounts of international humanitarian food aids. Therefore, such enormous dependency has often led to considerable wheat price fluctuations in Afghan wheat markets associated with imports superfluity or distortions from the external sources especially from Pakistan.

Exerting insincere trade policies on wheat and flour exports, Pakistan has been a hypocritical trade partner with Afghanistan for many years. Dumping its old stocks to Afghan wheat markets discouraged local producers off-site. As well as, imposing politically driven frequent trade bans Pakistan has often disrupted wheat market functionality in Afghanistan (Samim, 2016). For instance, Pakistan's strong ban on wheat and flour export to Afghanistan in 2008 led to wheat price extreme inflation (AFN 28.8/ kg) a price increase greater than a100 percent compared to its preceding year (AFN 13.7/ kg) (WFP VAM, 2017). According to WFP's monthly report, the overall trend of wheat retail price tends to be very low from 2001 to 2007 (a disincentive to local producers), highly volatile from 2008 to 2014 (a big concerns for consumers), and yet relatively stable from 2015 onwards. Hence, this study is to investigate the key underlying factors behind wheat markets failures as well as the recent relative stability.

OBJECTIVE

This research was designed to break the problem (Wheat Market Instability) down into two distinct but interlinked aspects defined as Wheat Domestic Production and Wheat Market in Afghanistan. Hence, within the scope of this study, we tried to target the problem through a holistic fashion targeting both of the research aspects concurrently in order to detect the most fundamental factors behind the problem as well as the most potential policy options for further progress in the long run. Therefore, this study was conducted to answer the following two questions.

1. What are the key underlying factors leading to wheat domestic production quantity and quality failure?
2. How can Afghanistan ensure a stable wheat market in favor of both consumers and producers in the long run?

METHODOLOGY

For data collection, we applied semi-structured questionnaires for our interviews and discussions with wheat farmers, wheat and flour traders and wheat consumers. Hence, using multistage sampling and focus group methods, in total, we interviewed with 62 wheat farmers, 31 wheat traders (Wholesalers and Retailers) and 69 wheat consumers in the provinces mentioned earlier. For data analysis, using SPSS, we ran Factor Analysis ($Xk = bk1F1 + bk2F2 + \ldots bkmFm + Ek$) to detect the core underlying factors (Invisible Factors) behind wheat domestic production malfunction given the predominant challenges (Symptoms) against wheat farmers in Afghanistan. For market analysis, we ran Pearson Correlation Coefficient to examine wheat markets integration between Afghanistan and its trade partners as well as the central and local ones within the country.

RESULTS AND DISCUSSION

Wheat Production in Afghanistan

Wheat production in Afghanistan is closely subject to precipitation circumstances of the year. Given high uncertainty of spring rainfall and the concomitant variability of yield from the rain-fed areas, output from the irrigated lands is considered as the main source of wheat domestic supply in the country. A study carried out by Rajiv et al (2011) argues that in a normal year, nearly 45 percent of land allocated for wheat production is brought under irrigation which contributes to roughly 70 percent of national wheat production while the remaining 55 percent of the area highly depends on spring rainfall and accounts for the rest 30 percent of the domestic wheat supply.

Wheat production in Afghanistan faces a number of natural calamities and man-induced challenges leading to its poor functionality in terms of both quantity and quality. Thus, since we got too many similar and mutually inclusive feedbacks from wheat farmers during our interviews and discussions, we came up with factor analysis application so that we can categorize these challenges (symptoms) into bunches of the same root, thereby, discovering the key underlying common factors (invisible factors) inducing these hindrances. Table 1 shows that there are five major common factors from which these challenges arise.

Table 1 Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.660	28.153	28.153	3.660	28.153	28.153	3.536	27.199	27.199
2	2.832	21.787	49.940	2.832	21.787	49.940	2.494	19.186	46.386
3	1.844	14.181	64.120	1.844	14.181	64.120	1.822	14.012	60.397
4	1.291	9.930	74.051	1.291	9.930	74.051	1.515	11.655	72.053
5	1.081	8.312	82.363	1.081	8.312	82.363	1.340	10.310	82.363
6	.814	6.262	88.625						
7	.525	4.041	92.666						
8	.299	2.297	94.963						
9	.268	2.059	97.022						
10	.186	1.433	98.456						
11	.119	.915	99.370						
12	.061	.468	99.838						
13	.021	.162	100.000						

Extraction Method: Principal Component Analysis. n = 62
Source: Own calculation

Although Table 1 explicitly detects five underlying factors behind the challenges against wheat production in Afghanistan with their respective and total explaining power, it does not provide any precise details on each of the factor's nature and existence. Hence, in order to know what the factors are exactly, Table 2 gives the ultimate response to this question.

Table 2 Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
Wheat loss induced by shortage of irrigation water on a Jerib of land (kg)	.212	**.903**	.063	.183	-.097
Wheat yield loss associated with land problems on a Jerib of land (kg)	-.094	.465	.182	**.733**	035
Potential yield increase given credit services are available (kg/ Jerib)	**.739**	-.091	-.257	.293	.462
Enough access to certified seeds	.057	-.218	-.272	**.839**	.127
Potential yield increase given enough certified seeds are available (kg/ Jerib)	**.926**	-.067	.149	-.005	-.100
Total amount of fertilizers wheat farmers apply on a Jerib of land (kg)	-.144	**.888**	-.156	-.202	.060
Enough application of fertilizers	-.038	.085	**.679**	.046	.353
Pesticides application by wheat farmers	**. 885**	-.161	-.166	-.137	.181
Wheat farmers membership to any farmers' organization	-.008	-.065	-.032	-.089	**.950**
Wheat farmers receiving extension services	-.818	-.239	-.392	-.192	.131
Wheat farmers market motivation	-.738	-.030	.305	.073	.059
Wheat farmers having off-farm jobs	.236	-.786	.028	.186	.065
Wheat farmers' formal education	.039	.459	**.742**	.087	-.048

Extraction Method: Principal Component Analysis. n = 62
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.
Source: Own calculation

As shown in bold in Table 2, three symptoms fall under factor 1, two symptoms fall under factor 2, two symptoms fall under factor 3, two symptoms fall under factor 4 and finally, one symptom falls under factor 5. Thus, considering the linkage among the symptoms under each category, we can interpret that the factors are seemingly going to be weak financial status, irrigation water use inefficiency, farmers' low level of knowledge, low land productivity and farmers' individuality respectively. Principally, the symptoms (existing hindering challenges) shown in Table 2 are mostly collinear with each other and have loading coefficients somehow with all of the recognized factors. However, factor analysis categorizes them into same groups and introduces mutually exclusive factors containing the symptoms with the highest loadings.

Wheat Market in Afghanistan

Afghanistan has been a wheat deficit country associated with domestic production shortfalls. Thus, to fill the supply-demand gap, the country has been highly dependent on wheat imports from a number of countries in the region such as Kazakhstan, Pakistan, Uzbekistan, Iran and others together with huge amounts of international humanitarian food aids for many years. Although wheat production has significantly increased over the recent years in Afghanistan, still domestic supply is far below its market demand in the country. Figure1 shows that even during the most favorable year (2016) for domestic production, still the country imports more than 2.5 million MT of wheat and flour from the external sources.

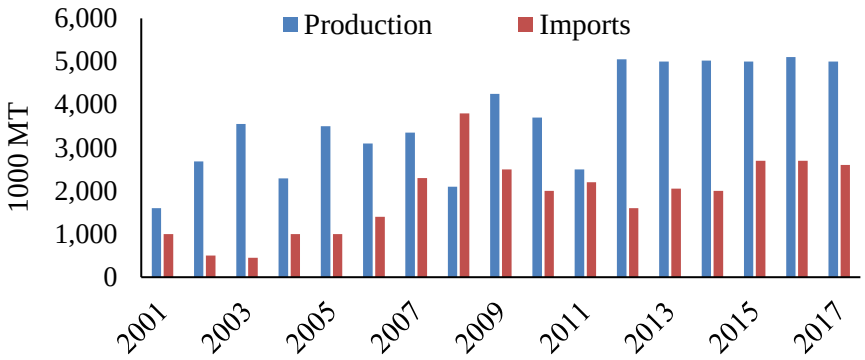

Fig. 1 Wheat production and import trends in Afghanistan
Source: USDA, PSD online database

After the collapse of Taliban regime in 2001 and the establishment of interim government in Afghanistan, Pakistan used to be the major supplier of wheat and flour to Afghanistan due to historically close transactions background coupled with the long shared borderline of 2,640 km between the two nations. However, exerting hypocritical trade policies over the years as explained earlier, the country was a major player of wheat market instability in Afghanistan, too. Therefore, its consistent exploitive trade policies led to stronger trade ties between Afghanistan and the Central Asian countries particularly Kazakhstan, and as a consequence, wheat price relative stability over the recent years. Fig. 2 illustrates average wheat retail price fluctuations in Afghanistan since 2003.

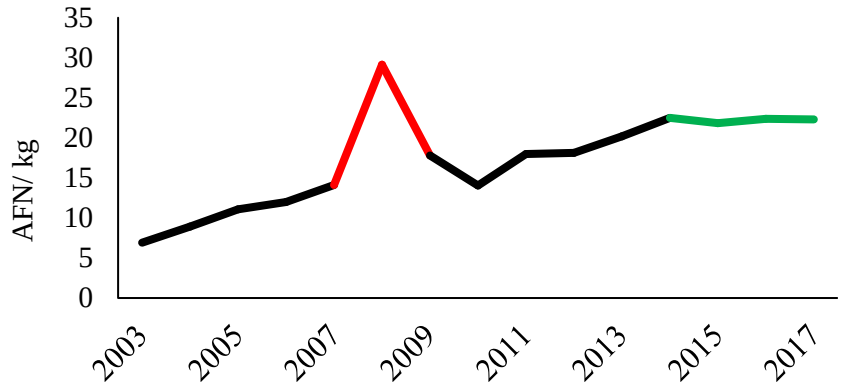

Fig. 2 Average wheat retail price in Afghanistan
Source: WFP VAM, Food Security Analysis

As shown in Fig. 2, Pakistan's double-faced trade policies drove significant fluctuations in wheat price over more than one decade with unprecedented shock in 2008. On the other hand, Afghanistan's access to Kazakhstan's (one of the top ten wheat-exporting countries in the world) wheat stocks through trade negotiations has recently ensured relative stability in this regard. Pakistan lost its wheat market concentration in Afghanistan in favor of Kazakhstan due to two main reasons: First, Kazakhstan has the least wheat export variability in the region, and second, its products are by far better in quality and flow safety compared to those of Pakistan.

To confirm the scenario, we considered wheat markets integration through linear correlation between Afghanistan and some of its major trade partners. Table 3 shows that since 2009 onwards, in general, wheat markets in Afghanistan move more closely with those in Kazakhstan rather than in Pakistan. Therefore, it explicitly implies that any positive or negative changes in Afghan wheat markets since 2009 are more because of wheat exports from Kazakhstan rather than Pakistan.

Table 3 Afghanistan's wheat market integration with its trade partners (2009 – 2016)

	Afghanistan	Kazakhstan	Pakistan	Iran
Afghanistan	1			
Kazakhstan	**.582**	1		
Pakistan	.349	.258	1	
Iran	.331	-.159	-.395	1

Source: For Afghanistan wheat price (WFP VAM) and for the others (FAOSTAT)

CONCLUSION

Unless food diversification policies and programs in the long-run, for the time being, wheat is the mainstay of food security in Afghanistan. Hence, any policy option to ensure its year-round availability, achieves food security to a great extent in the country. Despite significant progress over the recent years, still wheat domestic production is far below its market demand and as a result, Afghanistan imports huge amounts of wheat and flour annually to fill the market supply-demand gap. There are five key underlying factors namely, weak financial status, irrigation water use inefficiency, farmers' low level of knowledge, low land productivity and farmers individuality respectively leading to wheat production malfunction in the country. Therefore, unless these factors are addressed concretely, Afghanistan will never reach self-sufficiency in this regard. Moreover, regarding wheat imports, Pakistan's unfair trade policies mostly due to politics has been one of the key factors behind wheat market instability in Afghanistan while the Central Asian countries particularly Kazakhstan has recently emerged as an effective trade partner with Afghanistan by supplying more stable and higher quality products to Afghan wheat markets.

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REFERENCES

CSO. 2016-17. Agriculture development. https://tinyurl.com/ybbdok6z

D'Souza, A. and Jolliffe, D. 2012. Food security and wheat prices in Afghanistan: A distribution-sensitive analysis of household-level impacts. https://tinyurl.com/yabpfllx

FAO and European Commission Humanitarian Aid. 2013. Wheat markets and food security in Afghanistan. https://tinyurl.com/y8wjjce7

FAOSTAT. Online database. http://www.fao.org/faostat/en/#home

Rajiv, K., Sharma, Osmanzai, M. and Ward, R. 2011. Wheat research: A crucial prerequisite to food security in Afghanistan. https://tinyurl.com/y98qxc6a

Samim, M. 2016. Pakistan: Afghanistan's unreliable breadbasket. The diplomat, https://thediplomat.com/2016/08/pakistan-afghanistans-unreliable-breadbasket/

USDA. PS & D Online Database, https://apps.fas.usda.gov/psdonline/app/index.html#/app/home

WFP VAM. 2017. Food security analysis. http://vam.wfp.org/CountryPage_overview.aspx?iso3=AFG

Research article

The Impact of *Mimosa pigra* on Local Livelihood in the Stung Sen Core Area, Tonle Sap Biosphere Reserve

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Abstract The Stung Sen Core Area is situated at the southeastern end of the Tonle Sap Lake, and comprises an area of 6,355 ha. It was created under the Royal Decree on the establishment of the Tonle Sap Biosphere Reserve (TSBR), dated 10 April 2001, and aims to protect unique evergreen riverine forests and associated vegetation assemblages. Stung Sen is the buffer zone of the three core zones within the TSBR, and provides the most important inland wetland in Southeast Asia, both for biodiversity conservation and for livelihoods based on the harvesting of aquatic resources and agricultural farming in the surrounding areas. This core area has been interrupted by an invasive alien plant, namely *Mimosa pigra (M. pigra)*, which has had significant physical and economic impacts upon the natural habitat, local community livelihoods, animals and plants, human health, jobs and the ecosystem. This study discusses the negative impacts of the invasive *M. pigra* on local livelihoods. It uses economic analysis to calculate the cost of its impact and the cost for recovery; and then provides recommendations on how these impacts can be mitigated. The distribution of *M. pigra* in core areas has been mapped, and only those areas, which have a high-density of *M. pigra*, are identified for economic analysis in this study. Face to face interviews were carried out with local authorities, rangers, community members, and farmers within the Stung Sen Core Area, Phat Sonday District. The data analysis is focused on the impact on farming land, fishing yields, local income generation, and natural habitat distruction. This paper is developed on the basis of the results of a pilot site experiment on methods of removing *M. pigra* to explore the best option for mitigating the spread of *M. pigra*, and removing existing *M. pigra* from the Stung Sen core area.

Keywords *Mimosa pigra*, impact, local livelihood, Stung Sen Core Area, Cambodia

INTRODUCTION

Invasive alien species (IAS) is non-indigenous plant, animal and microorganism that have been delivered or accidentally introduced into new areas beyond their native ranges by people, or as a result of their activities; as well as through natural means such as wind, water, or animal movement, and which then spreads, impacting negatively on the biodiversity, the ecosystem and economic development (Chornesky and Randall, 2003). *Mimosa pigra* is a thorny invasive alien plant which originates from tropical South and Central America and has been spreading into all tropical regions (Heard, 2009). Richard (2007) indicated that *M. pigra* is a branched prickly bush that can grow up to 6 meters and can withstand low nutrient levels and a wide range of soil types. *M. pigra* has invaded and subsequently become invasive across Southeast Asian countries. It is one of the most common invasive species found in Cambodia, and it spreads through many parts of wetland areas, lakes and river edges, canals, ponds, floodplains and wherever water flows with its seeds.

The Royal Government of the Kingdom of Cambodia (RGKC) recognizes the Tonle Sap and Mekong rivers as priority inland water ecosystems for management due to their significant role in food security and agricultural productivity (NBSR, 2016). The Tonle Sap is a primary source for

jobs and incomes and around 3 million people live on or beside it. Approximately 750,000 people live in the flooded villages, 40% of them live on the floodplains, with the remainder living dependently on the lake (Mak, 2005). The priority occupation for those living on or beside the Tonle Sap is fishing, either as a whole family business or on a smaller scale.

Stung Sen Core Area (SSCA) is one among many core areas of the Biosphere Reserve located in Kampong Thom Province on the lower part of the Stung Sen. Stung Sen River receives water from 3 major sources: 57% from the Mekong mainstream, (52% through the Tonle Sap River, and 5% from overland flooding), 30% from tributaries of Tonle Sap Lake, and 13% from direct precipitation (Kosal, 2011). A population of 5,252, equals to 1,164 households is living in the SSCA, and their major incomes are from fisheries and seasonal vegetable farming. However, the change in land use in the region, in particular an increase in rice cropping, has been a significant factor in the spread of *M. pigra*, with neglected or abandoned fields being particularly susceptible to invasion. Recently, the major pathway and spread of *M. pigra* surrounding the Tonle Sap Lake, especially within the SSCA, has resulted in negative impacts on the biodiversity, the ecosystem, agriculture, socio-economic, health, and other economic activities. Therefore, this study explores the negative impact of *M. pigra* on local livelihoods and the ecosystem in SSCA.

OBJECTIVE

This study aims to assess and analyse the methodologies and strategies for interrupting and eliminating the negative impacts of *M. pigra* that are harming the economic growth of local communities. The study also aims to introduce applicable methods to remove barriers to invasive species management in the production and protection of wetland ecosystems in Cambodia; with the ultimate goal of enhancing biodiversity conservation and management within protected areas through local livelihood improvements.

METHODOLOGY

Data and information about the *M. pigra* in SSCA and around the Lower Mekong Basin (Fig.1) was mainly collected through conducting face-to-face interviews with 80 key local authority representatives, community members, rangers and the director and deputy director of the SSCA.

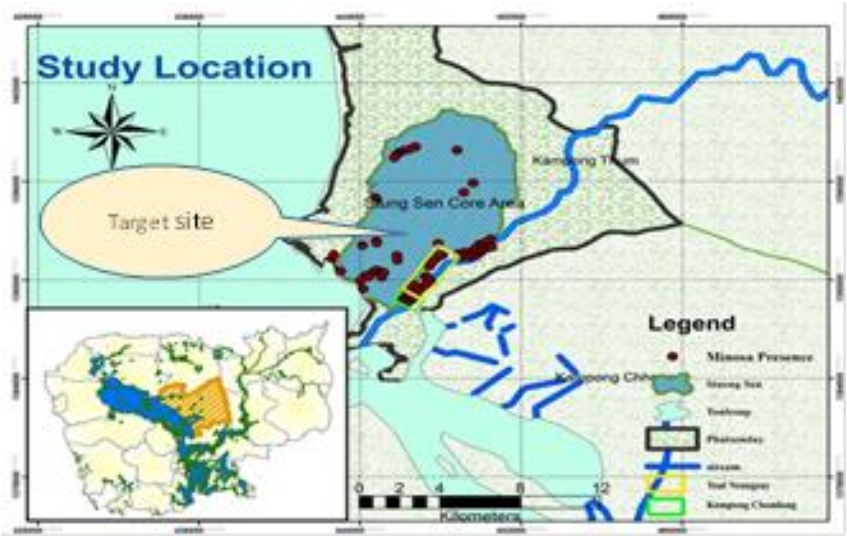


Fig. 1 *M. pigra* distribution map in SSCA

The consultation process for selecting these specific stakeholders was underpinned by this study. Survey questionnaires and interview questions were developed to focus on the status of *M.*

pigra and its distribution, the socio-economic impact, local income generation and the impact of *M. pigra* on that. Best practice and/or methods used by the local community to prevent/remove *M. pigra* was also taken into account. The secondary data collection focused on previous or similar projects from scientific publications, case studies, relevant literature, the media, books, websites, documents and other related publications, and was used to support or confirm the findings of this study. A distribution map of *M. pigra* within the SSCA was produced according to data obtained from GPS The dataset on the income generation status and land occupancy by *M. pigra* was utilized to assist analysis of the negative impacts on socio economics and natural habitats in the SSCA. The study also draws upon experimental results from existing projects for policy recommendation on methods to remove *M. pigra*.

RESULTS

Distribution of *M. pigra*

M. pigra has encroached into Cambodia for decades from its neighboring countries. It was originally considered to be a wild plant and was introduced from Indonesia to Thailand for controlling riverbank erosion, covering tobacco crops, and producing natural fertilizer (Napompeth & Wara, 1983). In 1949, the *M. pigra* was found in northern Thailand and had spread into Vietnam, most likely before 1970 (Thi et al., 2004); it continued its advance into Long An province by 1979 (Triet et al., 2004). The weed spread into Cambodia from 1980 around the Tonle Sap Great Lake and especially along the Mekong Rivers where it occupied thousands of hectares of flooded wetlands and abandoned fields (Samouth, 2004). Around 1997, *M. pigra* had encroached into many provinces of Cambodia, including Steung Treng, Kratie, Kampong Cham, Kandal, Kampong Chhnang, Kampong Thom, Pursat, Battambang, Siem Reap, Prey Veng, Svay Rieng, Takeo and some parts of Kampong Speu (GSSD, 2013). Fig. 1 shows the distribution of *M.pigra* within the SSCA, however the target site for this study is Phat Sonday Commune in Kampong Thom Provine, which has a high density of *M. pigra*.

Socio Economics and Income Generation in the SSCA

According to the field interviews with 80 families in the SSCA and 90 families in Phat Sonday Commune, their major income is earned from the fisheries sector. Their secondary income is based on farming the surrounding SSCA (Table 1).

Table 1 Occupation and income generation

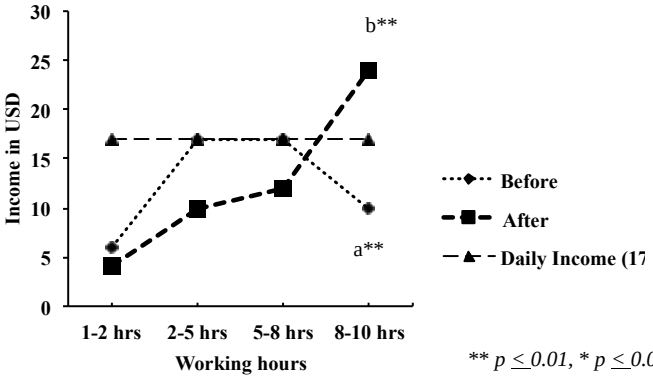
Major Income of Phat Sonday/SSCA			Occupation of Phat Sonday/SSCA		
Source	No. of family	Percent (%)	Occupation	No. of family	Percent (%)
Fisheries	53	66	Fisherman	48	53
Farmer	17	21	Farmer	34	38
Animal husbandry	3	4	Animal husbandry	5	6
Other	7	9	Other	3	3
Total	80	100	Total	90	100

Impact Analysis of *M. pigra*

Table 1 shows that more than 50% of local income depends on fishing activities whilst the second main income comes from farming. Four major factors have been identified as reasons for the

negative impact to the fisheries yields: invasive species (*M. pigra*), climate change, illegal fishing, and poisoning from chemical usage in agriculture. The results of the survey suggest that *M. pigra* has the most significant impact factor (60%), while illegal fishing is the secondary factor (20%), and climate change & poisoning present around 20% of the impact. Therefore, this section analyses the impact of *M. pigra* on local livelihoods especially in relation to incomes earned from fishing activities.

Two indicators "Time Spent" and "Income" earned from fisheries have been identified to measure the impact of *M. pigra* on local income generation. Data on both indicators "before" and "after" presentation of *M. pigra* have been collected by category. As shown in Figs. 2 and 3, "time spent" for fishing was classified into 4 categories (G_1 = 1-2 hrs, G_2 = 2-5 hrs, G_3 = 5-8 hrs, and G_4 = 8-10 hrs), and "income" received from fishing was grouped into five categories represented by C_1 = 2.5-5 $, C_2 = 5-10 $, C_3 = 10-20 $, C_4 = 20-30 $, and C_5 > 30 $. The average income "benchmark" has been set at 17 $ per day per fisherman in accordance with the data received from the interviews with 50 fishermen as shown in Table 2. The results in Fig. 2 clearly indicated that as *M. pigra* continued to spread, the fisherman had to engage in fishing activities for at least 7 more hours to earn an income at the benchmark level. Previously they had only needed to fish for 2-5 hrs to achieve that benchmark figure. This result is evidence that *M. pigra* has disturbed the fish habitat and its ecosystems that and has led to fish stock shortages. Fig. 3 shows the trend of local incomes from fisheries before and after *M. pigra* presented. The "before" graph represents incomes received from fisheries before *M. pigra* presented, and the "after" graph represents the post *M. pigra* situation. The "before" graph represents a high proportion of fishermen who received a good daily income of between $15-$25, whilst the "after" graph clearly shows quite dramatic reductions in the fishermen's incomes to between just $5 and $10 per day.



** $p \leq 0.01$, * $p \leq 0.05$

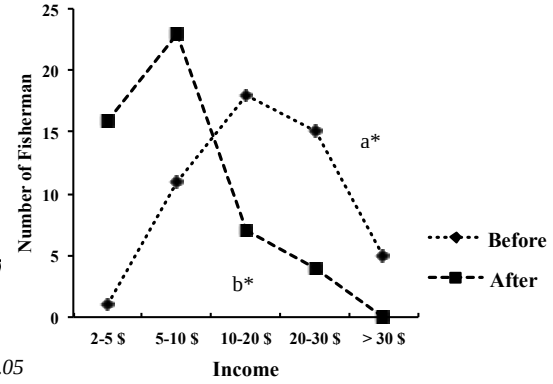


Fig. 2 Change in time spent on fishing **Fig. 3 Change in income from fishing**

Table 2 Daily and annual profit loss after presentation of *M. pigra* in the SSCA

Description	Income earned from fisheries by category					Total family		Income	
	C_1=5$	C_2=10$	C_3=20$	C_4=30$	C_5=50$	Survey	SSCA	Family	SSCA
Before (family)	1	11	18	15	5	50	1,164		
After (family)	16	23	7	4	0	50	1,164		
Daily income									
Income before	$5	$110	$360	$450	$250	$1,175		$24	$27,936.00
Income after	$80	$230	$140	$120	0	$570		$11	$12,804.00
Daily and annual profit loss									
Daily income loss								$13.00	$15,132.00
Annual income loss								$4,745.00	$5,523,180.00

Table 2 shows daily and annual incomes from the fisheries sector and the profit loss of the 1,164 families in the SSCA. This figure is based on the results of the interviews with 50 selected families in the target area.

$$DI=\frac{Nf_1x + Nf_2xC_2 + Nf_xC_3 + Nf_4C_4 + Nf_{x5}C_5}{TNf} \quad \text{Eq. (1)}$$

Where DI = daily income; Nf = Number of family/category
C = Value/category; TNf = Total number of family for survey

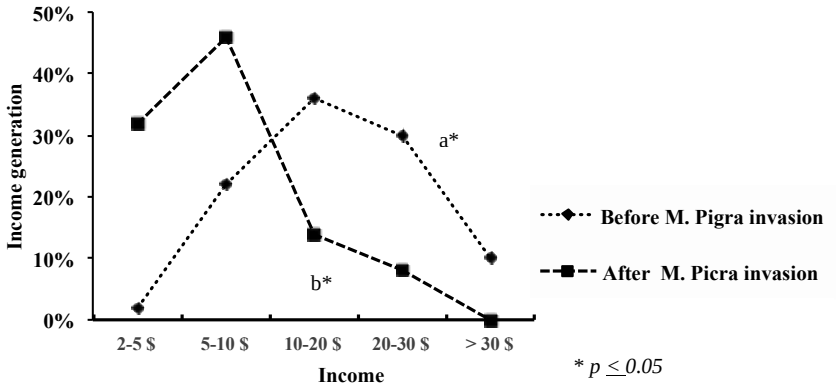


Fig. 4 Change in daily income from fishing

This assignment used the Eq. 1 to estimate local incomes in each category identified in Table 2. According to this calculation, when *M. pigra* had not yet presented, each family in around 30-35% of the total population, was able to generate a daily income of between $ 20 to $ 30; but after *M. pigra* had presented, each family in nearly half of the total population was only able to earn $ 10 per day. Therefore, each family had experienced a loss of more than 50% of their income to a rate of $ 13 per day and an overall loss of $ 4,745 annually due to the fish habitat being interrupted by *M. pigra.* In addition, the total profit loss for the SSCA amongst 1,164 families has been the huge amount of more than 5.5 million dollars annually.

RECCOMENDATIONS

Experiment and Control Methods to Remove *M. pigra*

Several methods have been applied in the developed countries to control the quick invasion of *M. pigra*, including physical controls, chemical controls, re-vegetation, and biological controls (Marko, 1999). Each method has always had its pros and cons. In Cambodia, three methods have been applied and one method is currently under assessment.

1. Physical methods: Hand clearance was the first method used by local people to deal with *M. pigra*; this included cutting stumps, uprooting seedlings and stumps, and burning them. This method was very labor intensive and thus expensive, because a significant seed store in the soil appeared and the plants would geminate in the next rainy season and re-infest the cleared areas; so more labor was required to go back and deal with the new emerging seedlings. The longer the plant was allowed to grow, the more costly it became to clear them because the plants just grew bigger which made it more difficult every time, and it took much longer to destroy them. According to the results of an experiment conducted by the biodiversity department team (BDB) of General Secretariat of the National Council for Sustainable Development (GSSD) in 2013, this form of control can only be cost effective when undertaken on a small scale.

2. Chemical methods: Foliar spraying of herbicides, specifically glyphosates, on weeds like *M. pigra* is a method that is often used in Cambodia. However, this method has been attempted within the SSCA by applying glyphosates onto the cut stumps of the plant, which is a combination technique of both physical and chemical methods. This technique is also very labor intensive but it provides significant results in terms of destroying the *M. pigra* compared to just using the physical control method alone. The chemical method is usually applied during the dry period, when bark spraying, stem injection and soil treatments are followed by burning. Unfortunately, due to the SCCA being located inside the Tonle Sap Protected Areas, herbicide usage is not recommended, and this method could provide negative impacts on the water quality and natural habitat, especially if there is over-usage of the herbicides or their use is uncontrolled.

3. Biological controls methods: Biological control is the use "Bio-Agene" to destroy the stems, flowers, leaves, seeds, or roots of M. pigra. These agents include phytophagous insects, species that attack roots, stems, leaves, flowers, and fruits, either as larvae or as adults or in both stages, and fungal pathogens. Four hundred and forty-one phytophagous insects have been found on *M. pigra* in Central and South America (Harley et al., 1995; Marko, 1999). Based on a survey report (DBD, GSSD/MoE, 2013), even though this method has been applied in Thailand and Vietnam on *M. pigra*, there is no evidence that biological controls succeed in eliminating the weed. When DBD, GSSD conducted a survey of insects in the SCCA and the 8 provinces that surround the Tonle Sap Great Lake, the results showed that different insects and larvae are damaging the stems, leaves and flowers of *M. pigra*, but there is no proof that those insects are bio-agene to *M. pigra* and this requires further research.

4. Re-vegetation methods: This is a method of rehabilitating native species or installing plantations of local vegetation in degraded land to prevent the sunlight reflecting on the buried *M. pigra* seeds. It can be rehabilitation of degraded ecosystem, plantations of fast grow vegetables and plantations of native trees. Re-vegetation produces better results with fast growing species. Part of this method includes local people using water hyacinth and water spinach to suppress new seedlings and the sprouting of *M. pigra* on their agricultural land. This practice is very common and costs less through just capturing and keeping water hyacinth and water spinach in agricultural land during the flooding season. When the water recedes, all of the trapped water hyacinth dies before it is able to spread and cover the agricultural land. People are then able to grow crops such as maize and pumpkins by cultivating small patches of the land.

Fig. 5 Re-vegetation through native plant

5. Policy recommendations: This study demonstrates that *M. pigra* negatively impacts not only on natural habitats, but also on local income generation. Although there are four methods that can be introduced to tackle the weed, very few of the methods have been effective in its complete eradication. The re-vegetation method proved to be the more feasible option for larger scale attempts to suppress and kill *M. pigra,* and this method was the least costly; while physical

methods have proven to be too expensive and unsustainable. Chemical methods have been effective but have produced negative side effects and result in negative consequences on the ecosystem and water quality. In this regard, any policy recommendation should consider both short and long term solutions. Supporting and encouraging local people to continue their practice of using water hyacinth and water spinach to suppress new seedlings and the sprouting of new *M. pigra* on agricultural land can only be a short term solution to the problem. Longer term solutions should concentrate on the development of plantations and the planting of native species to rehabilitate degraded ecosystems and land.

CONCLUSION

According to the results and discussions conducted through this study, it can be concluded that the SSCA is not only rich in biodiversity, but it has contributed enormously to national and local economic growth. Each family living in Phat Sonday commune has the ability to earn around $8,760 annually from fisheries alone; and they are also able to generate an additional income from agriculture and farming the surrounding areas. Unfortunately, the SSCA has been effected by the Invasive alien species *M. pigra* which was introduced into Cambodia from 1980 and which has rapidly spread, surrounding the Tonle Sap Great Lake as well as along the Mekong Rivers. The impact of this IAS on the ecosystem and fish stock at the SSCA has led to profit losses of at least 5.5 million dollars annually; and this does not include the impact on agricultural production and farming yields. In order to respond to the rapid invasion of *M. pigra*, four methods of control have been introduced in an attempt to eradicate *M. pigra.* These have included physical controls, chemical controls, biological controls, and re-vegetation controls. Based on the geographical area of the SSCA and the limited research available on bio-agenes, chemical and biological controls are not a recommended method going forward. Therefore, only the physical and re-vegetation controls should be applied, even though the physical method can be costly and *M. pigra* is not permanently removed through utilising that method.

Aware of serious impacts from the spread of *M. pigra* to local livelihoods, ecosystems, and natural habitats, this study highlights two possible policies recommendations: 1) for the short term strategy, continue use local methods to suppress new seedlings and sprouting of *M. pigra* on agricultural land with local vegetable cover such as water hyacinth and water spinach to suppress growth; and 2) develop and implement rehabilitation programs to replant native species on abandoned agricultural land and degraded ecosystem areas as a long term strategy.

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REFERENCES

Chornesky, E.A. and Randall, J.M. 2003. The threat of invasive alien species to biological diversity: Setting a future course. Annals of the Missouri Botanic Garden, 90, 67-76.

DBD, GSSD/MoE. 2013. Survey of insects on *M. pigra* in the Tonle Sap Great Lake and the surrounding provinces with reference to Natural Enemies. 2.

GSSD. 2013. Baseline study on biodiversity & socio-economic prior management investment on *M. pigra* at SSCA National Pilot Site. 1.

Harley, K., Gillett, J., Winder, J., Forno, W., Segura, R., Miranda, H. and Kassulke, R. 1995. Natural enemies of M. pigra and M. berlandieri and prospects for biological control of *M. pigra*. https://academic.

oup.com/ee/article-abstract/24/6/1664/499992?redirectedFrom=fulltext
Heard, T.A. 2009. Application to release the tip weevil, *T. debilis* a potential biological control agent of *M.pigra*. www.researchgate.net/profile/Tim_Heard
Kosal, M. 2011. Initial findings of wetland and climate change impacts in Stung Sen wetland, Cambodia. www.icem.com.au/documents/biodiversity/wetlands%20wshop/8.%20Stung%20Sen%20initial%20findings%20-%20Cambodian%20Team.pdf: 4
Mak, S. 2005. Sustainability, livelihoods, and development in Tonle Sap. Fisheries Action Coalition Team.
Marko, M. 1999. Restoration and reclamation review: Controlling invasion of the exotic shrub (*M. pigra*) in tropical Australian wetlands. Student On-Line Journal, 4 (6), 1-10.
Napompeth, Wara, A. 1983. Modelling integrated weed management of an invasive shrub in tropical Australia.
NBSR. 2016. National biodiversity status report. Department of Biodiversity, National Council for Sustainable Development, Ministry of Environment, Camboda. www.researchgate.net/publication /37617697_Modelling_Integrated_Weed_Management_of_an_Invasive_Shrub_in_Tropical_Australia
Richard, B. 2007. Adaptive management of the invasive shrub *M. pigra* at Gorongosa National Park, Department of Scientific Services.
Samouth, C. 2004, *Mimosa pigra* infestation and current threat to wetlands and floodplains in Cambodia, Research and Management of Mimosa pigra, CSIRO Entomology, Canberra, Australia.
Triet, et al. 2004. Determining suitable methods for the control of *M.pigra* in Tram Chim National Park, VN. www.academia.edu

International Society of Environmental and Rural Development

Philosophy of ISERD:

Recently, in developing countries, subsistence agriculture is being converted to export-oriented mono-culture, and the amounts of agricultural chemicals applied to the farmland are increasing every year. The applied chemicals in farmland cause serious environmental problems downstream such as eutrophication, unusual growth of aquatic plants, decrease in dissolved oxygen and accumulation of bottom mud in water resources. Also, there seem to be many cases in which people apply agricultural chemicals without understanding its impact to health and food safety. Therefore, it is necessary to promote and enhance understanding of sustainable rural development among local stakeholders including farmers.

Sustainable rural development aims to meet human needs while preserving the natural environment. As it should cover not only social and economic development but also natural environment conservation, no single organization can achieve sufficiently the aspirations of sustainable rural development. Collaboration among international, governmental and non-governmental organizations, together with the academe and scientific sector, is indispensable.

The knowledge and intelligence accumulated in universities and research institutions are also expected to make the programs facilitated by the international, governmental and non-governmental organizations more adequately implemented and meaningful to societal development. However, these cases especially those implemented locally have been scattered without having been summarized well or recorded in annals academic or scientific societies.

So, the International Society of Environmental and Rural Development founded in 2010, aims to discuss and develop suitable and effective processes or strategies on sustainable rural development focusing on agricultural and environmental aspects in developing countries. The ultimate goals of the society are to contribute to sustainable rural development through social and economic development in harmony with the natural environment, and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

Purposes of ISERD:

The primary purposes of ISERD are to contribute to sustainable rural development through social and economic development in harmony with the natural environment and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

In order to enhance the realization of the primary purposes of ISERD, the secondary purposes are;

- to facilitate interaction among international, governmental, non-governmental organizations and local communities,
- to hold conferences or symposia on environmental and rural development,
- to publish the International Journal of Environmental and Rural Development, and
- to encourage and develop local awareness concerning sustainable rural development.

Membership:

There shall be two categories of membership.

(a) Individual

(b) Organizational

An application for membership of ISERD shall be submitted to the secretariat of ISERD, where is located in the Research Center at Institute of Environmental Rehabilitation and Conservation (Japan) by writing or by other appropriate means.

Also every presenter who attends the International Conference on Environmental and Rural Development (ICERD) is registered as an Individual Member of ISERD.

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